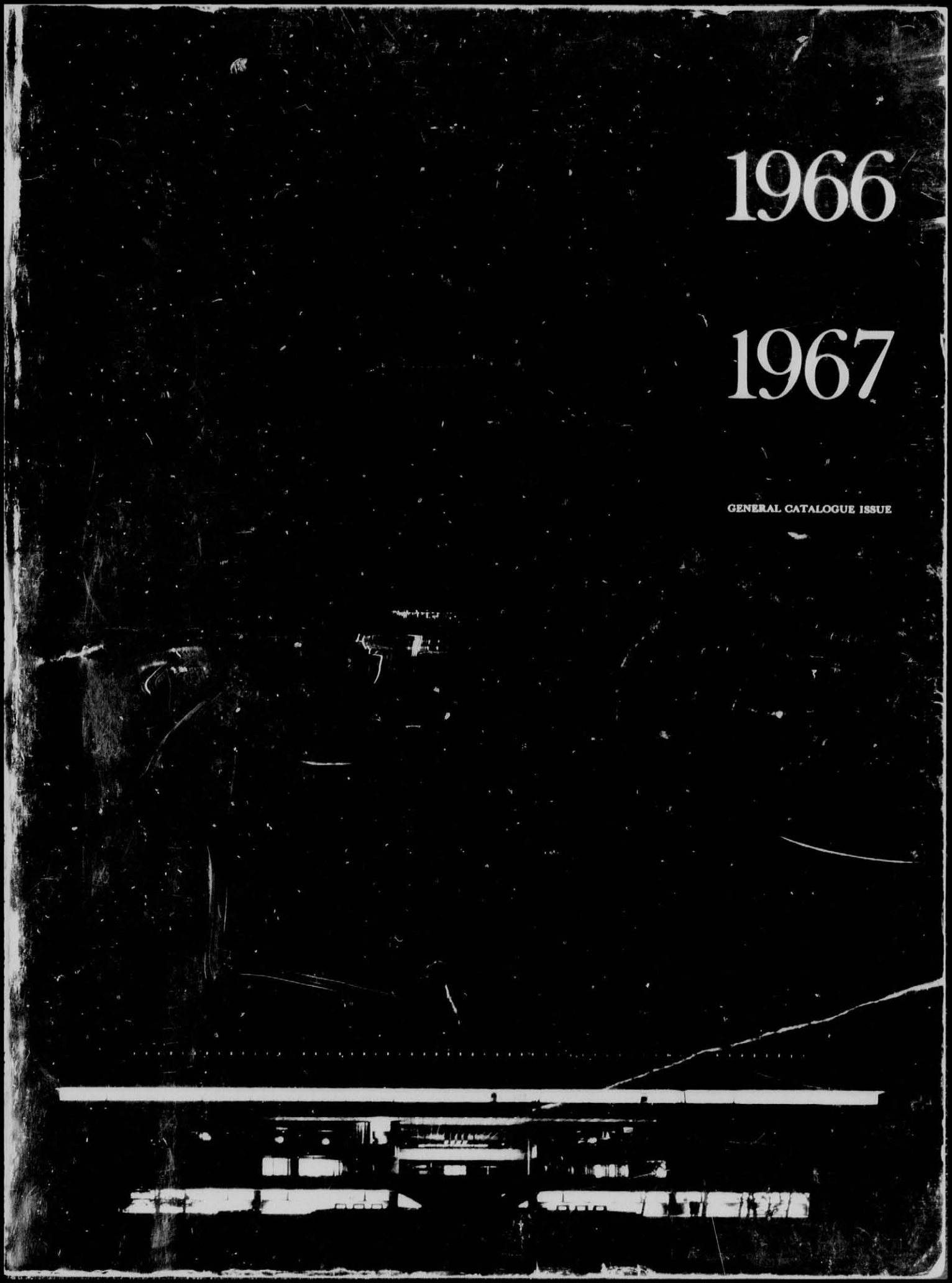
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THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY BULLETIN

1966-1967

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AERONAUTICS AND ASTRONAUTICS

ARCHITECTURE

BIOLOGY

CHEMICAL ENGINEERING

CHEMISTRY

CITY AND REGIONAL PLANNING

CIVIL ENGINEERING

ECONOMICS

ELECTRICAL ENGINEERING

GEOLOGY AND GEOPHYSICS

HUMANITIES

MANAGEMENT

MATHEMATICS

MECHANICAL ENGINEERING

METALLURGY

METEOROLOGY

MODERN LANGUAGES AND LINGUISTICS

NAVAL ARCHITECTURE AND MARINE ENGINEERING

NUCLEAR ENGINEERING

NUTRITION AND FOOD SCIENCE

PHYSICS

POLITICAL SCIENCE

PSYCHOLOGY

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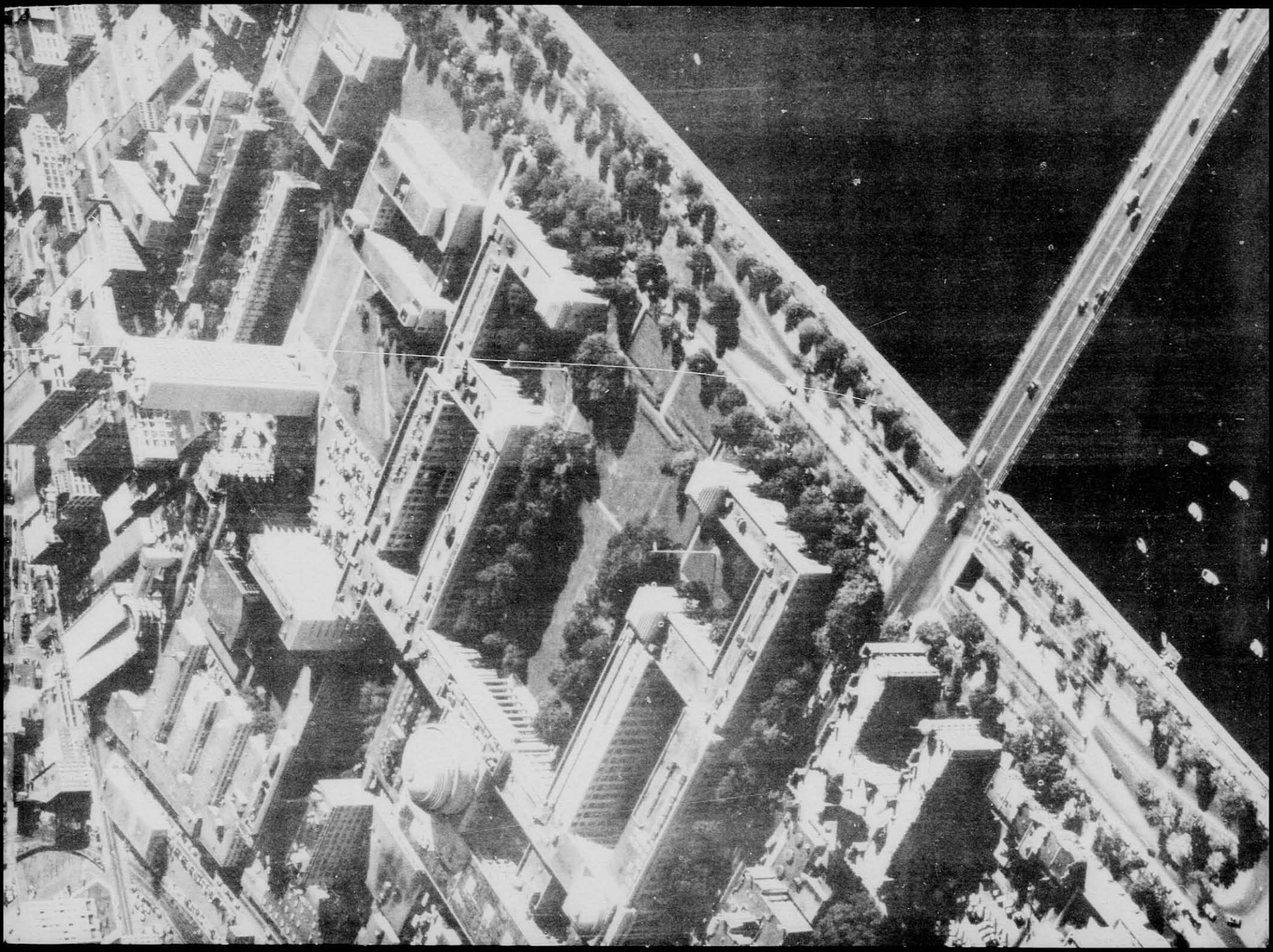
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ACADEMIC CALENDAR

1966

SEPTEMBER 14	FIRST TERM BEGINS FOR FRESHMEN
SEPTEMBER 19	FIRST TERM BEGINS FOR UPPERCLASSMEN AND GRADUATE SCHOOL (*Registration Day*)
OCTOBER 12	COLUMBUS DAY (*holiday*)
NOVEMBER 11	VETERANS' DAY (*holiday*)
NOVEMBER 24 *through* NOVEMBER 27	THANKSGIVING VACATION
DECEMBER 22 *through* JANUARY 3	CHRISTMAS VACATION



1967

JANUARY 18	LAST EXERCISES OF THE FIRST TERM
JANUARY 19 *through* JANUARY 21	READING PERIOD
JANUARY 23 *through* JANUARY 27	EXAMINATION PERIOD
FEBRUARY 6	SECOND TERM BEGINS (*Registration Day*)
FEBRUARY 22	WASHINGTON'S BIRTHDAY (*holiday*)
MARCH 27 *through* APRIL 2	SPRING VACATION
APRIL 19	PATRIOTS' DAY (*holiday*)
MAY 23	LAST EXERCISES OF THE SECOND TERM
MAY 24 *through* MAY 26	READING PERIOD
MAY 27 *through* JUNE 2	EXAMINATION PERIOD
MAY 30	MEMORIAL DAY (*holiday*)
JUNE 9	COMMENCEMENT DAY
JUNE 19	SUMMER SESSION 1967 BEGINS
SEPTEMBER 18	FIRST TERM 1967 BEGINS



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The Adventure of Learning

A statement of the purposes and aims of the Massachusetts Institute of Technology by its twelfth President.

From its founding more than one hundred years ago, M.I.T. has sought to provide the student with opportunities for education in *depth* — an education with strong foundations in science and engineering that will serve him with a constructive control over a basic intellectual field for the rest of his life. This remains a basic tenet of M.I.T. education.

In more recent student generations, the M.I.T. student has had a learning experience in *breadth* which has added a liberalizing element of range to his outlook and expectations.

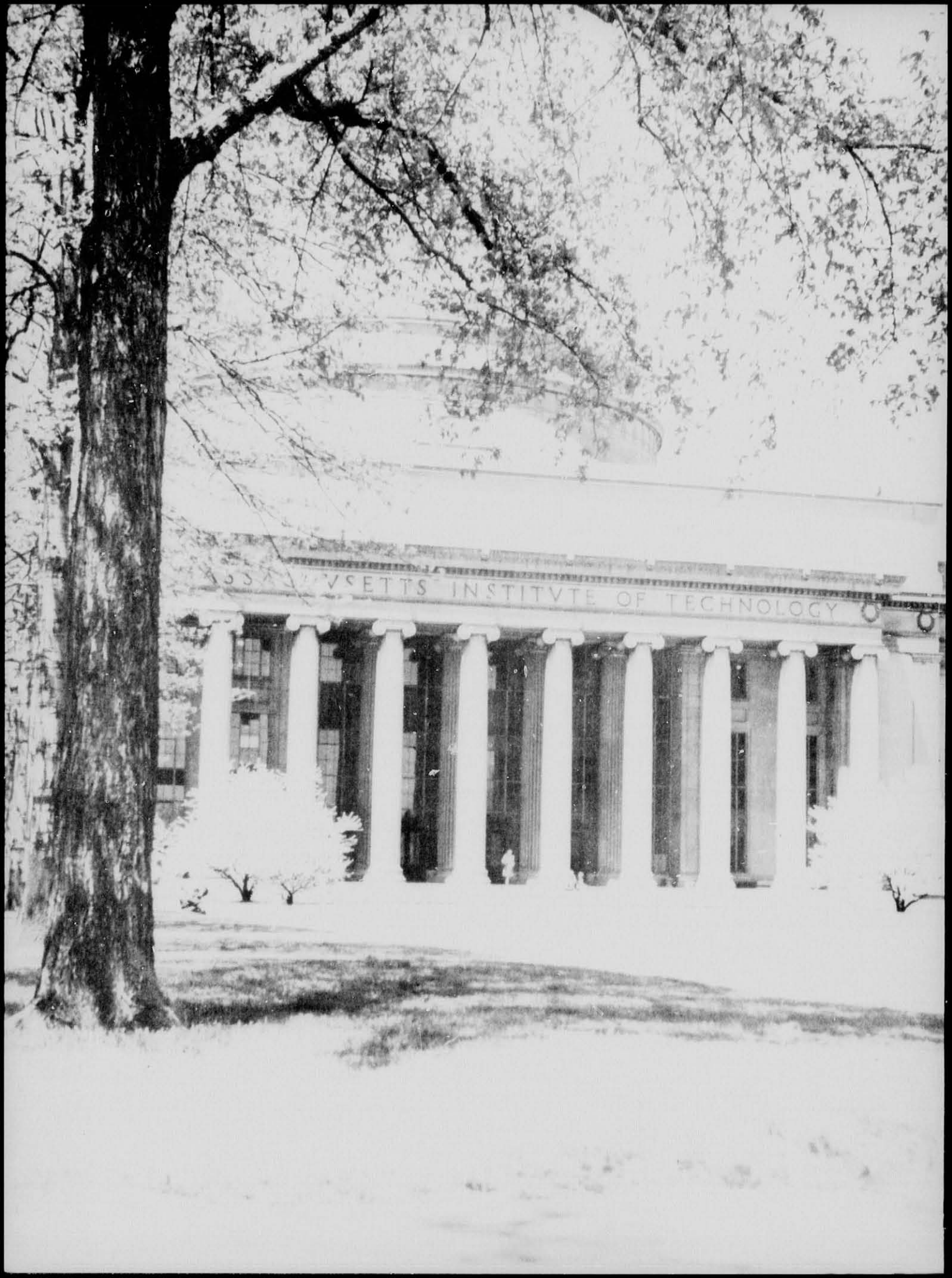
These two qualities, depth and breadth, do not yet describe today's M.I.T. To them must be added the vigorous *spirit of inquiry*, of search and discovery that pervades the Institute, and a *sense of service*, the effective use of knowledge for the general good. Together these qualities form an effective description of the university.

The total of this learning experience marks the M.I.T. student with certain identifying characteristics which will remain with him as he deals with the problems of a complex and changing

world: The student develops high standards for himself, based on his own confidence in having solved difficult problems. He learns to pose the right questions, the prerequisite for dealing with problems in a meaningful way. He is able to deal with those hardest of questions that involve ambiguity, for these will be the types of problems most often encountered in the world of tomorrow. Finally, his demonstration of effectiveness in solving problems soon presents him with responsibility for leadership, and he accepts it gladly.

We believe that the full involvement of the student in the development of intellectual and personal growth is consonant with the tenor and quality of today's young person. The M.I.T. student wants and expects early responsibility, and in this he is like all of the M.I.T. students who have gone before him. He wants to become an effective participant in the world's affairs and a mature dreamer of what the world of tomorrow could become. The faculty of the Institute welcomes those who share this spirit and who seek to join this bold company.

HOWARD W. JOHNSON


VSETTS 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 7,400 students (including nearly 350 women), more than 3,700 of them studying for undergraduate degrees; about 900 members of the faculty; and a supporting teaching staff of almost 600. The Institute is located on a well-equipped residential campus of 120 acres fronting the Charles River in Cambridge, opposite Boston.

M.I.T. awards bachelor's, master's, professional (engineer), and doctor's degrees in a total of 36 fields of study; 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 superb command of basic principles, versatility of mind, keen insight and perspective of 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 explosive 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 inevitably shares.

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 very broad limits, determined each year by each student himself (in collaboration with a faculty adviser) 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, international relations, linguistics, and the history and philosophy of science.

Every M.I.T. undergraduate must study one subject each semester in the humanities program — approximately 20 per cent of his undergraduate work. An undergraduate who wants more work in this area may register for a program

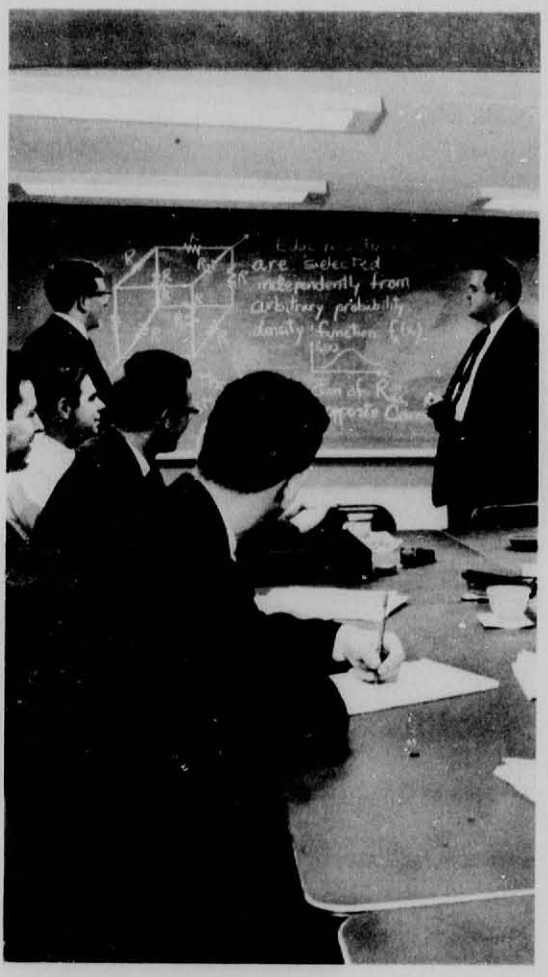
which combines study in one field of humanities or social science with work in one science or engineering discipline.

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.

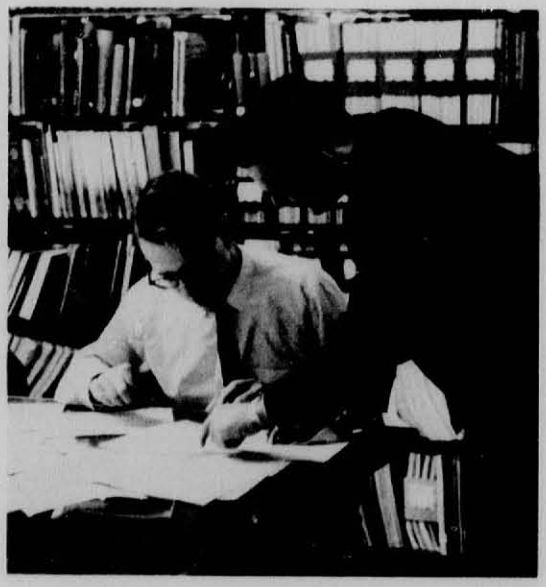
"As a great educational institution," Dr. Stratton has said, "we shall be judged not only by the quality of our students' intellectual discipline but by the firmness of their moral fiber, by their attitudes toward the whole of learning, by the manner in which they speak and act, and by their understanding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






are selected
independently from
arbitrary probability





The Academic Program

The primary organization of the academic program is along the lines of the traditional disciplines. Each of the twenty-two 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.).

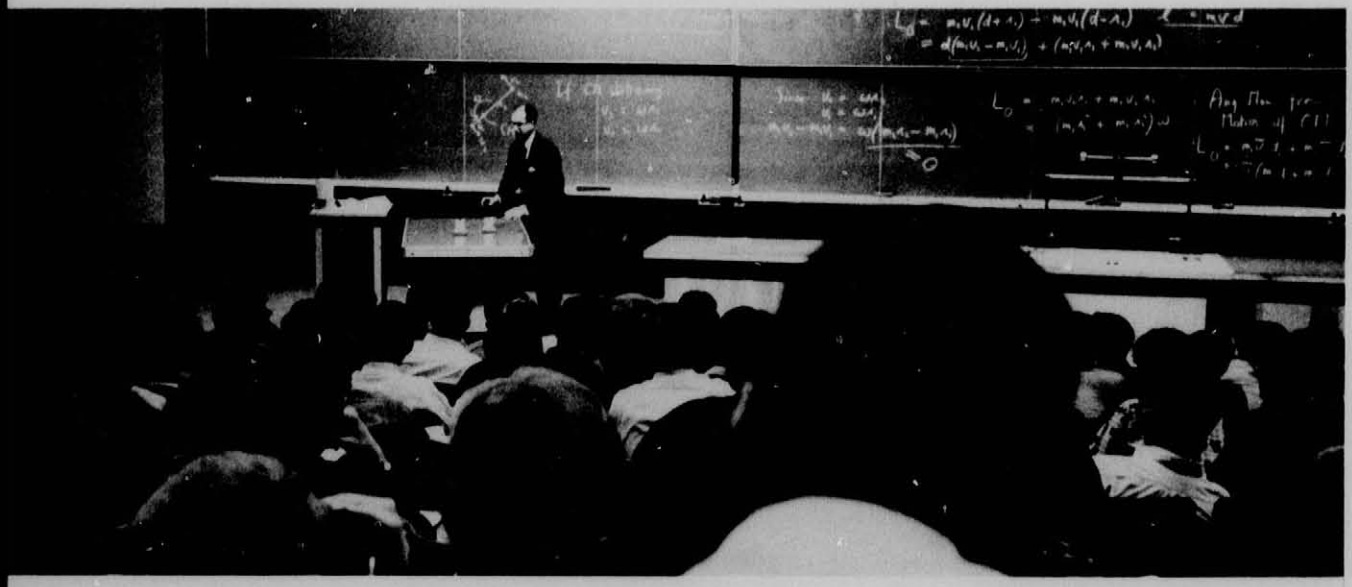
The chart on the following pages shows schools, departments, undergraduate and graduate Courses and degrees, and Course numbers. Undergraduate Courses, including Courses which provide periods of on-the-job experience in industry, require four years of full-time study for the Bachelor of Science degree.

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 M.I.T. the word *Course* refers to an organized curriculum leading to a specified degree. The word *subject*, on the other hand, refers to the individual classes. 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.), Material s Engineer (MAT.E.), Mechanical Engineer (MECH.E.), Metallurgical Engineer (MET.E.), Mineral Engineer (MIN.E.), Naval Architect (NAV.ARCH.), Naval Engineer (NAV.E.), and Nuclear Engineer (NUCL.E.).

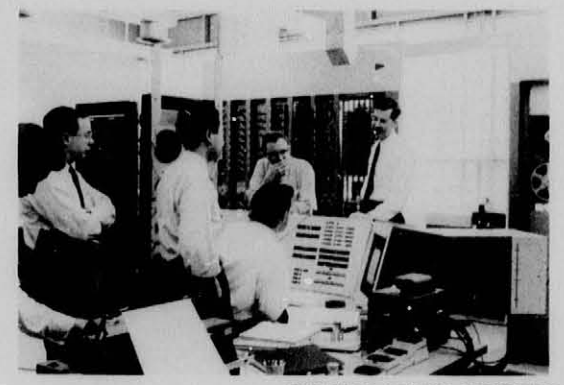


SCHOOLS, DEPARTMENTS, COURSES, AND DEGREES

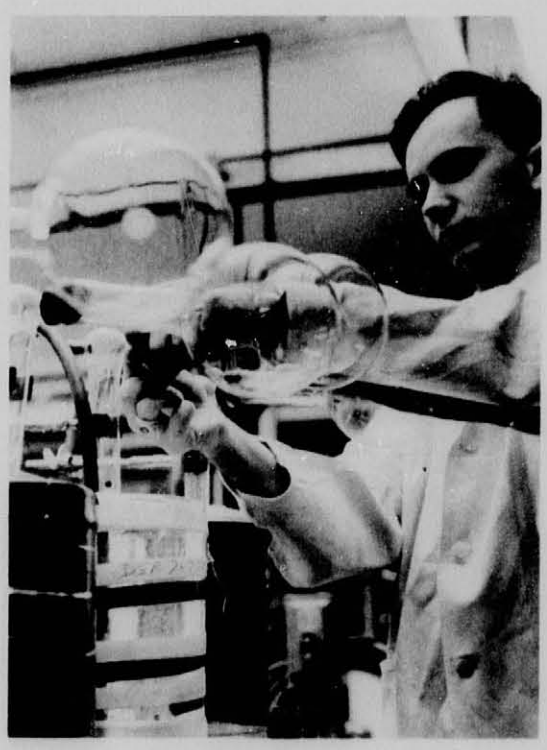
Schools and Departments	*Undergraduate Courses (and Course Numbers)*	*Bachelor's Degrees*	*Graduate Courses*	*Graduate Degrees*
School of Architecture and Planning				
Department of Architecture	ARCHITECTURE (IV)	S.B.	ARCHITECTURE (IV)	B.ARCH. M.ARCH
Department of City and Regional Planning			CITY AND 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[3] (XVI-B)	S.B.		
Department of Chemical Engineering	CHEMICAL ENGINEEKING (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[2] (VI-A)	S.B.	ELECTRICAL ENGINEERING[2] (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	METALLURGY AND MATERIALS SCIENCE[2] (III)	S.B.	METALLURGY[1] (III)	S.M., MET.E., MIN.E., SC.D., PH.D.
			CERAMICS	S.M., SC.D., PH.D.

[1] The degrees of Materials Engineer (MAT.E.) and Doctor of Science in Materials Engineering are also 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] The degrees of Master of Science and Doctor of Philosophy in Oceanography are also offered.

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.
	SHIPPING AND SHIPBUILDING MANAGEMENT[2,3] (XIII-B)	S.B.	SHIPPING AND SHIPBUILDING 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[4] (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.
Department of Mathematics	MATHEMATICS (XVIII)	S.B.	MATHEMATICS (XVIII)	S.M., PH.D., SC.D.
Department of Meteorology			METEOROLOGY[4] (XIX)	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



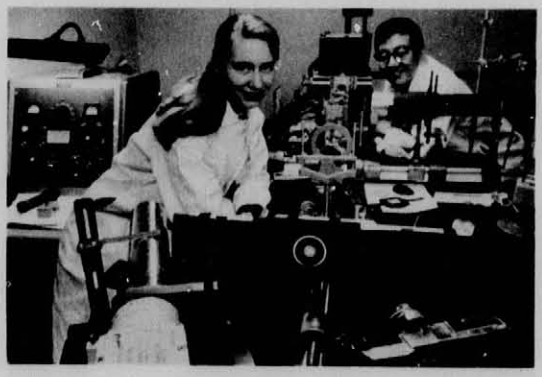
IN THE FOOD SCIENCE LABORATORIES



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 seventy 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 interdepartmental laboratories established to facilitate work in fields which cross the lines of traditional disciplines. The most important of these interdisciplinary research activities are described below.

Cambridge Electron Accelerator

The Cambridge Electron Accelerator, a 6-Bev synchrotron built and supported by funds from A.E.C. contracts, is operated jointly by M.I.T. and Harvard for high-energy research by faculty and students from both institutions.

Center for International Studies

The Center for International Studies reflects the growing interest of M.I.T. in the social, political, and economic aspects of technological change. Although the Center has no teaching program of its own, most of its 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, Soviet education, the international Communist movement, 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 expanded 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 will 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.

Center for Space Research

The Center for Space Research has been formed to stimulate graduate education and research in space-related disciplines in all departments at M.I.T. It provides financing for research activities, encourages collaboration between workers in many different fields, and will provide common facilities for research projects. A new building to house the Center's principal activities is now being planned for completion during 1967; both the building and the research program are financed in part from grants of the National Aeronautics and Space Administration.

Computation Center

The Computation Center is the largest and most versatile data processing facility in the country devoted entirely to education and basic research; its facilities are available both to M.I.T. and to fifty New England colleges which participate in a cooperative program. The majority of students entering M.I.T. learn to use a digital computer before they complete undergraduate or graduate degrees; the Center allots computer time each semester to over forty academic subjects given at M.I.T. and the cooperating colleges. Approximately half of these are concerned directly with the teaching of computation processes and programming methods; the remainder involve the application of computer techniques to specific fields.

International Business Machines Corporation makes available to M.I.T. the I.B.M. 7094 computer in the Computation Center without charge, contributes to maintenance and operating costs, and makes funds available to the Center for research appointments to graduate and postdoctoral students. The Center carries on research on areas and methods of computer utilization; most notable among its achievements has been the introduction of time-shared computer usage, a system which allows direct and multiple access to the 7094 by a number of users located at remote consoles.

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. A project for the Venezuelan government in the rapidly industrializing region of Guayana, which includes studies for a new city of several hundred thousand people, is affording special experience in the urban and regional growth of newly developing countries.

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 a number of high-energy accelerators: a 7-Mev proton cyclotron, a 20-Mev electron linear accelerator, 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 sometime in 1969. This will displace the Laboratory's existing linear accelerator and extend greatly the Laboratory's capabilities in this field. 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 in experiments in high-energy physics at the Brookhaven and Argonne National Laboratories. Experiments are also underway 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 U. S. Air Force and the Advanced Research Projects Agency of 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 space 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 laboratory 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 truly responsive to their individual needs. This includes the development of languages most suitable for man-machine interaction and capable of evolving with the conceptual structure of the field in which they are used. Another major research topic is the development of general-purpose "eyes" and "hands" 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 I.B.M. 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.

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

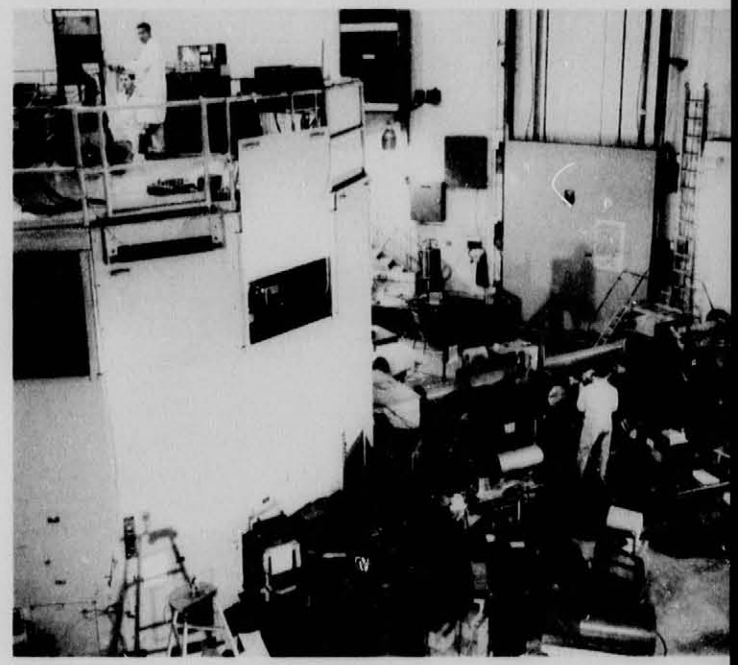
National Magnet Laboratory

The 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 Laboratory conducts research and teaching in solid state physics, and its experimental facilities are available to students and faculty from M.I.T. and to workers from other educational, government, and industrial laboratories.

Electromagnetic radiation from radio frequencies to gamma rays is employed to probe the properties of matter in intense magnetic fields. Continuous fields up to 250,000 gauss are produced by a 10-megawatt direct current power supply. Short time pulse fields exceeding 500,000 gauss in practical working volumes are also in use.

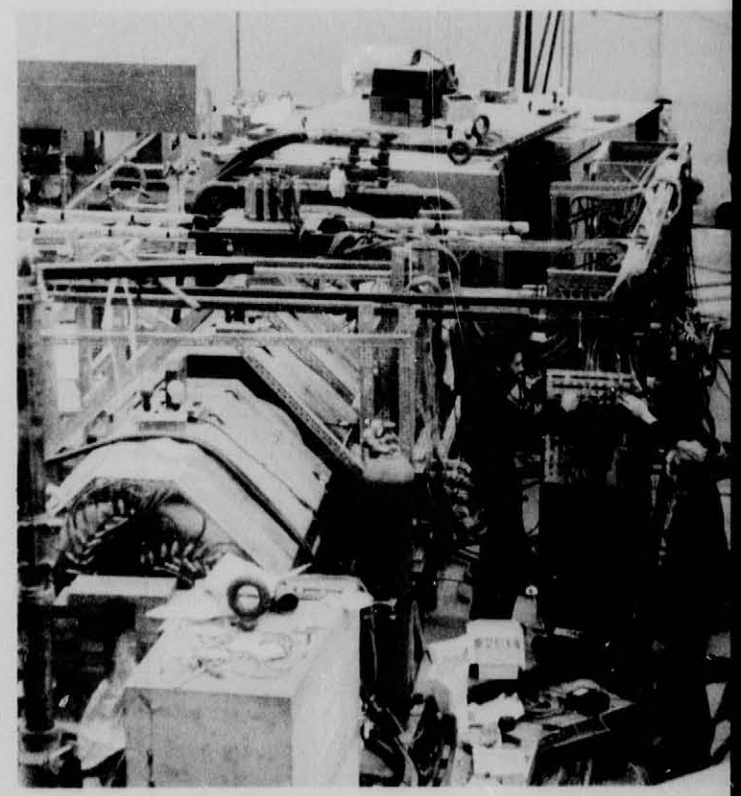
Operations Research Center

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. 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 doctor's degrees. Some graduate students prefer to work mainly in the department of their registration, taking the examinations and courses required for a graduate degree in that department and obtaining operations research experience by taking elective courses and conducting their thesis research in this field. Doctoral stu-



THE M.I.T. REACTOR

A LARGE SCINTILLATION COUNTER AT THE CAMBRIDGE ELECTRON ACCELERATOR



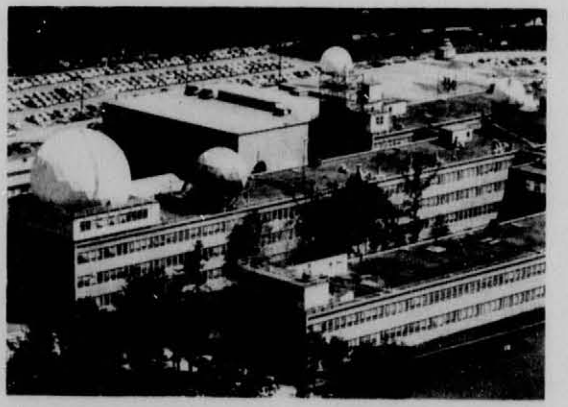


PROJECT MAC



COMMUNICATIONS BIOPHYSICS

LINCOLN LABORATORY



dents who desire to concentrate more heavily in operations research may arrange for interdepartmental supervision of their graduate program by special faculty committees.

Research Laboratory of Electronics

The Research Laboratory of Electronics provides a research environment in which faculty and students from eleven academic departments participate. The activities of the Laboratory fall into three broad categories — radio physics, plasma dynamics, and communication sciences. The research in radio physics includes microwave spectroscopy, radio astronomy, molecular beam studies, microwave electronics, far infrared spectroscopy, and several other topics. The research in plasma dynamics ranges from basic physics to engineering applications such as microwave oscillators and amplifiers, ion propulsion, controlled thermonuclear reactions, and plasma magnetohydrodynamics.

Studies of the various aspects of communication in both living and man-made systems comprise the activities of the Center for Communication Sciences. The major areas of interest include processing and transmission of information, statistical communication theory, artificial intelligence, speech communication, linguistics, mechanical translation, communications biophysics, neurophysiology, sensory aids research, circuit theory, and computer research.

Spectroscopy Laboratory

The Spectroscopy Laboratory has pioneered in the ruling of large, high-performance diffraction gratings and in designing, building, and utilizing high-resolution spectrometers. These instruments are used in studies of molecular geometry, of the properties of solids, and of complex atomic spectra. Investigations in the application of lasers to such problems as the generation of radiation in the far infrared region and stimulated Raman and Brillouin emission are in progress.

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.

The Campus

M.I.T.'s 120-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 960,000 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.

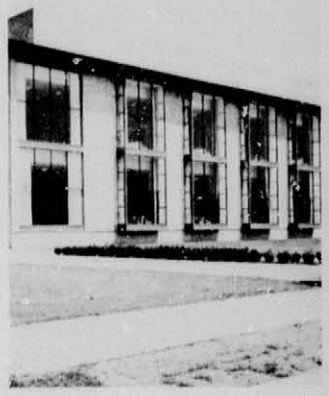
The library system, with headquarters in the Charles Hayden Memorial Library building, includes five school libraries, three branches, and four reading rooms: The Rotch Library of Architecture and Planning; the Dewey Library (economics, industrial management, industrial relations, and political science); 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 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



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.

Museums

The Museum Committee presents monthly exhibitions in the Hayden Library Gallery of the work of recognized contemporary painters and sculptors. The permanent art collection is displayed throughout the Institute, the latest addition being *La Grande Voile* by Alexander Calder. This large "stabile" is in McDermott Court, adjacent to Hayden Library and the Green Building.

In addition, the Francis Russell Hart Nautical Museum, containing a magnificent collection of ship models and the Allan Forbes and Arthur H. Clark print collections, has ample quarters of its own.

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.

A superb new Student Center, 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, football, track, and tennis are on the West Campus. Here, too, are the John Rockwell Athletic Cage, which has a large area for wintertime recreational and varsity athletics, including 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, 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 supplied with eight-oar shells, and there are excellent facilities for dinghy sailing at the nearby Sailing Pavilion.

Auditorium and Chapel

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

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

THE HAYDEN LIBRARY GALLERY



ENDICOTT HOUSE



Endicott House

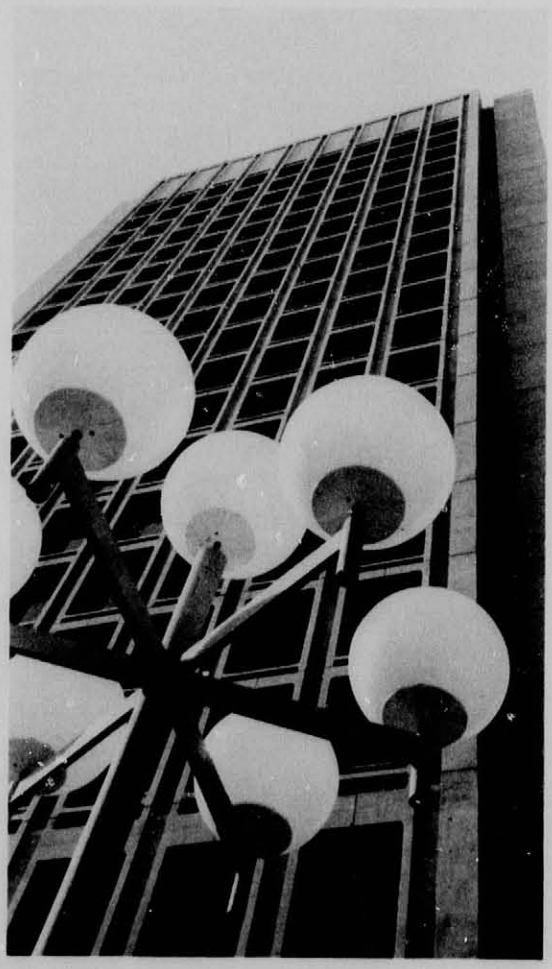
Endicott House, a former private estate located in suburban Dedham, is M.I.T.'s center for off-campus educational and administrative conferences. Set in spacious grounds, the House has meeting and dining rooms for seventy-five guests and overnight accommodations for thirty-two guests.

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.

GREEN BUILDING (EARTH SCIENCES)



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 sixty 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 five 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, asso-

ciate 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 2,800.

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 3,600, about 1,650 single men live in five men's residences on the campus; about 150 single women live in the women's residence, McCormick Hall, and an annex thereto also on campus; and about 1,150 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."

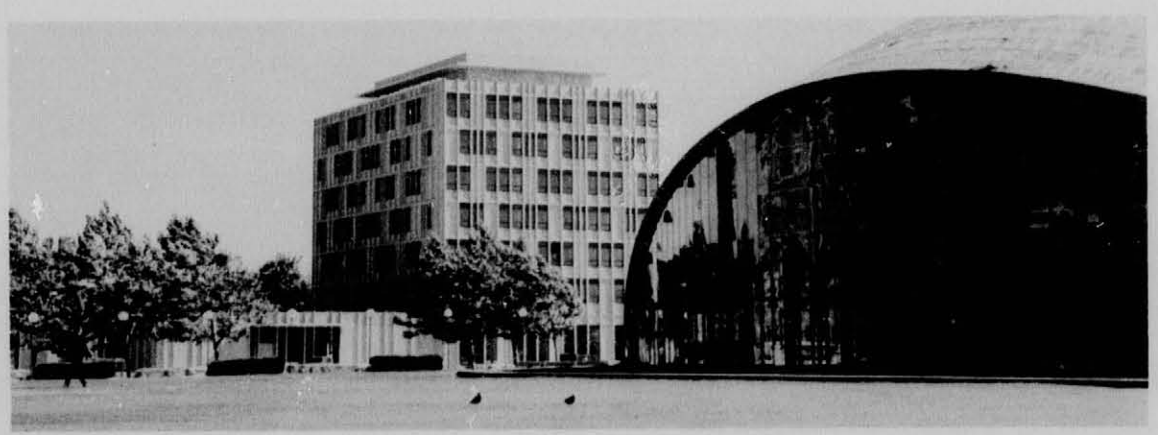
The central purpose of the residential system is to provide environment and programs conducive to personal development as well as to academic achievements and in this way to extend the experience of higher education which M.I.T. offers its undergraduates. Great reliance is placed by the Institute on 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 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 all dormitory governments — to help support these 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 twenty-eight 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 or its annex unless they reside at home with

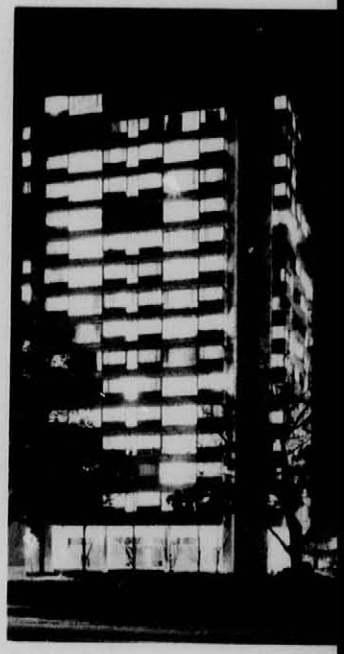




BURTON HOUSE



BAKER HOUSE



WESTGATE

SENIOR HOUSE



MC CORMICK HALL (*below and opposite*)



their families. 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 (West Campus), 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 (West Campus), 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 140 men can be accommodated.

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 430.

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 common meals and à la carte service are provided, and a modern social room and soda bar, where light refreshments are served. The latter, known as Pritchett Lounge, is open during evening hours and has a dance floor and other facilities for entertainment.

Rooms in the Institute Houses for undergraduate men are engaged for the full academic year. For the year 1966–67, the residence fees range from $185 to $250 per term. Commons meals for men are served Monday through Friday — 15 meals per week. Election of the commons plan is for the full term in which it is made. For the academic year 1966–67, the commons fee is $246.50 for the fall term and $232 for the spring term.

Residence for Undergraduate Women

McCormick Hall, a new building at 320 Memorial Drive overlooking the Charles River and adjacent to the main educational buildings, has accommodations for 134 undergraduate women students in 64 single and 26 double or triple rooms.

The inclusive rate for the academic year 1966–67 is $1,150, which provides for occupancy of a single, double, or triple room, dining service of twenty meals a week except for stated vacation periods, and linen service which supplies blankets for the year and fresh bed linen weekly. During the academic years 1966–67 and 1967–68, while construction of an addition to McCormick Hall is underway, residence for undergraduate women will also be provided in apartments on the second and third floors of the Westgate tower (the Institute's apartment residence for married students). The residence fee is $275 per term, without meals; the fee including dinner in McCormick Hall seven days per week is $425, and the fee including all meals in McCormick Hall is $575 per term. Residence in McCormick Hall or its annex in Westgate is required for all undergraduate women who do not live at home.

Other Housing Facilities

FRATERNITIES

Recognized fraternities at the Massachusetts Institute of Technology include twenty-seven 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 advisers. Each has its own dining room and provides experience in community planning and living similar to that achieved in the Institute Houses.

COOPERATIVE LIVING

The M.I.T. Student House is an independent, cooperative living group sponsored by a group of House alumni. The thirty-four 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 two 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 3,500, a comparatively small number reside on the campus. About 400 single men and 30 single women are accommodated in Ashdown House and about 200 married students live with their families in Westgate, an apartment complex at the west end of the Institute's playing fields. Additional married student apartments are presently under construction on the Sloan Campus to the east; these should be ready for occupancy in September, 1967.

The Avery Allen Ashdown House

Ashdown House, located at Memorial Drive and Massachusetts Avenue, Cambridge, across from the main educational buildings, was established in the belief that "the most natural training comes from free social intercourse between men of different interests but of equivalent intellectual outlook."

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

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

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

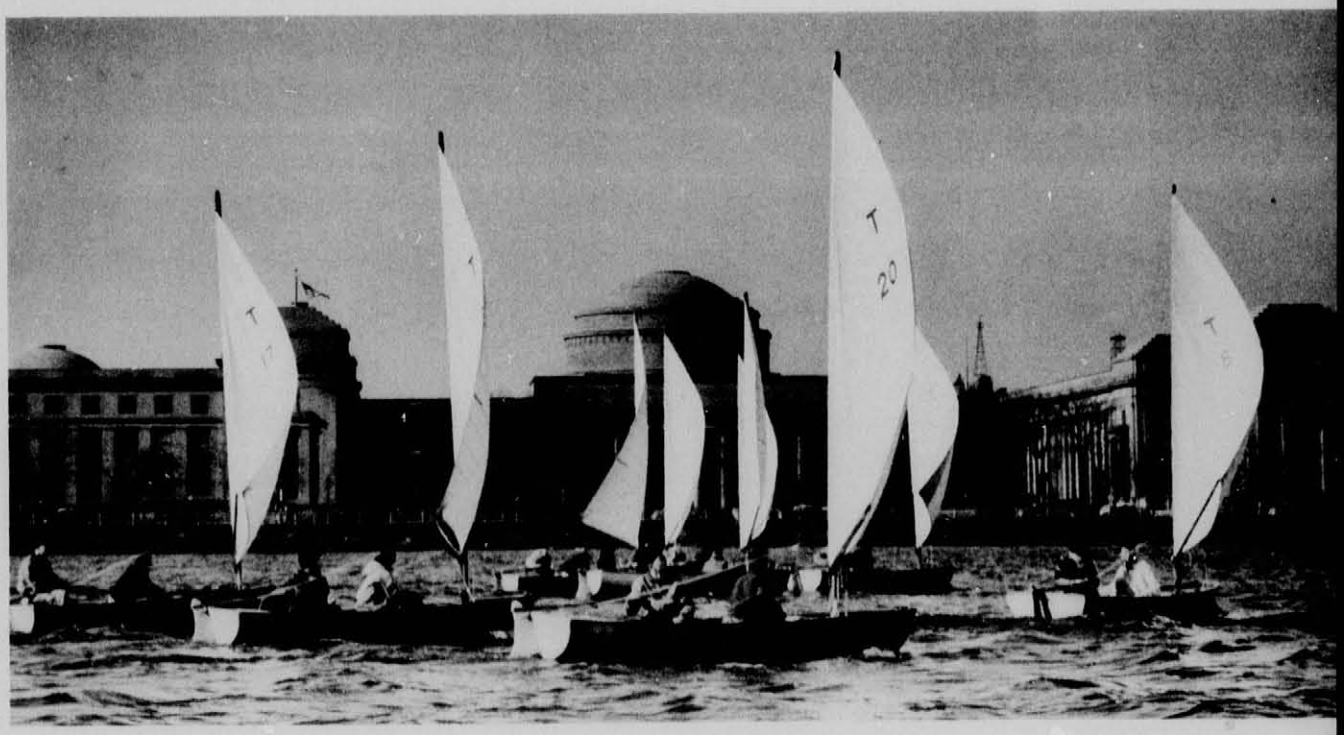
Rooms in Ashdown House are engaged for a full academic year; rents range from $160 to $235 per person per term. The equipment and service in Ashdown House, basic regulations, key deposits, and parking and automobile regulations are set forth in a booklet which is distributed, together with room application forms, to entering graduate students with their notifications of admission.

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.

Westgate

Five new buildings known as Westgate, at the west end of the M.I.T. Campus, provide 210 modern, efficient apartments. The West Campus location near Memorial Drive and the Charles River is within five to ten minutes' walk of the Institute's main buildings and convenient to public transportation.

The sixteen-story tower contains 90 one-room efficiency-type apartments and 60 one-bedroom



units. In addition, there are four three-story garden-type buildings which provide a total of 60 two-bedroom apartments. Community services, such as a coin-operated laundry, store, service and reception areas, free parking spaces for a majority of the tenants, and landscaped grounds with a children's play area, trees, and benches are provided. A nursery school in the tower building 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 at Westgate.

Residence in this project 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. Monthly rentals range from $95 to $137, including utilities.

For the academic year 1966–67 and 1967–68 undergraduate women students will occupy the second and third floors of the tower building as an annex to McCormick Hall.

Married students should send applications to the Campus Housing Office, Building W-31, Massachusetts Institute of Technology, 120 Massachusetts Avenue, Cambridge, Massachusetts, 02139. Since the number of accommodations in Westgate is limited, married students are well advised to consult the Institute Community Housing Service (see below) regarding off-campus residence.

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.

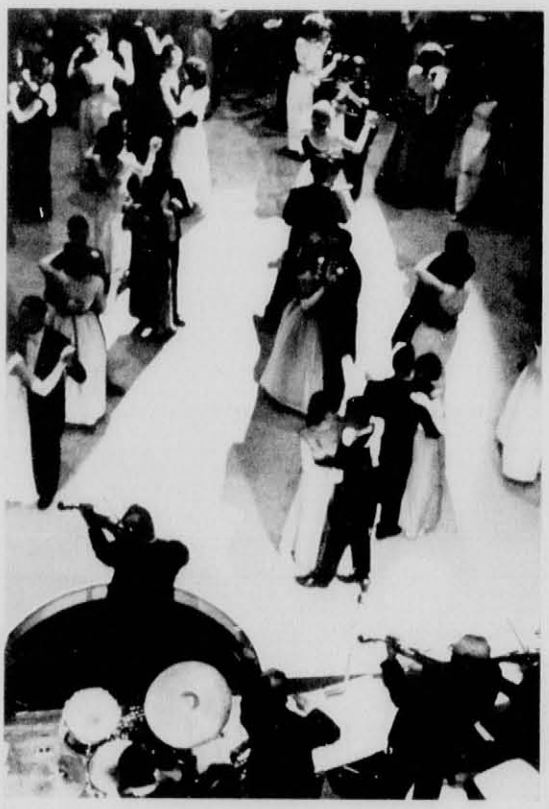
The Community Housing Service is located in Room 7-102; the mail address is Box 42, M.I.T. Branch Post Office, Cambridge, Massachusetts, 02139.

Campus Activities

M.I.T. is a community with wide extracurricular interests and liberal opportunities to enjoy them.











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

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



CHORAL SOCIETY

DRAMASHOP





OUTING CLUB



TECH SHOW

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 over 1,000 students to competition in eighteen 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, 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, softball, volleyball, swimming, track, tennis, table tennis, sailing, badminton, hockey, golf, squash, water polo, wrestling, rifle, and bowling. Club sports, with intercollegiate competition but less formal organization than varsity teams, include gymnastics, bicycling, rugby, water polo, cricket, judo, 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 Armory, Briggs Field, the Alumni Swimming Pool, Pierce Boathouse, fourteen ten-

nis courts, outdoor skating rink, and the Sailing Pavilion and boat house on the Charles River. There are also pistol and rifle ranges on the campus.

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. The entire intramural program, for example, including scheduling of games and arranging for referees, is the responsibility of this student group.

Student Government

The M.I.T. Undergraduate Association, operating through the Institute Committee as an elected legislative body, has broad responsibility for student activities throughout the campus. Its Judicial Committee handles disciplinary cases involving students or student activities; its Finance Board controls the budgets and expenditures of student organizations, allocating an annual budget of over $70,000 provided by the Institute for student activities; its Student Committee on Educational Policy makes recommendations to the faculty concerning academic matters; its Student Center Committee has a key role in the management of the Student Center; and other subcommittees are responsible for many of the chief events on the campus.

In addition, there are elected governments for each undergraduate class and in each dormitory and fraternity. Dormitories are represented in the Dormitory Council, which works with the Dean's Office in managing the Institute's undergraduate houses, and fraternities join in the Interfraternity Conference. Freshmen participate in student government through the Freshman Council, whose members are elected early in the fall term.

The Graduate Student Council performs similar student government responsibilities for graduate students, and the Ashdown House has its own elected group to plan House government and activities.

Drama

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

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

Lecture Series Committee

The Lecture Series Committee organizes popular and classic movie showings on the campus each weekend and is responsible for an outstanding program of guest lecturers. Recent lecturers have included Jacques-Yves Cousteau, Vance Packard, Dr. Wernher Von Braun, Dr. Herman Kahn, Dr. Arnold Toynbee, Bennett Cerf, Drew Pearson, T. S. Eliot, and Norman Rockwell.

Music

M.I.T. is a musical community. It has a busy season of musical activities and programs performed by many different musical groups, all of which are open to graduate as well as undergraduate students. The Combined Musical Clubs include a Glee Club, Symphony Orchestra, Concert Band, Woodwind and Brass Ensembles, and a concert jazz band — the Techtonians; there are also a Choral Society, which draws its members from the entire M.I.T. community, and a barber shop octet — the Logarhythms. All these out-of-classroom activities draw a large following among the musicians in the student body. These organizations give public concerts on the campus and in the neighboring communities, frequently in combination with musical groups of other colleges. The Choral Society has three European concert tours to its credit, the last — in 1962 — including appearances in London, Cambridge, Paris, Bonn, Berlin, and Munich; the Glee Club has combined concerts with girls' colleges; in 1965 the Glee Club (with Vassar) gave the American premiere of the Haydn opera, *Orfeo ed Euridice;* and the Concert Band, which specializes in contemporary compositions written especially for band, has a yearly, week-long concert tour which, this past year, culminated with a performance in New York City's Town Hall.

Chamber music groups, symphonic groups, and concert soloists appear at M.I.T. each year as part of the Humanities Series. Other pro-

fessional 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.

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

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

The Technology Community Association

With the help of a permanent staff, T.C.A. conducts a diversified program of year-around services to the M.I.T. community. Work with Boston settlement houses and mental hospitals, a handbook for new arrivals on the campus, a theater ticket service, book exchange, duplicating machines for student use, and annual blood donor and charity drives are a few of the activities sponsored by the student members.

Student Publications

Student publications at M.I.T. include *The Tech*, bi-weekly student newspaper; *Technique*, 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*.

Other Student Activities

There are more than eighty 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 local broadcasting station).

Technology Student Enterprises, Inc., is a new corporation which provides management facilities under which M.I.T. students develop individual and group entreprenurial efforts. Members of such organizations as Alpha Phi Omega (the national service fraternity) and the M.I.T. Social Service Committee join to take part in social service work in many areas of Greater Boston.

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

For foreign students, there are organizations where students of like nationalities may meet periodically to participate in cultural and social activities each year.

The Technology Dames

The wives of M.I.T. students — both undergraduate and graduate — form the Technology Dames. A social and service organization, the group numbers nearly four hundred and sponsors twice-monthly program meetings; weekly bridge, bowling, swimming, and cultural group meetings; a Holiday Dance, neighborhood Newcomer Teas, and a "Graduation" dinner. Membership is $2.50 and includes a subscription to the Dames' monthly newsletter.

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, otolaryn-

gology, dental hygiene, X-ray, and laboratory diagnosis. An infirmary with twenty-three beds and an operating room are located on the upper floors. Facilities of the Boston and Cambridge hospitals are used in cases involving major operations or complicated medical procedures, after which students may return to the Infirmary for convalescence.

A 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. The cost of the Student Health Program per year is $74.00 for a single student; $173.00 for a student and wife; and $198.00 for a student, wife, and children. Students who do not wish to be enrolled in this plan must sign a waiver at the time of registration.

A student and his wife may receive routine medical care in the clinic without charge. However, unless the patient is enrolled in the Student Health Program, a fee will be charged for diagnostic services, care in the specialty clinics, and hospitalization in the Infirmary. 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 Boston 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 Medical 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 53,000 former students informed of M.I.T. affairs. Chief among its publications is the *Technology Review*, a monthly alumni magazine. There are nearly one hundred regional M.I.T. clubs throughout the world, and the Alumni Fund ranks annually in the country's top half-dozen. Other alumni activities include Alumni Day, 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 Trustees of the Lowell Institute established this free evening school in 1903, under the auspices of M.I.T. It offers two regular two-year courses in engineering fundamentals — mechanical and electrical — and on occasion, if the demand justifies, a course in structural or civil engineering fundamentals. A number of supplementary single subjects are also offered. The program is designed to bring systematic

STUDENT CENTER (*top right*)

KRESGE AUDITORIUM (*below*)







engineering study within the reach of young people in industry who would otherwise be denied these opportunities. For further information, write to the Director of the Lowell Institute School, Room 5-111, Massachusetts Institute of Technology, Cambridge, 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 two noncommercial educational stations, WGBH-FM (89.7 mc.) and WGBH-TV (Channel 2), are operated with the advice and cooperation of the Council.

M.I.T. participation in programming of WGBH is centered in 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 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.

Placement

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

An Alumni Placement Bureau helps former students secure positions and aids industry in

selecting men for positions requiring engineering or scientific education.

The M.I.T. Press

The M.I.T. Press, one of seventy American university presses, has complete facilities for editing, designing, producing, promoting, and selling its titles. While The M.I.T. Press tends to specialize in titles in science and technology, its books range in subject matter from the history of science and linguistics through architecture and planning, the social sciences and economics, management, and the computer sciences. Most of its 400 published books are still in print, and it is currently publishing about 100 titles per year. Featured among its publications are a Research Monograph series, the M.I.T. Paperback series, which has greatly increased the audience for many specialized titles, and trade or general publications in fields from literature through mathematics to general statements about scientific and technical topics. A catalogue of current books is available on request.

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 also sponsor many service projects for the Institute community, among them a program welcoming new faculty and staff families, a Student Furniture Exchange, aid for foreign students seeking housing, hospitality activities, and English conversation classes for foreign wives.

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 adviser. Each student's program must be approved by this faculty member, and changes may be made only with his approval. After thirteen 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 advisers faculty members of the Freshman Advisory Council. Other undergraduates enrolled in a department have a Faculty Counselor from that department, and graduate students have Graduate Registration Officers.

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

Attendance

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

Grade Reports

Grade reports are issued by the Registrar at the end of each term and summer session to all registered students. 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.

Condition Examinations

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

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

Examinations for Advanced Standing

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

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

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

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

Faculty-Student Relations

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

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

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

tute Houses and fraternities, and extracurricular activities, including athletics.

Official Notices

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

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 $950 per term. The tuition for graduate fellows, trainees, and academic staff in the Summer Session, beginning with the 1967 Summer Session, is $640. (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 $30 per unit taken either for credit or not for credit. Except for thesis, the minimum tuition is $180 for regular students and for Special Students who are employed by the Institute or who are dependents of employees or students and $360 for other Special Students. The maximum tuition is $950 per term.

The tuition fee for thesis research for the Bachelor's degree is $30 per unit credit in either regular term, with a minimum of $150 and a maximum of $950. 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 $180 applies to the total tuition for the term.

Any graduate student making progress on his thesis research 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 preceding regular term, or if the immediately preceding term was the Summer Session and he was registered for thesis in the Summer Session, his tuition for thesis will be adjusted after delivery of the completed document on the basis of a charge of $95 per week from the starting date of the term, with a minimum of $190. 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.

The tuition fee for thesis presentation only is $100 for the Bachelor's, Master's, or Engineer degree and $150 for the Doctor's degree. Thesis presentation refers to those necessary academic events beginning with the actual delivery of the completed document. Registration for thesis presentation is appropriate only on Registration Day, and then only if the completed document has been delivered and only if the student was registered for thesis in the immediately preceding term, regular or summer.

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 twelve-month period, July 1 to June 30, is $1,900, payable $950 on or before August 1 and $950 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) will pay the specified tuition fees for the subjects for which they register during the Summer Session they attend. Students in Course II-B will register and pay a $100 tuition fee for the six-month period they are at the plant. Students in Course XVI-B will register and pay a

[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.

$35 tuition fee for the term they are at the plant.

For the School of Chemical Engineering Practice (Course X-A) for the period September through January or February through June, the tuition fee is $950.

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.

Dormitory 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 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

A charge of $10 is made for each condition or special examination and $10 for the completion of incomplete work. 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 $30.00 for this purpose. Any student who fails to appear for a predoctoral language examination is subject to a fine of $10.00. The fee for the Student Health Program, which is required of all students who do not sign waivers, is $37.00 per half-year in the case of a single student; $86.50 for a student and wife; and $99.00 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 1966–67 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	$1,900.00	September 14	$ 375.50
Average dormitory rent	400.00	October 14	376.00
		November 15	376.00
Commons meals	478.50	December 15	376.00
Medical insurance	74.00[1]	February 1	359.00
Laboratory and/or military equipment deposit	50.00	March 1	360.00
		April 3	360.00
		May 1	360.00
	$2,942.50		$2,942.50

[1] Covers a twelve-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 few exceptions stated.

Scholarship and low-interest loan awards are available to undergraduates with financial need. M.I.T. is today able to ensure that assistance equal to the full financial need of every undergraduate will be available from these two sources, thus achieving a long-standing objective: that no applicant be denied an M.I.T. education for financial reasons. Further information on scholarship and loan assistance and a definition of financial need will be found in Section 2 of this Catalogue.

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 for the payment of part of the M.I.T. tuition fee is also available to help reduce the burden of educational costs for students and their parents. Under this plan, any tuition cost in excess of $1,000 may be met by applying to the Director of Student Aid for credit in amounts of up to $900 for an academic year. Thus a student may use the Credit Plan to obtain a maximum four-year credit of $3,600.

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

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

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

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

Student Employment

The Office of Student Personnel is maintained to help students who wish to help themselves meet part of their expenses by earnings in on-the-campus jobs. The requirements of the Institute curriculum are such that only a limited amount of time may be given to employment, and prospective students are advised to have sufficient funds to cover the expenses of the first year at least. The average that can be earned through part-time employment 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 effectively assume 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, humanities, and social sciences; and in part of science-oriented subjects and project-type laboratory and upperclass humanities offerings among which each student may exercise a limited, but nevertheless 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, time for electives is available to every student in the first, third, and fourth years.

Every student can use these elective opportunities to follow special interests, to deepen or

broaden his educational background, or to prepare for graduate study, including areas in which M.I.T. gives no undergraduate degrees such as ceramics, city and regional planning, meteorology, oceanography, and nuclear engineering. In the same way, programs may be arranged to prepare undergraduates for advanced study in interdisciplinary fields such as astrophysics, communication science, and space science and technology and in such professional fields as medicine, law, and teaching.

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 twenty-five 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 in each case 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. Furthermore, flexibility in the choice of electives and subjects fulfilling the Science Distribution and Laboratory Requirements, the substitution of other subjects for certain of those specified in his Course, and, for superior students, the opportunity to take examinations for advanced standing, all permit a student to design a program around his own particular background, interests, abilities, and future goals.

To assure that substitutions for specified subjects in approved curricula be well thought out and not haphazardly chosen, a student must obtain permission from his Faculty Counselor, between the end of his fourth and the start of his seventh semester, 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. Recently, however, the faculty has authorized all departments offering this designated Bachelor of Science degree also to offer an undesignated degree of Bachelor of Science. The purpose of this new arrangement is to provide further flexibility by making available curricula which may cross disciplinary and departmental lines. While a Department's undergraduate curriculum for an undesignated Bachelor of Science degree 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. However, students who wish to make variations in their programs are allowed to do so in consultation with their Faculty Counselors.

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 and electives.

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 each school's description of its undergraduate

program, and the Departmental Programs are listed by each department.[1]

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 all of the various Courses available at the Institute. Students are encouraged to attend departmental orientation programs and to seek out and talk with faculty and others who have experience in fields of potential interest to them. They are also urged to exercise great care in selecting first-year electives and Science Distribution and Laboratory Subjects in order to take full advantage of the flexibility that these subjects offer 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.

[1] The requirements and curricula described in this Catalogue are those adopted by the faculty for students in classes entering the Institute in September, 1965, and thereafter. Requirements for students in earlier classes are given in supplementary material available on request.

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. Another reason for using care in the selection of these subjects is that one result of choosing a Course at the end of the second year, instead of at the end of the first, can be the exchange of elective freedom in the third and fourth years for that used in the second year; Counselors can help students utilize most effectively the elective freedoms which are assured in all M.I.T. curricula.

Premedical Education

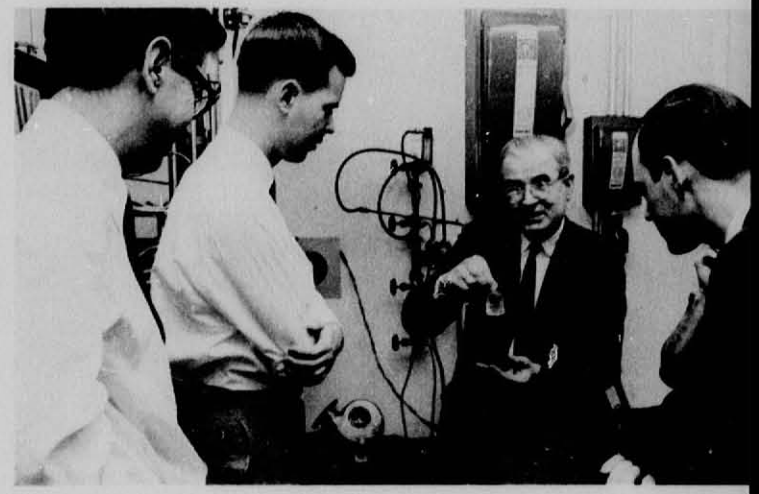
In recent years an increasing number of students have entered medical school from M.I.T. Specific medical school entrance requirements can be met in almost any of the Institute's Courses by proper selection of electives, and this type of broad premedical program fully meets the specifications of the Association of American Medical Colleges.

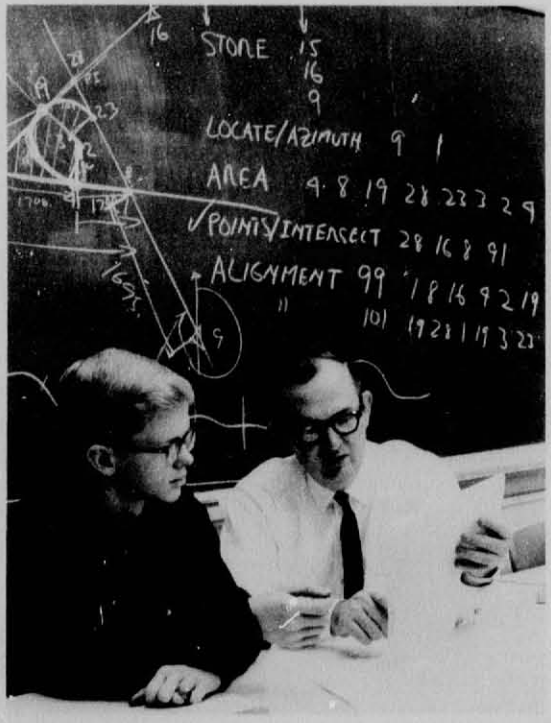
The flexibility and diversity of the programs which are available make it desirable that each student have guidance from a member of the Institute faculty. Dr. Harriet L. Hardy, a member of the Institute's Medical Department, serves as the adviser to premedical students. Specialized advice from other departments is freely used by Dr. Hardy to make certain that the student's program serves the needs of both medical school and a sound education.

Prelaw Education

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






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M.I.T. education fits well with the preferences of the leading schools, students may wish to consult Professor Stanley M. Jacks, the Institute's Prelaw Adviser, 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 Richard M. Douglas, Head of the Department.

Program for the Bachelor's and Master's Degrees

Any regular undergraduate student may undertake a program of study leading to the simultaneous award of the Bachelor's and Master's degrees, provided his department recommends him to the 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. 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 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. The division of time between class, laboratory (or design), and preparation for the various subjects is shown in the description of each subject.

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. 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 Requirements and curricula described in this Catalogue are those adopted by the Faculty for students in classes entering the Institute in September, 1965, and thereafter. Requirements for students in earlier classes are given in supplementary material available on request.

The General Institute Requirements include:

1. Completion of the science subjects CHEMICAL PRINCIPLES I (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 46-49 of this Catalogue.

3. Completion of the Science Distribution Requirement, described on pages 44–45 of this Catalogue.

4. Completion of the Laboratory Requirement, described on page 45 of this Catalogue.

5. Completion of the physical education requirements described on pages 45–46 of this Catalogue.

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

GENERAL INSTITUTE REQUIREMENTS		*Total Units*
Specific Science Subjects:		
CHEMICAL PRINCIPLES I (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	CHEMICAL PRINCIPLES I	5 2 5
8.01	PHYSICS I	5 0 7
18.01	CALCULUS	4 0 8
21.01	[1]THE GREEK TRADITION	3 0 6
		45

Second Term

8.02	PHYSICS II	5 0 7
18.02	CALCULUS	4 0 8
21.02	[1]THE EUROPEAN TRADITION	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 CHEMICAL PRINCIPLES I (5.01)] until the second term of the year. They can use the time thus made available to pursue independent study or to improve their high school preparation by registering in appropriate subjects. To this end, another possible schedule is:

First Term

		Units
5.01	CHEMICAL PRINCIPLES I	5 2 5
18.01	CALCULUS	4 0 8
21.01	[1]THE GREEK TRADITION	3 0 6
		33
	Additional elective subjects if desired	6 to 12
		39 to 45

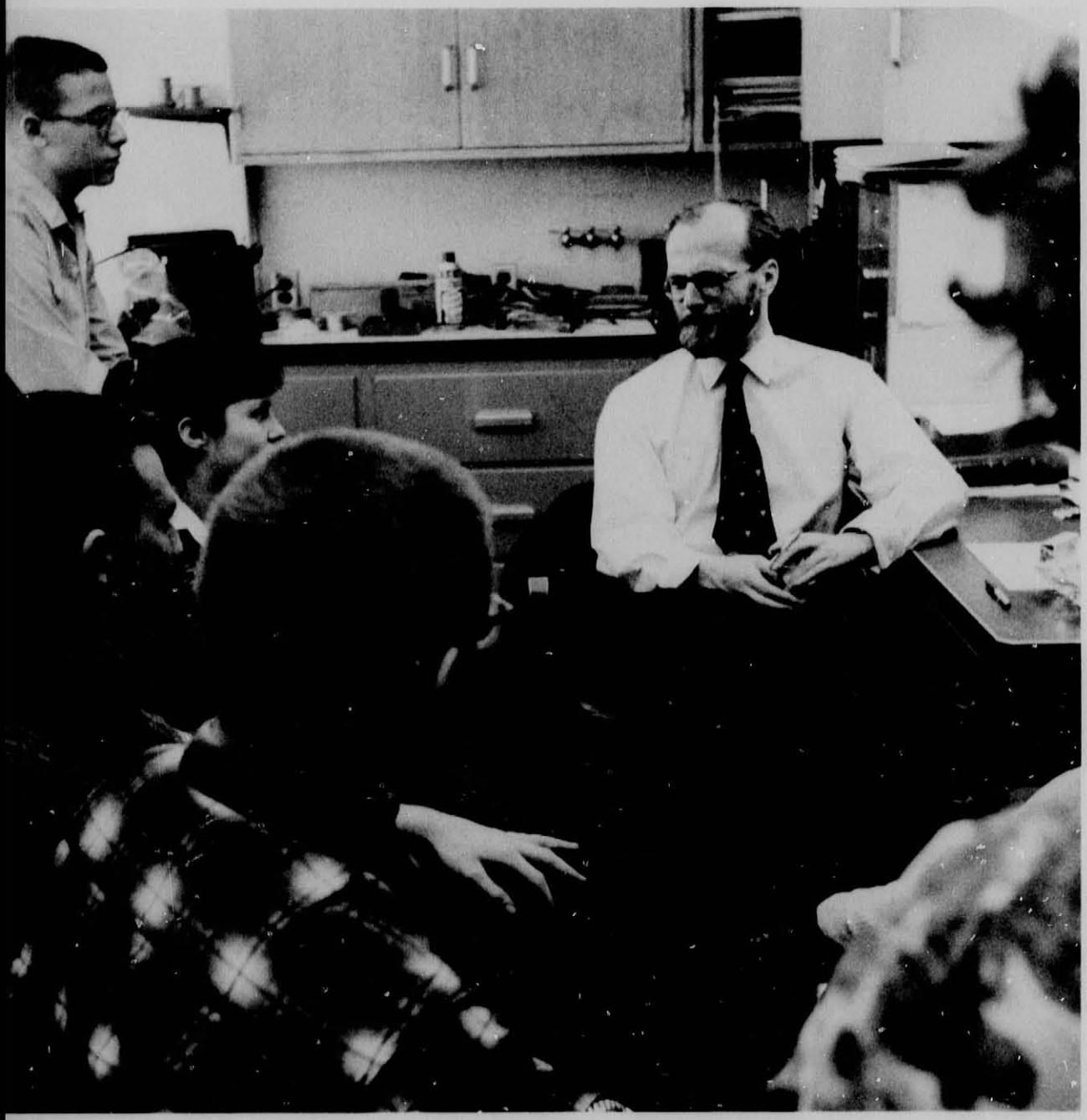
Second Term

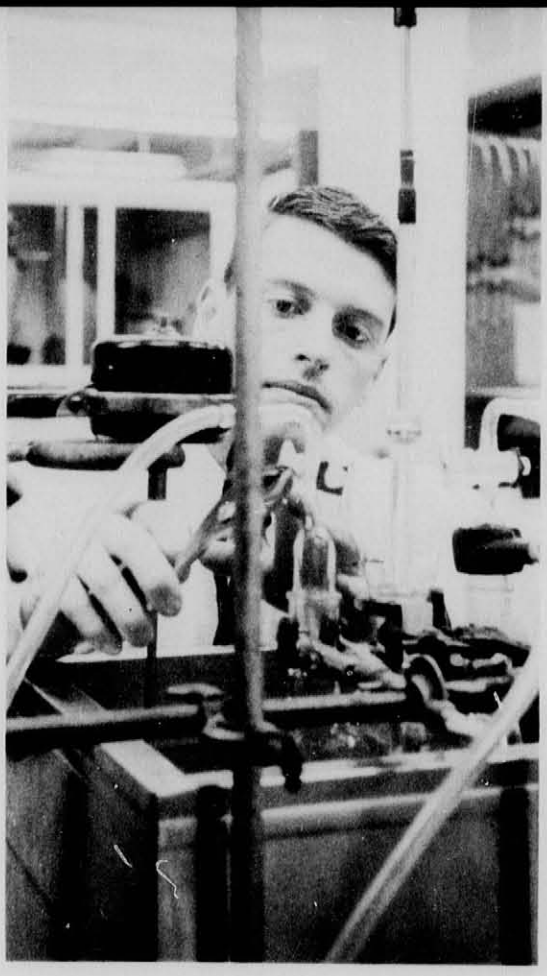
8.01	PHYSICS I	5 0 7
18.02	CALCULUS	4 0 8
21.02	[1]THE EUROPEAN TRADITION	3 0 6
	Elective	12
		45

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.011 THE GREEK TRADITION (in place of 21.01); 23.021 THE JUDAEO-CHRISTIAN TRADITION (in place of 21.02). The following subject is offered in German for students having an adequate background in German and will be accepted in place of the Humanities subject listed in parentheses: 23.022 THE EUROPEAN TRADITION: THE ERA OF GOETHE (in place of 21.02).

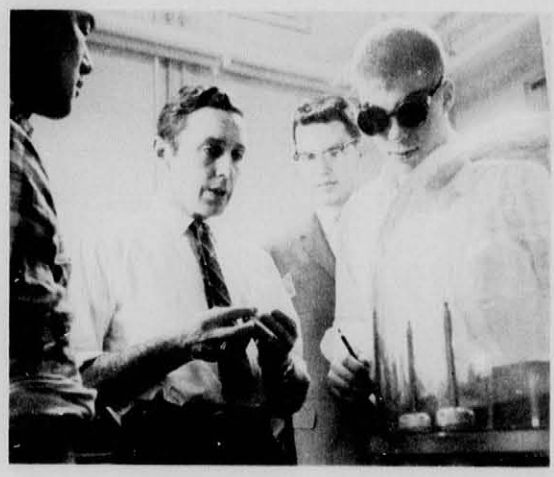
Variations in the First-Year Program

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 59).

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 Freshman Electives and Undergraduate Seminars listed on pages 43-44 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 (the regular Freshman Electives and the Undergraduate Seminars), from foreign language subjects for which the student is qualified, from upperclass electives in humanities without prerequisites, or from any other subjects offered by the Institute for which the student has sufficient preparation to justify the waiving of the prerequisite by the instructor in charge.

The Regular Freshman Electives and the Undergraduate Seminars

Both the Freshman Elective Subjects and the Undergraduate Seminars provide opportunities to explore fields of potential interest. Faculty Counselors stand ready to assist students with respect to their selection. Students may receive credit for the regular Freshman Electives and the Undergraduate Seminars only when taken in the freshman and sophomore years, and then only to the extent of 12 units. The following subjects are available, subject to possible restriction of enrollment where demand exceeds facilities.

First Term

1.40 INTRODUCTION TO ELECTRON MICROSCOPY (1–3–2)
1.401 PHYSICS OF MATERIALS (3–0–3)
2.711 ENGINEERING GEOMETRY (0–4–2)
2.722 DESCRIPTIVE GEOMETRY (0–4–2)
2.723 ELEMENTARY NOMOGRAPHY (2–0–4)
3.09 STRUCTURE AND PROPERTIES OF MATERIALS (3–0–3)
4.011 GRAPHICS LABORATORY I (0–3–2)
8.001 INTRODUCTION TO PHYSICAL IDEAS (2–0–4)
12.201 EARTH SCIENCE (2–1–3)
15.00 INTRODUCTION TO MANAGERIAL ACCOUNTING (3–0–3)
16.70 AIRCRAFT AND SPACECRAFT DESIGN (2–4–0)
16.81 FLIGHT VEHICLES (3–0–3)
18.00 ELEMENTARY NUMBER THEORY (2–0–4)
21.091 PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–0–4)
21.094 INTRODUCTION TO CONTEMPORARY PHILOSOPHY (2–0–4)
21.096 ENGLISH COMPOSITION (2–0–4)
AS11 [1]WORLD MILITARY SYSTEMS (3–1–3)
MS11T MILITARY SCIENCE (2–1–1)
MS21T MILITARY SCIENCE (2–1–1)
NS11 [1]ORIENTATION AND SEA POWER (3–1–5)
SEM11 [2]UNDERGRADUATE SEMINAR (0–6–0)
SEM12 [2]UNDERGRADUATE SEMINAR (0–6–0)

Second Term

1.15 COMPUTER LABORATORY (1–3–2)
1.40 INTRODUCTION TO ELECTRON MICROSCOPY (1–3–2)
2.711 ENGINEERING GEOMETRY (0–4–2)
2.722 DESCRIPTIVE GEOMETRY (0–4–2)
2.723 ELEMENTARY NOMOGRAPHY (2–0–4)
3.17 CASE HISTORIES IN ENGINEERING SCIENCE (3–0–3)
4.012 GRAPHICS LABORATORY II (0–3–2)
7.00 PERSPECTIVES IN LIFE SCIENCE (2–0–4)
12.202 ELEMENTARY ASTRONOMY (2–0–4)
15.00 INTRODUCTION TO MANAGERIAL ACCOUNTING (3–0–3)
19.003 ELEMENTARY METEOROLOGY I (2–0–4)
21.092 INTRODUCTION TO MORAL AND POLITICAL PHILOSOPHY (2–0–4)
21.096 ENGLISH COMPOSITION (2–0–4)
AS12 [1]AIR POWER AND THE WORLD MILITARY SYSTEMS (3–1–3)
MS12T MILITARY SCIENCE (2–1–1)
MS22T MILITARY SCIENCE (2–1–1)
NS12 [1]ORIENTATION AND SEA POWER (3–1–5)
SEM11 [2]UNDERGRADUATE SEMINAR (0–6–0)
SEM12 [2]UNDERGRADUATE SEMINAR (0–6–0)

[1] Open only to students accepted for A.F.R.O.T.C. or N.R.O.T.C. programs.

[2] A separate brochure is available.

The Undergraduate Seminars differ from the regular Freshman 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.

Other First-Year Electives

All subjects offered by the Department of Modern Languages and Linguistics are open to qualified freshmen, and any language subject may be chosen as a first-year elective. Students who wish to continue study of a language begun in school are welcome to consult with the instructors in the Department about the appropriate subject with which to begin. The R.O.T.C. programs, described below, are normally begun in the freshman year.

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, beginning on page 220.

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)
2.012 MECHANICS OF SOLIDS (4–0–8)
2.022 INTRODUCTION TO SYSTEM DYNAMICS (3–1–8)
2.403 THERMODYNAMICS (4–0–8)
2.404T STATISTICAL MECHANICS AND KINETIC THEORY (4–0–8)
2.41J THERMODYNAMICS AND STATISTICAL MECHANICS (3–2–7)
2.42 ELEMENTS OF CLASSICAL AND STATISTICAL THERMODYNAMICS (4–0–8)
3.00T THERMODYNAMICS OF MATERIALS (4–0–8)
3.141 SCIENCE OF MATERIALS (4–3–5)
4.30 STRUCTURES I (3–3–6)
5.02 CHEMICAL PRINCIPLES II (5–2–5)
5.41 ORGANIC CHEMISTRY I (4–0–8)
5.61 PHYSICAL CHEMISTRY I (4–0–8)
5.63 PHYSICAL CHEMISTRY III (4–0–8)
6.01 INTRODUCTORY CIRCUIT THEORY I (4–0–8)
6.013 INTRODUCTORY CIRCUIT THEORY I (4–0–8)
6.14 ELECTRONIC NETWORKS AND DEVICES (4–2–6)
6.43 INTRODUCTION TO ELECTRICAL SCIENCE (4–2–6)
7.01 GENERAL BIOLOGY (4–0–8)
8.03 ELECTRICITY AND MAGNETISM (4–0–8)
10.12 CHEMICAL ENGINEERING (3–0–5)
10.13 CHEMICAL ENGINEERING THERMODYNAMICS (4–0–6)
12.223 CRYSTALLOGRAPHY (2–2–2)
12.224 THEORETICAL MINERALOGY (2–0–4)

12.231 PHYSICAL GEOLOGY (3–4–5)
12.612 EARTH AND SOLAR SYSTEM (3–0–9)
12.811 PHYSICAL OCEANOGRAPHY (3–0–9)
16.00J THERMODYNAMICS AND STATISTICAL MECHANICS (3–2–7)
16.01 DYNAMICS (4–2–6)
16.09 FIELDS IN CONTINUOUS MEDIA (4–2–6)
16.20T SOLID MECHANICS I (4–2–6)
18.034 DIFFERENTIAL EQUATIONS (3–0–9)
18.10 APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES (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)
2.671T EXPERIMENTAL ENGINEERING (1–8–3)
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)
5.412 ORGANIC CHEMISTRY LABORATORY I (1–5–0)
5.422 ORGANIC CHEMISTRY LABORATORY II (1–5–0)
5.613 PHYSICAL CHEMISTRY LABORATORY I (0–4–2)
5.623 PHYSICAL CHEMISTRY LABORATORY II (0–4–2)
6.70 EXPERIMENTAL ELECTRONICS (1–4–1)
6.71 ELECTRONIC CIRCUITS AND SIGNALS LABORATORY (1–4–1)
6.711–6.719 PROJECT LABORATORY IN ELECTRICAL ENGINEERING (each 2–8–2)
6.72 ELECTROMAGNETIC LABORATORY (1–4–1)
7.02 GENERAL BIOLOGY LABORATORY (1–8–3)
8.09 [2]EXPERIMENTAL ATOMIC PHYSICS I (0–6–6)
8.14 PHYSICS LABORATORY (1–6–5)
10.91 EXPERIMENTAL RESEARCH PROBLEM (Arr.—minimum 6 units)
16.61 PROJECTS LABORATORY (1–4–1)
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.

Only students in Course VIII may use 8.09 to satisfy the Laboratory Requirement.

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 18 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, beginning tennis, and intermediate tennis. *Second quarter* — mid-November through January: badminton, basketball, development class, fencing, judo, scuba diving, skating, skiing, squash, beginning swimming, intermediate swimming, and Red Cross senior life saving. *Third quarter* — February through March: development class, diving, fencing, judo, skating, skiing, squash, beginning swimming, volleyball, 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, 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. Those who do not meet certain minimum standards are recommended for swimming or development classes. If the medical examination indicates any disability which might limit physical activities, 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 cutting in depth in a field outside the student's professional specialization. Finally, it seeks to develop skill in accurately and effectively communicating facts and ideas orally and in writing.

Every candidate for a Bachelor's degree must

(*text continues on page 49*)

HUMANITIES FIELDS AND SUBJECTS

FIRST YEAR[1]

First Term

THE GREEK TRADITION (21.01)

Second Term

THE EUROPEAN TRADITION (21.02)

SECOND YEAR[1]

LITERATURE: LANGUAGE, FORMS AND THE INDIVIDUAL AUTHOR (21.03T)
or
LITERATURE: SELF, NATURE AND SOCIETY (21.031)
or
PHILOSOPHY: CLASSIC AND CONTEMPORARY (21.04T)
and
THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM" (21.05T)
or
THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS (21.06T)
or
SOCIETY AND MAN (17.01T)

THIRD AND FOURTH YEARS

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

FIELD ONE: HISTORY

Any three of the following:

CHARACTER AND SOCIETY IN AMERICA: FROM THE PURITANS TO DAVID RIESMAN (21.401) †
DEVELOPMENT OF AMERICAN ECONOMIC INSTITUTIONS (21.403) †
AMERICAN IDEAS AND INSTITUTIONS (21.404) †
AMERICAN INTELLECTUAL HISTORY (21.405) †
HISTORY OF TRANSPORTATION IN THE UNITED STATES (21.406) †
TOTALITARIANISM (21.407) †
PRE-INDUSTRIAL EUROPE (21.501) †
THE NORTHERN RENAISSANCE AND THE REFORMATION (21.502T) †
ITALIAN RENAISSANCE (21.504) †
INTELLECTUAL HISTORY OF MODERN EUROPE (21.505) †
MARX, DARWIN, AND FREUD (21.506) †
REFORMATION AND REVOLUTION (21.507) †
RECONSTRUCTION OF EUROPE, 1945–1965 (21.508) †
WAR AND THE MILITARY INSTITUTIONS OF THE MODERN STATE (21.509) †
VIENNA AND VERSAILLES (21.51) †
CHINA, JAPAN, AND THE WEST (21.511) †
RUSSIAN REVOLUTION AND THE SOVIET UNION (21.512) †

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.011 THE GREEK TRADITION (in place of 21.01); 23.021 THE JUDAEO-CHRISTIAN TRADITION (in place of 21.02); 23.031 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.051 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T). The following subjects are offered in German for students having an adequate background in German and will be accepted in place of the Humanities subjects listed in parentheses: 23.022 THE EUROPEAN TRADITION: THE ERA OF GOETHE (in place of 21.02); 23.032 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.052 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T).

INTRODUCTION TO THE FAR EAST (21.513) †
SCIENCE AND NATURAL PHILOSOPHY IN THE CHINESE TRADITION (21.514) †
NEAR EASTERN ARCHAEOLOGY: THE FOUNDATIONS OF CIVILIZATION (21.515) †
SPANISH CIVIL WAR, 1936–1939 (21.516) †
CULTURES OF THE NON-WESTERN WORLD (21.517) †
CULTURES AND SOCIETIES OF AFRICA (21.518) †
CULTURES AND SOCIETIES OF THE CARIBBEAN ISLANDS (21.519) †
HISTORY OF MATERIALS (21.521) †
HISTORY OF ENGINEERING (21.523) †
HISTORY OF ENGINEERING (21.524) †
TECHNOLOGY AND ECONOMIC GROWTH (21.525) †
INDUSTRIALIZATION AND SOCIAL PROTEST SINCE 1815 (21.526T) †
HISTORY OF TECHNOLOGY IN THE UNITED STATES (21.528) †
HISTORY OF MATHEMATICAL ASTRONOMY (21.535) †
INTRODUCTION TO ANTHROPOLOGY (21.539)
CULTURES AND SOCIETIES OF LATIN AMERICA (21.541T)
THE BUSINESSMAN IN AMERICAN HISTORY (21.542) †
PEASANT SOCIETY (21.547) †
CULTURES AND SOCIETIES OF MEXICO (21.548) †
PHILOSOPHY OF HISTORY (21.662) †
SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS (21.701) †
ORIGINS OF MODERN SCIENTIFIC THOUGHT (21.702)

FIELD TWO: PHILOSOPHY

Any three of the following:
HISTORY OF PHILOSOPHY I (21.611) †
HISTORY OF PHILOSOPHY II (21.612) †
CLASSICAL PHILOSOPHY (21.613) †
PROBLEMS IN CONTEMPORARY PHILOSOPHY I (21.631) †
PROBLEMS IN CONTEMPORARY PHILOSOPHY II (21.632) †
PHENOMENOLOGY AND EXISTENTIALISM (21.634) †
EXISTENTIALISM IN LITERATURE (21.638) †
SYMBOLIC LOGIC (21.641) †
THEORY OF KNOWLEDGE (21.643) †
PROBLEMS IN ETHICS (21.651) †
NATURE AND JUSTIFICATION OF LIBERTY (21.653) †
CAUSATION, SPACE, AND TIME (21.659) †
PHILOSOPHY OF HISTORY (21.662) †
PHILOSOPHY OF THE ARTS (21.671) †
PHILOSOPHY IN LITERATURE (21.672) †
PHILOSOPHIES AND RELIGIONS OF THE EAST (21.691) †
MAJOR RELIGIONS OF THE WEST (21.692) †
PHILOSOPHY OF RELIGION (21.693) †
SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS (21.701) †
ORIGINS OF MODERN SCIENTIFIC THOUGHT (21.702)
PHILOSOPHY OF SCIENCE (21.712)
PHILOSOPHY OF MATHEMATICS (21.714) †
PHILOSOPHY OF MIND (21.716)

FIELD THREE: LITERATURE

LITERARY ANALYSIS (21.11) †‡
plus any two of the following:
LITERARY CRITICISM (21.12) †
THE EPIC (21.13) †
THE BIBLE (21.14) †
THE OLD TESTAMENT (21.141) †
SHAKESPEARE (21.15) †
CHAUCER (21.16) †
LITERATURE OF THE ENGLISH RENAISSANCE (21.19) †
COMPARATIVE STUDIES IN BRITISH AND AMERICAN FICTION (21.20) †
ROMANTIC POETS (21.22)
MAJOR AMERICAN WRITERS OF THE NINETEENTH CENTURY (21.23) †
SOURCES OF MODERNISM IN CONTEMPORARY LITERATURE (21.24) †
THE MODERN NOVEL (21.25) †
MODERN DRAMA (21.26) †
MODERN POETS: YEATS, ELIOT AND STEVENS (21.27) †
MODERN AMERICAN LITERATURE (21.28) †
THE DOUBLE VISION OF RUSSIAN LITERATURE (21.29) †
SOVIET RUSSIAN LITERATURE (21.291)
GOGOL AND LITERARY METHODOLOGY IN RUSSIA (21.292)
TOLSTOI'S "WAR AND PEACE" (21.293)
MAYAKOVSKY AND PASTERNAK (21.294)
NON-WESTERN LITERATURE (21.30) †
CHINESE LITERATURE (21.302) †
NARRATIVE FICTION (21.31) †
THE NATURE OF POETRY (21.32) †
THE DRAMA AS THEATRE (21.33) †
THE SHORT STORY (21.34) †
THEATRE ARTS: ELEMENTARY STAGECRAFT AND PRODUCTION STUDIES (21.35) †
TOWARD A THEATRE OF REVOLT (21.351)
THE NATURE OF THE COMIC (21.36) †
TRAGEDY (21.37) †
DANTE I (23.87) †
DANTE II (23.88) †

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 (23.15T) †
GERMAN ROMANTICISM (23.16T) †
GOETHE'S "FAUST" (23.19) †
SEMINAR IN GERMAN POETRY (23.20T)
MODERN GERMAN DRAMA (23.21T) †
MODERN GERMAN FICTION (23.22) †

Group B — French

CONVERSATIONAL FRENCH (23.54) ¶
or
LITERARY ANALYSIS (21.11) †‡
plus any two of the following:
FRENCH DRAMA (23.56) †
FRENCH PROSE FICTION (23.59) †
SEVENTEENTH-CENTURY FRENCH LITERATURE (23.61) †
FRENCH POETRY (23.62) †

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 (23.96T) †
SELECTED PROBLEMS IN SOVIET LITERATURE (23.98T) †
SEMINAR IN RUSSIAN PROSE (23.99T) †

Group D — Comparative Literature

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

FIELD FIVE: MUSIC

INTRODUCTION TO MUSIC (21.81) †
plus any two of the following:
MUSICAL FORM AND ANALYSIS (21.812)

‡ Students who elect 21.03T 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 21.03T 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.

(*list continues on page 48*)

(*list continued from page 47*)

MATERIALS OF MUSIC (21.82)
MUSIC THEORY I (21.822)
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)
TWENTIETH-CENTURY MUSIC (21.87)
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)
INDUSTRIAL ORGANIZATION AND PUBLIC POLICY (14.04)
ECONOMIC FLUCTUATIONS AND GROWTH (14.05)
STRUCTURE OF THE AMERICAN ECONOMY (14.06)
COMPARATIVE ECONOMIC SYSTEMS (14.07)
ECONOMICS OF THE SOVIET UNION (14.08)
ECONOMIC PROBLEMS SEMINAR (14.09)
ECONOMIC GROWTH AND DEVELOPMENT (14.10)
ECONOMICS OF PARTICULAR INDUSTRIES (14.22)
MONETARY AND BANKING POLICY (14.40)
PUBLIC FINANCE (14.43)
INTERNATIONAL TRADE (14.54)

FIELD SEVEN: POLITICAL SCIENCE

Any three of the following subjects:
POLITICS, SOCIETY, AND POLICY MAKING (17.12)
POWER, INFLUENCE, AND POLICY DECISIONS (17.14)
THE AMERICAN POLITICAL PROCESS (17.21) †
STRUCTURE OF URBAN LIFE (17.22) *
SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS (17.23)
COMPARATIVE POLITICAL SYSTEMS (17.24) †
POSTWAR U. S. DEFENSE POLICIES (17.31)
CURRENT U. S. DEFENSE PROBLEMS (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)
POLITICAL SCIENCE SEMINAR (17.64)
PREDICTION OF SOCIAL AND POLITICAL CHANGE (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
LABOR PROBLEMS SEMINAR (14.69)

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

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)
DEVELOPMENTAL PSYCHOLOGY (9.89)
ADVANCED PSYCHOLOGY (9.92) §

FIELD TEN: VISUAL ARTS

Three subjects: selections within both groups required

Group A

VISUAL DESIGN PROBLEMS (4.021T)
VISUAL DESIGN PROJECTS I (4.022T)
CREATIVE PHOTOGRAPHY I (4.051) †
CREATIVE PHOTOGRAPHY II (4.052)
EVALUATING PHOTOGRAPHY (4.053)
PAINTING (4.071)

Group B

TOPICAL STUDIES IN THE HISTORY AND THEORY OF ART (4.601) †
INTRODUCTION TO MODERN ART (4.602) †
FRENCH PAINTING 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‡

LANDMARKS IN URBAN EVOLUTION (21.92T)
SEMINAR: COSMOLOGY, OLD AND NEW PROBLEMS (21.93T)
PHILOSOPHICAL ANTHROPOLOGY (21.94T)
POETIC AND SCIENTIFIC DISCOURSE IN CLASSICAL LITERATURE (21.95T)
BIOLOGICAL BASES OF PERCEPTION AND KNOWLEDGE (21.97T)
HISTORY AND PSYCHOANALYSIS (21.98T)
PSYCHOLOGY OF LITERATURE (21.99)
HISTORY AND PHILOSOPHY OF TWENTIETH CENTURY PHYSICS (21.992T)
HUMAN AND MECHANICAL INFORMATION PROCESSING (21.994)
INTELLECTUALS AND SOCIAL CHANGE (21.995)
AMERICAN VALUES OF THE 1920's (21.996)
SHAW, LAWRENCE, FAULKNER: SOCIAL VISION IN LITERARY ART (21.997)
ANALYSIS OF MUSICAL SOUND (21.999)

‡ 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 10 fields to satisfy the concentration requirement of three subjects in a single field.

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

(*text continued from page 46*)

take eight term subjects in the humanities and social sciences; normally one subject is taken during each of the eight terms of residence.

In the first year each student takes a two-semester sequence, THE GREEK TRADITION (21.01) and THE EUROPEAN TRADITION (21.02). Through intensive work with original texts, each freshman is given training in critical reading, representing the three liberal disciplines of history, philosophy, and literature. The two freshman subjects also introduce him to the foundations and values of the Western Tradition. In the second year the sophomore has a choice within two sets of options. In the first set he elects either LITERATURE: LANGUAGE, FORMS, AND THE INDIVIDUAL AUTHOR (21.03T) or LITERATURE: SELF, NATURE, AND SOCIETY (21.031) or PHILOSOPHY: CLASSIC AND CONTEMPORARY (21.04T). In the second he chooses between THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM" (21.05T); or THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS (21.06T); or SOCIETY AND MAN (17.01T). 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. Frequent written exercises, with criticism from instructors in scheduled conferences, give each student an opportunity to improve his writing ability. 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 Languages, 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), Economics (Course XIV), or Management (Course XV) 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 Schools of Architecture and Management; 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.

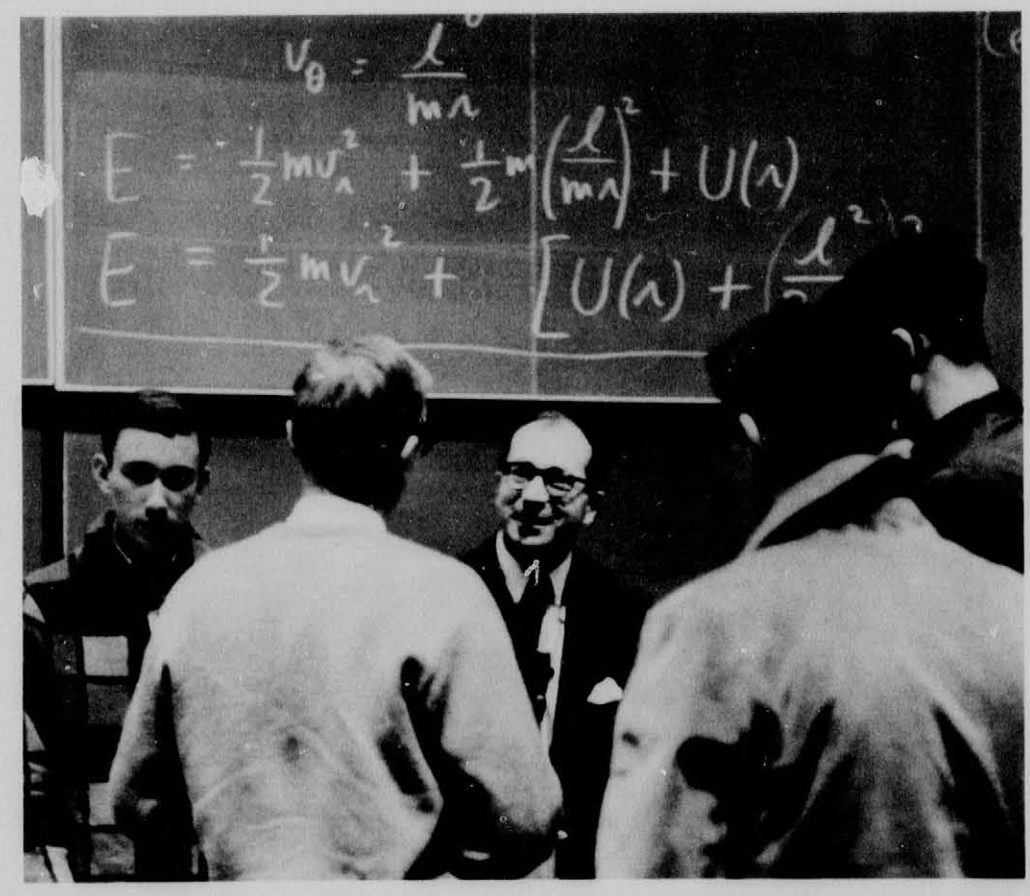
Military Science, Aerospace Studies, and Naval Science

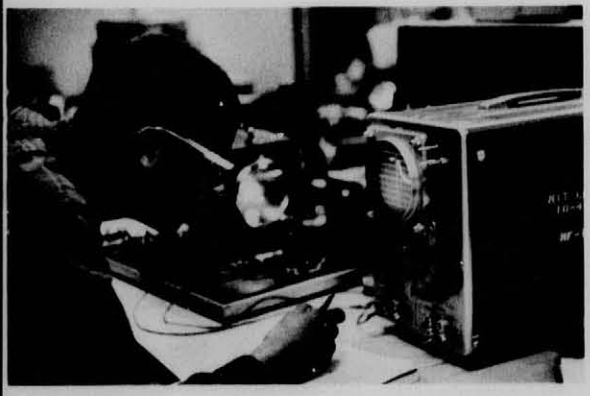
The general object of the Reserve Officers' Training Corps is to qualify students as officers in the active and reserve forces as well as for positions of leadership in civilian pursuits. The Army, Navy, and Air Force each conducts a program at M.I.T. for this purpose.

THE ARMY R.O.T.C. PROGRAM

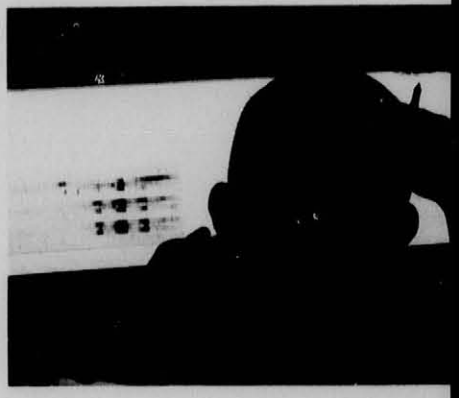
Full-time students who are U. S. citizens and who meet required medical standards may enroll for military science and earn commissions as Army Second Lieutenants while they pursue their regular academic courses. Books, uniforms, and equipment required for the program are furnished.

Four years of classroom work and a six-week Advanced Summer Camp qualify students for commissions upon graduation. Instruction in marksmanship, land navigation, drill, military history, and small unit tactics is presented


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







during the first two years of classroom work. Leadership, methods of instruction, world affairs, and the operations, tactics, logistics, and administration of battalions and brigades are covered in the junior and senior years. Practical application of lessons learned in the classroom and field training are covered in the Advanced Summer Camp at the end of the junior year. A six-week Basic Summer Camp prior to the junior year may be substituted for the first two years of classroom instruction.

Students receive $40 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 camps.

Two and four-year scholarships covering full tuition, fees, books, 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 February 1 of the year the student plans to enter M.I.T.

Newly commissioned officers normally begin their active duty in the Army within one year after receiving their bachelor's degrees and appointments as officers. However, active duty for graduate students continuing into advanced work may be delayed until graduate education is completed.

Elective Credit

All students completing MS11T, MS12T, MS21T and MS22T will earn 12 units of First-Year Elective credit. Elective credit is not given for MS31, MS32, MS41 and MS42.

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 required for aerospace study. Under the provisions of the Reserve Officers Training Corps Vitalization Act of 1964, Air Force R.O.T.C. cadets who have successfully completed the requirements of the first two years (General Military Course) of the four-year program are offered an opportunity to compete, on a nation-wide basis, for full scholarship assistance which includes tuition, laboratory fees, and books, plus a subsistence allowance of $50 per month during their junior and senior years. Those students who do not obtain a scholarship will receive $40 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; and if the student is physically qualified and desires to become a pilot or navigator, the required term of service is five 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. first-year elective credit)

Second Term
AS 12 AIRPOWER AND WORLD MILITARY SYSTEMS (3–1–3)
(M.I.T. first-year 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 (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 are unable to 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. Selections are based on a nationwide competition, with criteria similar to those for the scholarship program; but 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 $40 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 25 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 fifty-three nation-wide Naval R.O.T.C. programs designed to produce solely "engineering duty only" officers. Graduates of this program may serve their obligatory active duty as engineering officers aboard ship, in naval shipyards, or in other technical assignments. Students may apply for the Navy Nuclear Power Program or 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 approximately six 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 $40 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 $146 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 $40 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. Age 17 to 21 by July 1 of his entering year. (This age requirement may be lowered to 16 for outstanding students.)
3. Unmarried, never have been married, and willing to remain unmarried until commissioned.
4. 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.
5. Planning to pursue work at M.I.T. leading to a Bachelor's degree in any course except the following: Cooperative Course in Mechanical Engineering (II-B), Electrical Engineering (VI-A), Life Sciences (VII), Chemical Engineering Practice (X-B), Economics (XIV), Political Science (XVII), and Cooperative Course in Aeronautics and Astronautics (XVI-B).
6. Willing to sign a contract with the Navy which obligates the student, after completing the requirements for a commission, to fulfill the following additional requirements: to accept a commission, to serve on active duty for a period of 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. Unmarried, never have been married, and willing to remain unmarried until commissioned.

4. 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.

5. 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.

6. Planning to pursue work at M.I.T. leading to a Bachelor's degree in any Course except the following: Cooperative Course in Mechanical Engineering (II-B), Electrical Engineering (VI-A), Life Sciences (VII), Chemical Engineering Practice (X-B), Economics (XIV), Political Science (XVII), and Cooperative Course in Aeronautics and Astronautics (XVI-B).

7. 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. First-Year Elective Credit)

Second Term

NS 12 ORIENTATION AND SEA POWER (3–1–5)
(M.I.T. First-Year 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 NS42.

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 nation-wide 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.

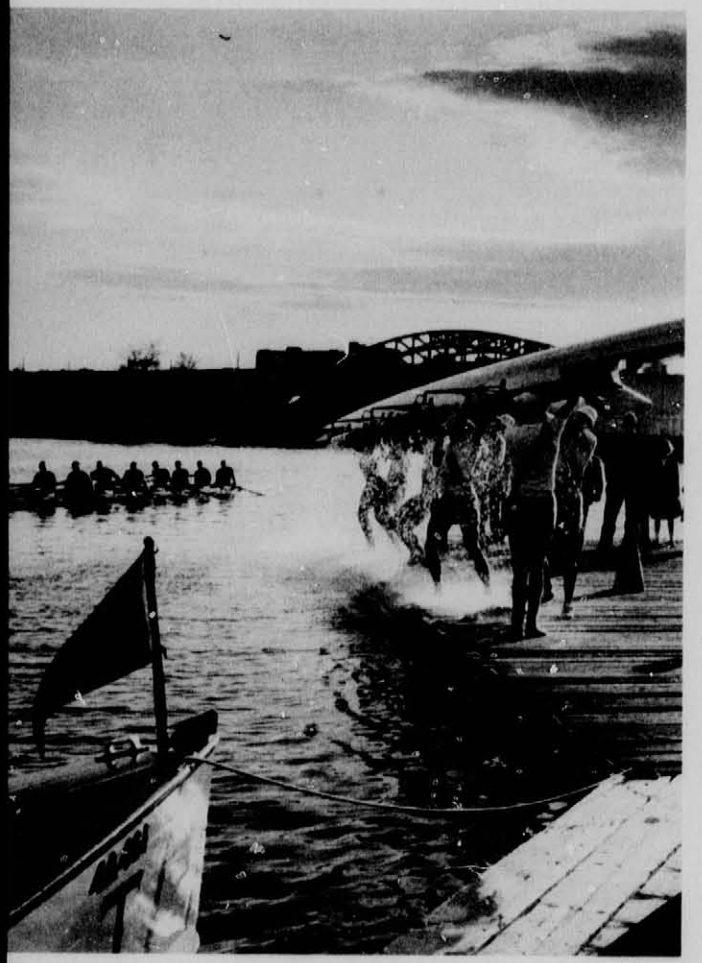
Sophomores interested in the two-year Naval R.O.T.C. Program must submit applications to the Commanding Officer, N.R.O.T.C. and Naval Administrative Unit, M.I.T., prior to May 1 of their sophomore year.

Military and Selective Service Office

M.I.T. undergraduates who may be subject to selective service will find help in their dealings with their local boards at the Institute's Military and Selective Service Office, Room 20E-226. Each student is expected to take one of the Selective Service College Qualification Tests. A Selective Service Form 109 is enclosed with first term registration material, and each student should fill out this form carefully according to instructions. Upon receipt of a classification questionnaire from a local board, students should report immediately to the Selective Service Adviser. Class 2-S student deferments are recommended, and application for renewal must be made each February. The Military Departments arrange for deferment of students who are enrolled in the advanced R.O.T.C. courses. 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.

Because of the important differences in academic practices and levels among overseas universities, there are no general rules for the application of academic credit earned overseas 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 John T. Norton of the Department of Metallurgy is Adviser on Overseas Study, 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.

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 $1,900 per year paid by each student covers less than half the cost of facilities and teaching. The balance is met by income from endowment and by gifts.

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 1966–67 at M.I.T.:

Tuition	$1,900
Board and room	1,130[1]
Books and materials	150
Medical insurance	74[2]
	$3,254

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.

Certain non-recurring expenses during the freshman year, such as drawing equipment and slide rules, are included in the allowance shown above for books and materials. In addition, there are deposits to cover breakage and laboratory equipment. These and other fees and expenses are described in detail in Section 1 of this Catalogue.

Financial Aid for Undergraduates

The Institute Student Aid Committee awards scholarships and low-interest 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. The Institute has sufficient resources to assure each student that his need will be met 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.

[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.

SCHOLARSHIPS

The Institute endeavors to provide the maximum possible assistance in scholarship for each incoming student and expects to continue to meet from 50 to 100% of each applicant's financial need in this way. The Student Aid Committee reviews applications and makes awards from the most suitable scholarship resources; applicants need not request aid from a specific fund. The difference between the scholarship award and total need will be met with a long-term, low-interest loan.

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 loans are granted only on the basis of financial need as established by the Parents' Confidential Statement. They are most frequently used to offset the difference between scholarship assistance and financial need.

Loans are available to M.I.T. students from the Institute's own Technology Loan Fund and from 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, 94704. 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 each year for continued assistance. Upperclassmen who have not received prior assistance may make application at this time. Except for those students who enter under a two-degree plan, students transferring from another college are not eligible for scholarship aid until they have satisfactorily completed one term of work at M.I.T. They may, however, be considered for assistance from loan funds.

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

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. But 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 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 will normally 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.

Application Procedure

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

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

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

Interviews

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 Preliminary Application in the Admissions Office. This personal conference is an essential part of the final application and should take place prior to January 15 of the year of entrance.

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

Entrance Examinations

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

Candidates who complete the tests in January and have submitted all other required material will be notified about admission to M.I.T. 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 his senior year, he may request the Committee on Admissions to review his application as soon as it is complete. If his test scores, school grades through the junior year, and other qualifications are so excellent that he will clearly be acceptable later, the Committee will offer him admission immediately; if it feels that it should compare his application with those of other candidates, it will hold his application until the usual time. A student who seeks early consideration in this way is free to file applications at other colleges and, if offered admission at M.I.T., is not required to reply to the Institute before the colleges' common reply date, May 1 in 1967. A student interested in his academic standing relative to M.I.T.'s standards should consult the published M.I.T. Freshman Class Statistics, available in the guidance office at his school or through the M.I.T. Admissions Office.

ADVANCED PLACEMENT

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

Qualified juniors and seniors who take college-level subjects offered in their schools in cooperation with the College Entrance Examination Board Advanced Placement Program should take the appropriate three-hour examinations administered by the Board each year in May and instruct the Board to send the scores, test papers, and reports from the school to M.I.T. 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 Adviser an optimum schedule.

In some secondary schools, selected students take college-level subjects directly under the auspices of the faculty of a local college. Such

students may submit an official transcript from the college showing subjects taken and grades earned in order to receive M.I.T. credit under the regular college transfer procedures.

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

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

COLLEGE TRANSFERS

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

Selection of Students

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

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

Advanced Credit

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

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

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

Application Procedure

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

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

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

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

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

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

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

Students who have attended another college will not be eligible for scholarship aid until they have satisfactorily completed one 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.

ADMISSION OF FOREIGN STUDENTS

Foreign citizens applying for undergraduate entrance must have their completed applications available for review by the Committee on Admissions by April 1. (Foreign students applying for entrance to the Graduate School should refer to Section 3 of this catalogue.) Decisions about admission cannot be made until complete records have been received. Applications received after April 1 cannot be considered for the September term of that year. Requests for application material, therefore, should be made at least nine months in advance of the September term. It is not possible to admit undergraduates for the February term.

The usual $10.00 application fee is not required of foreign students, except those studying in the United States or Canada and those of Canadian citizenship. The due date of January 15 also applies to these students.

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 April 1.

Candidates 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.

Candidates are expected to take the one-hour achievement tests in Level II Mathematics, (given only in January and May), Physics, and Chemistry. 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 and transfer 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 important cities of the world. Candidates pay a fee of $10.00 by International Money Order made payable to the Educational Testing Service. It is recommended that applicants take the test on January 16, 1967. Test registration forms and information regarding the test can be secured by writing to the Educational Testing Service at the above address.

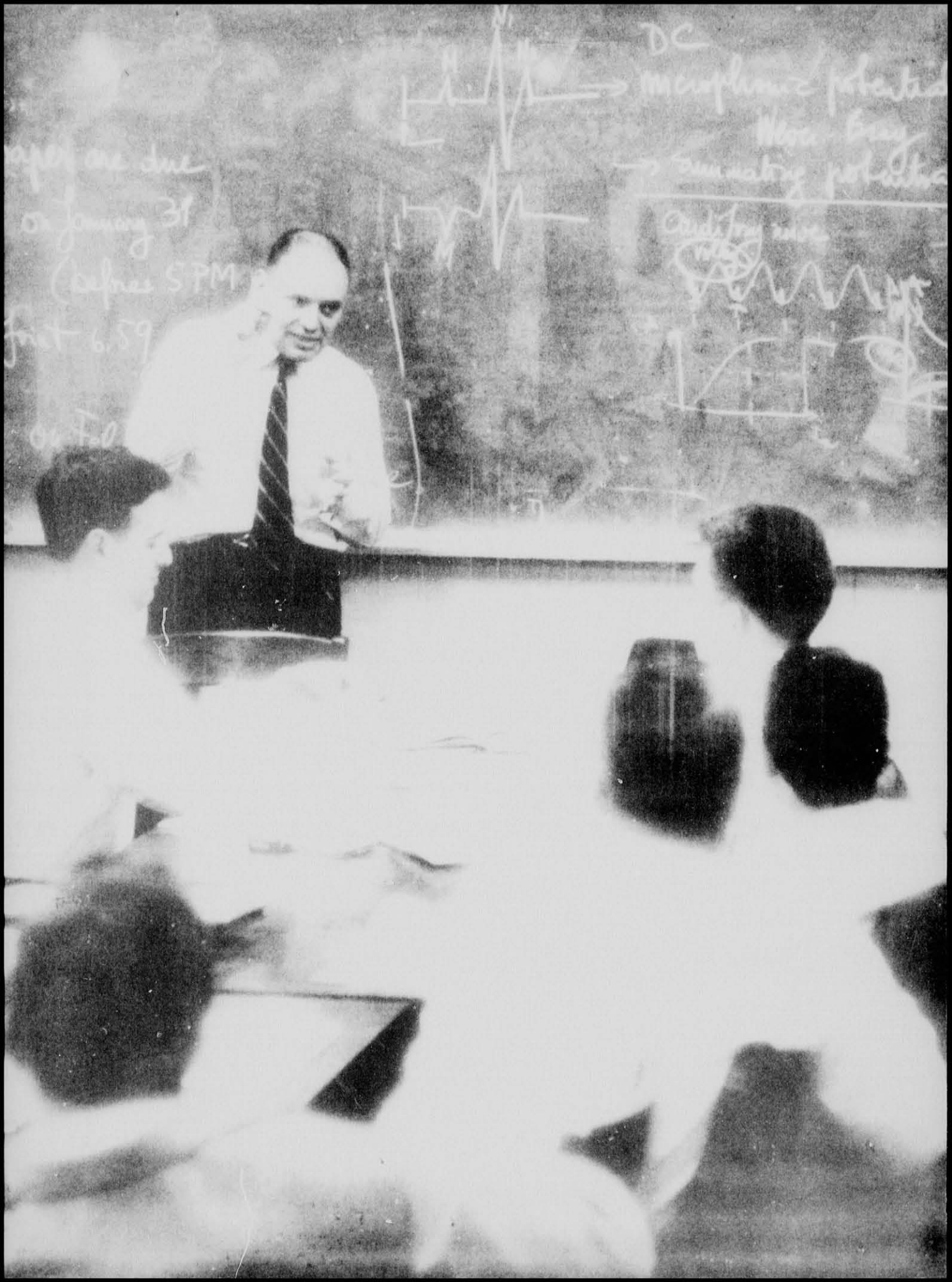
Foreign students should make all arrangements for their financial obligations to M.I.T. and for their entire stay in the United States before leaving their countries.

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

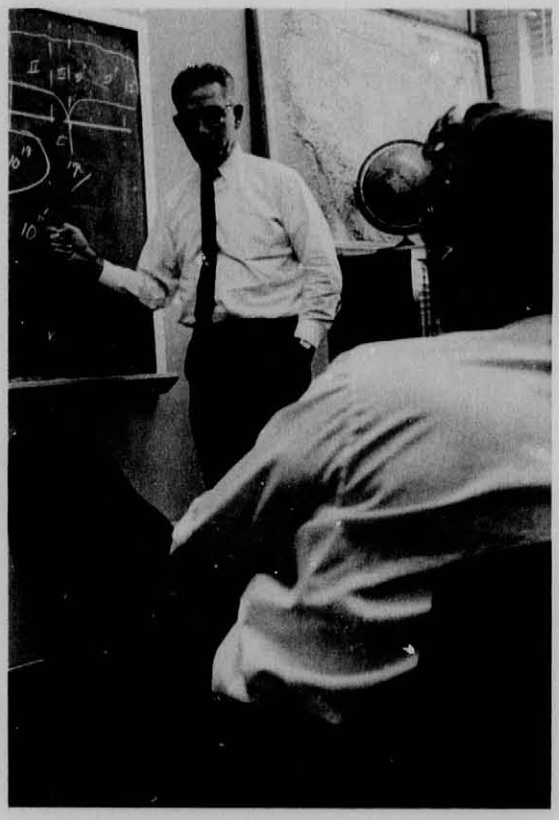
ADMISSION OF SPECIAL STUDENTS

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

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


DC

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 sixty years, with faculty members and post-baccalaureate students associated as a community of scholars sharing common endeavor in advanced professional study and creative work. The Graduate School, as the Institute-wide organization for academic administration of post-baccalaureate study, seeks to promote the best environment for advanced study and for intimate association among creative workers, faculty and students alike, who are extending the boundaries of knowledge in their professions. Through the Graduate School the various departments collaborate to establish common over-all requirements for admission, for character and quality of programs, for degrees, and for recommendation of the award of advanced degrees. Each student's program is guided by a department and its faculty in accord with these over-all requirements and 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.

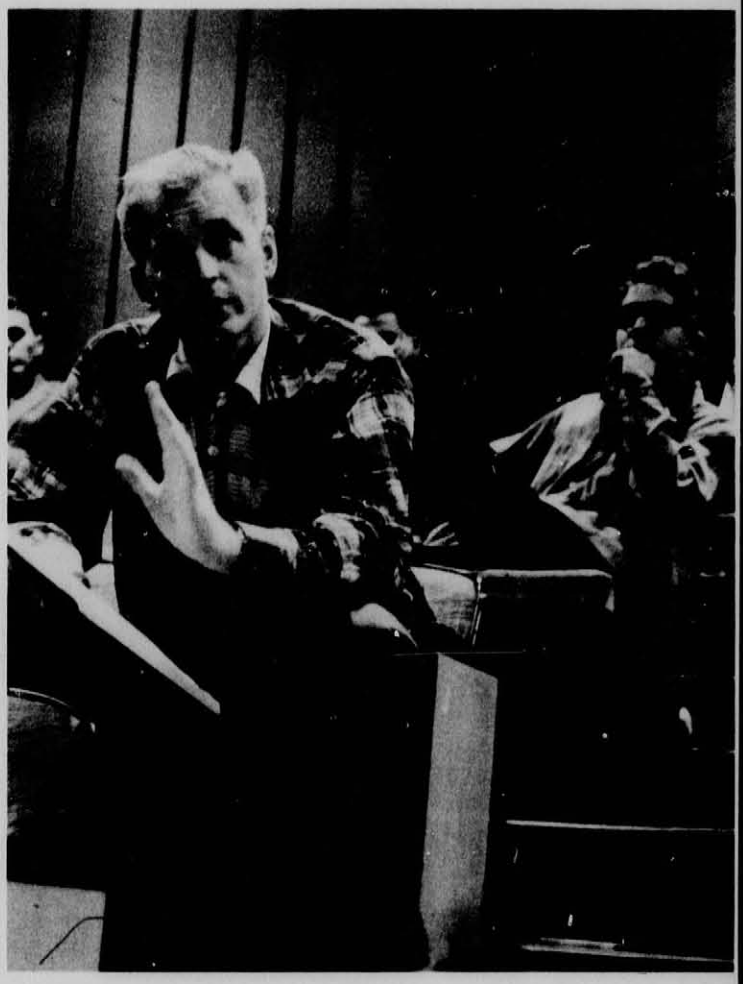
An outstanding characteristic of graduate education at M.I.T. is the atmosphere of intellectual independence and individual creativity combined with a strong sense of group unity and cooperation. This spirit is cherished as a major asset of the Graduate School.

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

to extending mental horizons, producing new orientations, and developing growth in intellectual courage and in depth of understanding. Achieving mastery of basic principles develops the mind as no mere acquisition of specialized knowledge can; it provides the power to attack unsolved problems with success and to explore new areas of knowledge with confidence.

Successful graduate study is closely associated with the ability to organize and express important ideas in clear and simple terms. 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 fifty 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. Enrollment of Regular Graduate Students now stands at over 3,000. 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 seventy foreign countries and more than 100 foreign universities are typically represented among the 600 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 under that heading in Section 1 of this Catalogue and by the individual departments in their respective sections, are a direct result. Graduate students — and, in







rapidly increasing 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 the students and faculty and to the success of the research itself.

Interdisciplinary developments, not new at M.I.T., are especially vigorous and seminal. For example, in the Research Laboratory of Electronics graduate students and faculty from twelve departments, ranging from physics and electrical engineering 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 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 and understanding 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 Westgate apartments for married students, both 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 68)
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.

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
Instrumentation
Propulsion
Space mechanics
Structures
Vehicle design

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

Department of Civil Engineering
CIVIL ENGINEERING, Course I
Applied earth science
Civil engineering systems
Construction management
Hydrodynamics
Materials
Operations research
Soil engineering
Structures
Transportation
Water resources

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

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

Department of Metallurgy
METALLURGY, Course III
Ceramics
Chemical metallurgy
Corrosion
Electron materials
Electron optics
Materials processing
Metal physics
Mineral engineering
Physical metallurgy

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

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

School of Humanities and Social Science

Department of Economics
ECONOMICS, Course XIV

Department of Humanities
HUMANITIES, Course XXI
Philosophy

Department of Modern Languages and Linguistics
MODERN LANGUAGES, 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

School of Science

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

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

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

Department of Mathematics
- MATHEMATICS, Course XVIII

Department of Meteorology
- METEOROLOGY, Course XIX
- Oceanography

Department of Nutrition and Food Science
- NUTRITION AND FOOD SCIENCE, Course XX
- Biochemical engineering
- Clinical nutrition
- Food engineering
- Food science and technology
- Food toxicology
- Nutrition
- Oral biology
- Physiological chemistry

Department of Physics
- PHYSICS, Course VIII



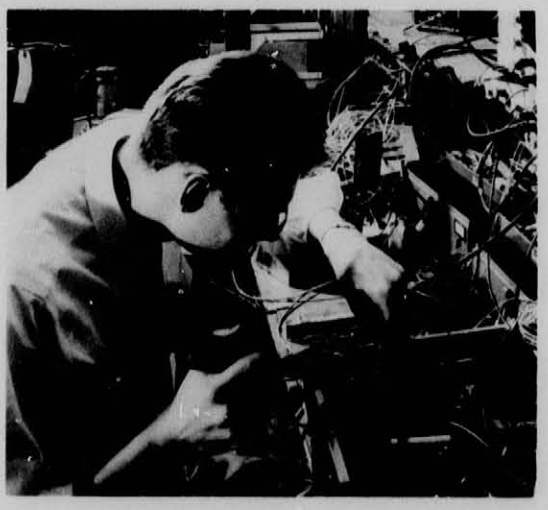
Each graduate student is officially enrolled in one department or Course. His program is not limited, however, to subjects offered in a single department. Subjects and research programs may be chosen from several departments, with the aid and counsel of the staff, as long as the over-all program is integrated 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 under the cooperative arrangement.



INTERDEPARTMENTAL DOCTORAL PROGRAMS

Their interdisciplinary character is a notable feature of many recent developments in science and engineering. Team research is one result of this; another result is that individual interests now frequently span a number of 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, oceanography, 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.

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

A student admitted to the Graduate School as a Regular Graduate Student is admitted as a candidate for a specific degree. If a student who has been admitted as a candidate for a Master's or Engineer degree obtains that degree, he cannot continue as a student at the Institute unless he is formally admitted as a candidate for a higher degree (or as a Special Student, if he is not interested in a higher degree).

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 8.03 (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. Believing that professional education should develop a student's awareness of himself and of his place in society, 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:

Economics, Electrical Engineering, and Physics: 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.

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 application material may be obtained.

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 Adviser 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. Other students applying to the Schools of Architecture and Planning, Engineering, Humanities and Social Science, and Science are urged to submit results in these tests. Normally applicants will be expected to rank not lower than the median in the verbal and quantitative aptitude tests and in the appropriate advanced tests.

All applicants for admission to graduate study in the Sloan School of Management are required to take the Admission Test for Graduate Study in Business (an aptitude test).

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.

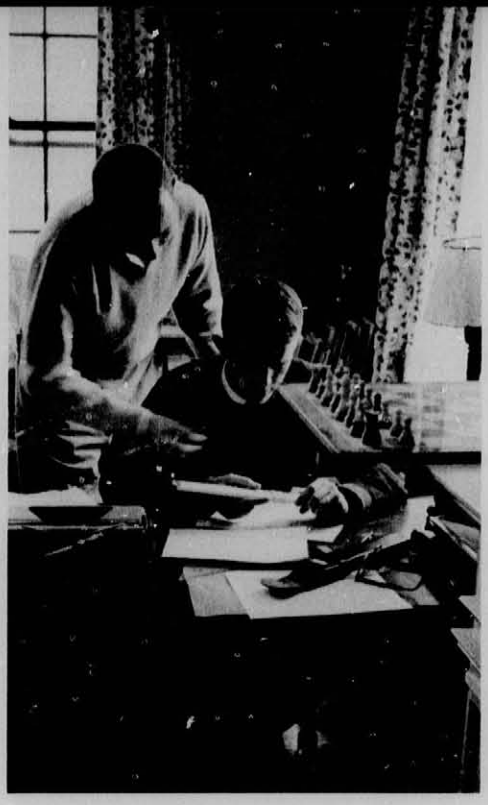
Academic Standards

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 strongly recommended 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 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. 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.

The Graduate School sends to the Local Board of each admitted student, on a separate S.S.S. Form 103, an official certification of his Graduate School admission with a request for his deferment in Class 2-S. A copy of this certification is also sent to the prospective student. Graduate students subject to Selective Service



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must comply with Operations Bulletin No. 46, as amended May 26, 1966. It limits deferment for students seeking a Master's degree to two calendar years beyond the Bachelor's degree and deferment for the doctorate to five years beyond the Bachelor's degree.

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.), and Nuclear Engineer (NUCL.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, 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 reading the technical literature of the field in modern foreign languages.

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:

a) Either

1. Substantial competence in speaking and reading one modern language in addition to English

or

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

and

b) If his native language is other than English, substantial competence in speaking and reading 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 field of his specialization. Accordingly, a student whose native language is other than English may expect acceptance of his native tongue as an approved language only if there is in that language a sufficient amount of important and pertinent literature.

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 semester in question. Written examinations in other 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 is required to submit with his application a receipt from the Bursar indicating that he has paid a special fee of $30.00 for this purpose. *Any student who fails to appear for a predoctoral language examination is subject to a fine of $10.00.*

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 on his research and thesis 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. However, work of certain types (such as the collection of data for an investigation) may, with approval of the departmental Committee on Graduate Students, be carried out elsewhere without registration or payment of tuition. A 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.

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

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 doctorates, the equivalent of at least two years of full-time graduate work must ordinarily be completed with residence credit, unless advanced work completed elsewhere is accepted as equivalent by the student's department. In no case may the required amount of work in residence be less than the equivalent of three full-time academic terms, including research for the thesis and writing of the thesis.

Financial Assistance to Graduate Students

Financial support 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. Each is awarded on the basis of academic promise and financial need, and each is intended solely to assist a student in the pursuit of his studies. No services 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 700 students at M.I.T. have fellowships or other grants from national agencies for the academic year 1966–67.

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 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. Application 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 by the national agencies and foundations. A student who wins one of these is not considered further for an award by M.I.T.

Award of Fellowships, Traineeships, and Scholarships

Notices of award by the Institute are mailed for delivery before the end of March. In accordance with a resolution of the Council of Graduate Schools in the United States, to which over

(text continues on page 78)

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 A.E.C. 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 Aeronautics and Space Administration

Forty-five traineeships (similar to fellowships) have been granted by N.A.S.A. in the last three years for award by M. I. T. to graduate students in space-related fields of study. Twelve months' tuition plus $2,800 and dependency allowances. Renewable. Application on standard M.I.T. fellowship form to the student's prospective department at M.I.T.

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 on-going 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.

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 N.I.H. 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 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 N.S.F. announcements on dates

Grants of the National Science Foundation provided for 132 traineeships in the same fields at M.I.T. in 1966–67 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 thousand 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 $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.

(*text continued from page 77*)

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

Over 350 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

Over 900 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 on-going 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 appoint graduate students to junior academic staff positions as graduate assistants; over 160 students held such appointments at M.I.T. in 1965–66. 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; the maximum available is $3,000 in any year. 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.

In addition to the Institute's loan funds, the Ford Foundation has made generous grants to the Institute for a program of forgivable loans for predoctoral students who intend to enter engineering teaching careers. Up to $10,000 may be borrowed over three years, to be repaid or forgiven at the rate of $1,000 or 20 per cent per year of the total owed at the time of termination of graduate study, whichever is greater. Forgiveness occurs if the recipient, after receiving his Doctorate from M.I.T., is employed as a full-time faculty member in the U.S. or Canada. Application forms are available from the School of Engineering, M.I.T.

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.

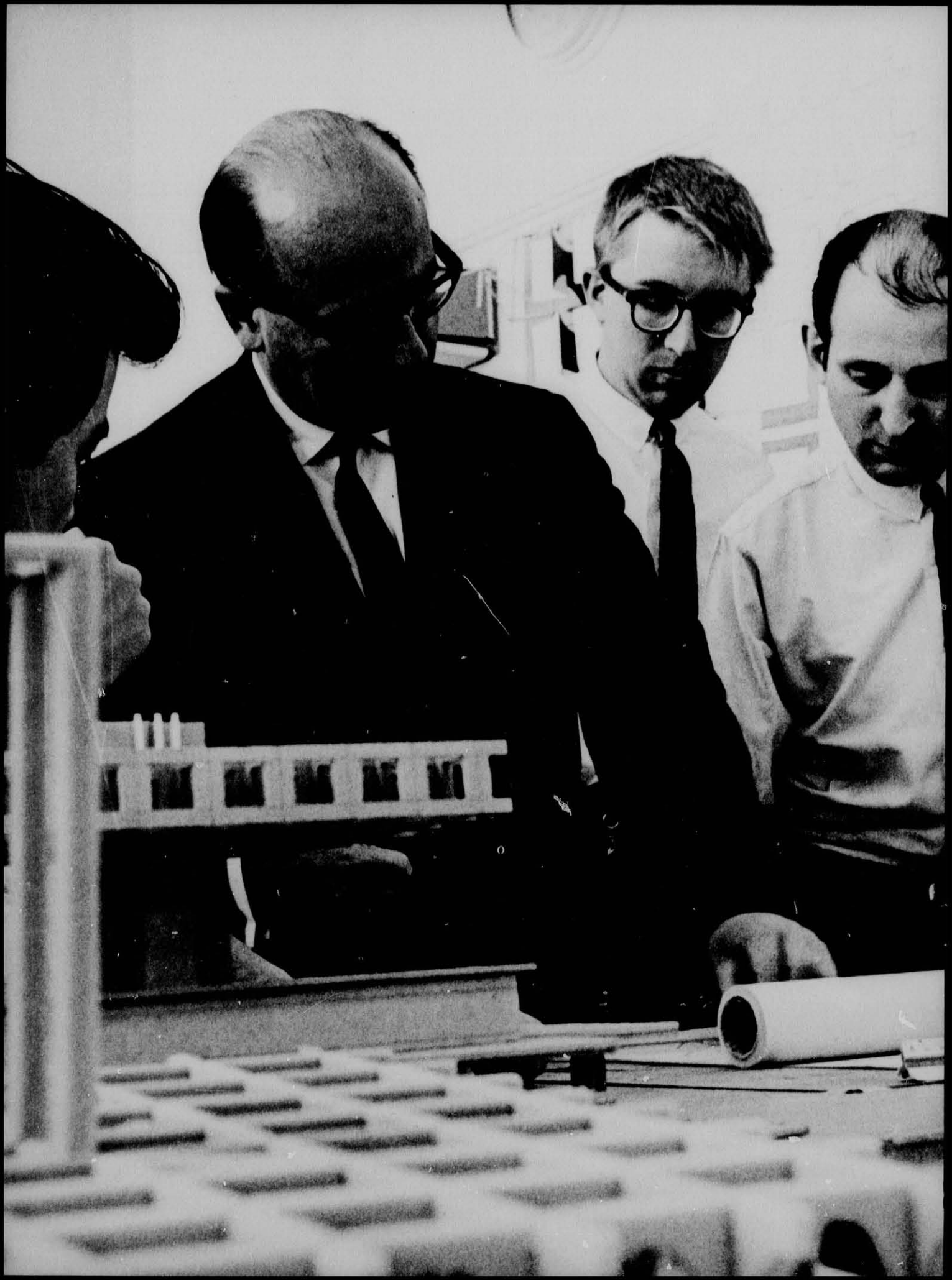
Any D.S.R. appointee may, by written permission from the Director of the Division (or his designate), apply for enrollment as a student in one subject only per term (but not thesis), either as auditor or for academic credit; he will be accepted for such enrollment if, in the opinion of the instructor 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, freed of ignorance-bred visual chaos and the assaults of commercialism, yet full of the stimulating and innovative possibilities of our time. This is why these professions are now concentrating on community design problems, from small to large.

LAWRENCE B. ANDERSON

Department of Architecture

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

HERBERT LYNES BECKWITH, M.ARCH.
Professor of Architecture

GYORGY KEPES, M.A.
Professor of Visual Design

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

EDUARDO FERNANDO CATALANO, M.ARCH.
Professor of Architecture

HORACIO CAMINOS, ARQ.
Professor of Architecture

MINOR WHITE
Professor of Photography (Visiting)

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

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

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

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

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

ROBERT ORMEROD PREUSSER
Associate Professor of Visual Design

WILLIAM JAMES LEMESSURIER, A.B., S.M.
Associate Professor of Structures

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

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

JAN LUBICZ-NYCZ, DIPL.ARCH.
Associate Professor of Architecture

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

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

JOSEPH JAMES SCHIFFER, M.ARCH.
Assistant Professor of Architecture

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

ROBERT GOODMAN, B. ARCH.
Assistant Professor of Architecture

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

Instructors

LEON BENNETT GROISSER, A.B., B.S., M.B.A.
LISE VOGEL, A.M.

Technical Instructors

NISHAN BICHAJIAN
GEORGE CULBRETH THOMAS, II, B.A., M.F.A.

Research Associates

IGNACIO HIPOLITO GARABIETA ORVETA, DIPL.
MARVIN EDWARD GOODY, M.AR H., M.C.P.
ROBERT JOSEPH PELLETIER, B.ARCH., BLDG.E.

Professors Emeriti

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

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

ERNEST NAPOLEON GELOTTE, S.B.
Associate Professor of Construction, 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.

The curricula requirements are as follows:

					Total units
GENERAL INSTITUTE REQUIREMENTS					
	Specific Science Subjects				
5.01	CHEMICAL PRINCIPLES I	5	2	5	
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				
21.01	[1]THE GREEK TRADITION	3	0	6	
21.02	[1]THE EUROPEAN TRADITION	3	0	6	
21.03T	[1]LITERATURE: LANGUAGE, FORMS, AND THE INDIVIDUAL AUTHOR				
	or				
21.031	[1]LITERATURE: SELF, NATURE AND SOCIETY	3	0	6	
	or				
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY				
21.05T	[1]THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM"				
	or				
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	6	
	or				
17.01T	SOCIETY AND MAN				
	Upperclass program[2] *(see pages 46–49)*	32			
					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 44-45) totalling				**12**
	Laboratory Requirement				
	At least 12 units *(see page 45)*				**12**
					152

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.011 THE GREEK TRADITION (in place of 21.01); 23.021 THE JUDAEO-CHRISTIAN TRADITION (in place of 21.02); 23.031 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.051 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T). The following subjects are offered in German for students having an adequate background in German and will be accepted in place of the Humanities subjects listed in parentheses: 23.022 THE EUROPEAN TRADITION: THE ERA OF GOETHE (in place of 21.02); 23.032 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.052 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T).

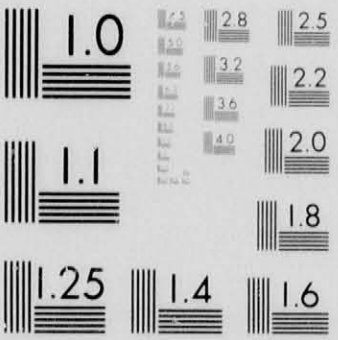
[2] ECONOMIC PRINCIPLES I (14.01) is required in all programs. In the following programs the subjects indicated may *not* be used to satisfy the Humanities and Social Science Requirement. *Program 1:* Field 9 — 9.00; Field 10 — 4.601, 4.61, 4.62, 4.63, 4.64. *Program 2:* Field 7 — 17.21, 17.22; Field 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	
2.701	ARCHITECTURAL GEOMETRY I	0	4	2	
2.702	ARCHITECTURAL GEOMETRY II	0	4	2	
4.031T	FORM AND DESIGN I	2	4	6	
4.032T	FORM AND DESIGN II	2	4	6	
4.30	STRUCTURES I	3	3	6	
4.402J	BUILDING PROCESS	3	3	6	
4.601	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	5	
6.47	INTRODUCTION TO AUTOMATIC COMPUTATION	2	2	2	
9.00	INTRODUCTORY PSYCHOLOGY	3	0	5	
11.50	URBAN SOCIAL STRUCTURES AND PROCESS	2	0	6	
4.121	ARCHITECTURAL DESIGN	2	5	5	
4.122	ARCHITECTURAL DESIGN	2	5	5	
4.131T	ARCHITECTURAL DESIGN	0	6	6	

(continued)



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

4.132T	ARCHITECTURAL DESIGN	0	6	6	
4.31	STRUCTURES II	2	2	4	
4.32	STRUCTURES III	2	2	4	
					166
	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[1]				36
Total units required for the S.B. degree					379

[1] Programs of students in Course IV, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the first year.

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)	
2.701	ARCHITECTURAL GEOMETRY I (0 4 2)	
2.702	ARCHITECTURAL GEOMETRY II (0 4 2)	
4.031T	FORM AND DESIGN I (2 4 6)	
4.032T	FORM AND DESIGN II (2 4 6)	
4.30	STRUCTURES I (3 3 6)	
4.402J	BUILDING PROCESS (3 3 6)	
4.601	TOPICAL STUDIES IN THE HISTORY OF ART (3 0 5)	
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)	102
	Restricted Electives	
	77 units to be chosen from the following:	
4.67	HISTORY OF URBAN FORM (3 0 5)	
11.01	COMMUNITY PLANNING DESIGN (0 8 12)	
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[1]	36
Total units required for the S.B. degre		367

[1] Programs of students in Course IV, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the first year.

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)	
2.701	ARCHITECTURAL GEOMETRY I (0 4 2)	
2.702	ARCHITECTURAL GEOMETRY II (0 4 2)	
4.031T	FORM AND DESIGN I (2 4 6)	
4.032T	FORM AND DESIGN II (2 4 6)	
4.30	STRUCTURES I (3 3 6)	
4.402J	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)	
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)	110
	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)	
4.022T	VISUAL DESIGN PROJECTS I (2 6 0)	
4.023	VISUAL DESIGN PROJECTS II (2 4 6)	
4.033T	FORM AND COLOR I (2 0 4)	
4.034T	FORM AND COLOR II (2 4 6)	
4.041	LIGHT AND COLOR I (2 4 6)	
4.051	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[2]	36
Total units required for the S.B. degree		366

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

[2] Programs of students in Course IV, Program 3, may always be arranged to leave available 12 units of unrestricted elective in the first year.

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)	
2.701	ARCHITECTURAL GEOMETRY I (0 4 2)	
2.702	ARCHITECTURAL GEOMETRY II (0 4 2)	
4.031T	FORM AND DESIGN I (2 4 6)	
4.032T	FORM AND DESIGN II (2 4 6)	
4.30	STRUCTURES I (3 3 6)	
4.402J	BUILDING PROCESS (3 3 6)	
4.601	TOPICAL STUDIES IN THE HISTORY OF ART (3 0 5)	
6.47	INTRODUCTION TO AUTOMATIC COMPUTATION (2 2 2)	
9.00	INTRODUCTORY PSYCHOLOGY (3 0 5)	
11.50	URBAN SOCIAL STRUCTURES 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	
					118
	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] totalling 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	
21.515	[3]NEAR EASTERN ARCHAEOLOGY: THE FOUNDATION OF CIVILIZATION	3	0	5	
	LANGUAGE[1]	4	0	8	
	Unrestricted Electives[4]				36
	Total units required for the S.B. degree				370

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

[4] Programs of students in Course IV, Program 4 may always be arranged to leave available 12 units of unrestricted elective in the first year.

GRADUATE STUDY IN ARCHITECTURE

The Department offers work leading to the degrees of Bachelor in Architecture and Master in Architecture. Both degrees are designed as preparation for architectural practice, although they may also attract students preparing for teaching, writing, or research. Proficiency in architectural design is an essential objective of both programs. Course work to develop and evaluate individual design skill and range of professional knowledge is prerequisite to approval for independent specialized studies or thesis. The entire Department faculty is concerned with the guidance of these advanced studies.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

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

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

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

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

Professional Subjects in Architecture. For the program for the degree of Bachelor in Architecture: two full years of subjects equivalent to those required in the Institute's curriculum for the Bachelor of Science in Art and Design (Program 1 — Architecture).[1] For the program for the degree of Master in Architecture: a Bachelor in Architecture degree or equivalent degree with high academic standing from a professional undergraduate program in architecture at an institution of recognized standing.

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

The Graduate Degrees

BACHELOR IN ARCHITECTURE

The 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 shall be in "A" subjects, and the completion of a thesis acceptable to the Depart-

[1] Deficiencies in professional subjects, mathematics, and physics may be removed by enrolling in subjects offered by the Institute. A student with deficiencies will be permitted graduate registration while taking the appropriate subjects at the Institute to remove them. Applicants should submit examples of their work in design to assist in the evaluation of their experience.

ment. Completion ordinarily requires two years of residence beyond the degree of Bachelor of Science in Art and Design or its equivalent. Students who enter without previous experience in a department of architecture may require four years of residence to fulfill the requirements.

MASTER IN ARCHITECTURE

The degree of Master in Architecture is awarded upon the satisfactory completion of an advanced program of study of at least 66 units, of which 42 units must be in "A" subjects, including a minimum of one term of architectural design, and the completion of an acceptable thesis. Completion ordinarily involves ten months of residence.

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
LLOYD RODWIN, PH.D.
Professor of Land Economics;
Chairman of the Faculty Committee,
Joint Center for Urban Studies of M.I.T. and Harvard
ROLAND BRADFORD GREELEY, M.C.P.
Professor of Regional Planning; Director of Admissions
KEVIN ANDREW LYNCH, B.C.P.
Professor of City Planning
JEROME ROTHENBERG, PH.D.
Professor of Economics
AARON FLEISHER, SC.D.
Associate Professor of Urban and Regional Studies
JAMES MONAHAN BESHERS, PH.D.
Associate Professor of Sociology
BERNARD JOEL FRIEDEN, PH.D.
Associate Professor of City Planning
DONALD SIDNEY APPLEYARD, M.C.P.
Associate Professor of Urban Design
STEPHEN MCKINLEY CARR, M. ARCH.
Assistant Professor of Urban Design
DANIEL WEISBERG, B.S.
Assistant Professor of Real Estate Economics (Visiting)

Senior Lecturers

PAUL OPPERMANN (*Visiting*)
Bemis Lecturer in Metropolitan Planning
LEWIS H. WEINSTEIN, LL.B. (*Visiting*)

Lecturers

ALEXANDER GANZ, B.A.
PHILIP BARNARD HERR, M.C.P.
IRA S. LOWRY, PH.D. (*Visiting*)
LISA REDFIELD PEATTIE, M.A.

Professor Emeritus

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

The Department of City and Regional Planning focuses attention principally on the study of our large-scale physical environment and its interaction with our society. The Department's graduate curriculum aims primarily at training practitioners or staff men in the fields of city and regional planning; and it also offers special opportunities for students interested in teaching and research in these and related fields.

UNDERGRADUATE PREPARATION

The Department does not offer an undergraduate degree. However, 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 in City and Regional Planning. The Course is open to students with varying backgrounds; architecture, landscape architecture, civil engineering, economics, sociology, law, and public administration all offer suitable preparation.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

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

Mathematics and Physics. 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.

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

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.

The Graduate Degrees

MASTER IN CITY PLANNING

The typical program leading to the degree of Master in City Planning requires two to two and a half years of study at M.I.T. The first-year curriculum for those who have done no previous work in this field normally includes the following subjects, plus one or two electives:

COMMUNITY PLANNING DESIGN (11.01)
CITY AND REGIONAL PLANNING (11.02)
SITE PLANNING (11.15)
COMPONENTS OF THE URBAN ENVIRONMENT (11.11)
CITY PLANNING TECHNIQUES (11.12)
URBAN SOCIAL STRUCTURE AND PROCESS (11.50)
METHODS OF RESEARCH IN CITY PLANNING (11.90)
CITY STRUCTURE AND ECONOMIC DEVELOPMENT (11.60)

The second year is given wholly to advanced study, in accordance with the general requirements for the Master's degree. The typical program includes THE LAW OF LAND USE (11.70), PROBLEMS IN CITY PLANNING (11.03), four elective subjects, and an individual thesis.

Students normally devote about half of their time to subjects required of all M.C.P. candidates and the balance to the thesis and to professional electives, which may be grouped into a specialization or may be in a variety of fields. Three months of office practice is required and is usually satisfied by summer employment between the two academic years.

DOCTOR OF PHILOSOPHY IN CITY AND REGIONAL PLANNING

Advanced students 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. The focus of an area of concentration may be generalized; or it may be from the point of view of a specialist emphasizing a function (e.g. transportation, or housing), a jurisdiction (e.g. the metropolis, or the resource region), or a discipline (e.g. visual design, or economics).

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.

Study for the doctorate 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.

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:

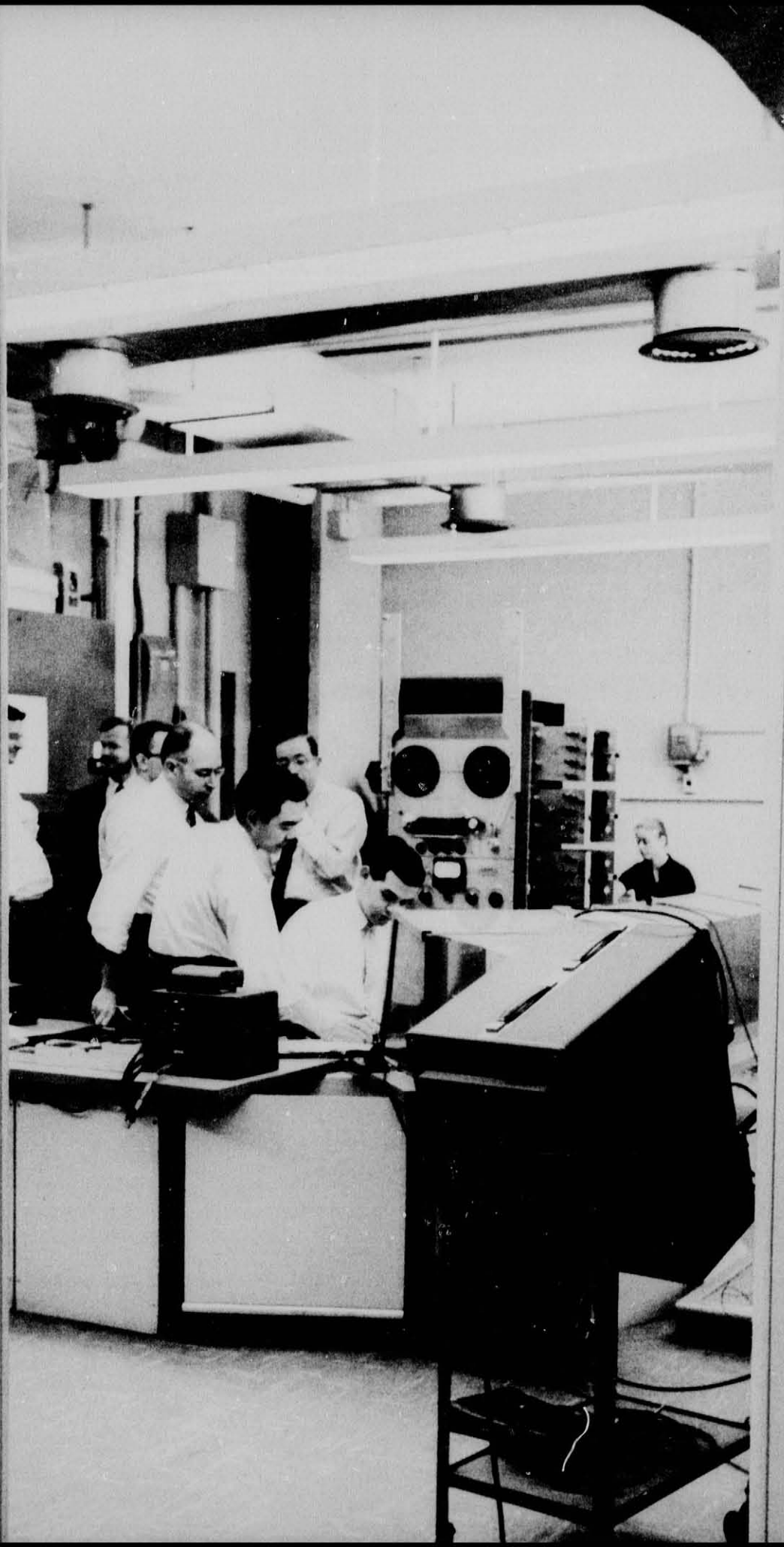
Planning problems of the developing countries of the world: Both regional and urban development planning are covered, extending from analysis of urban housing or economic growth problems to strategy of policy formulation and programming.

Urban design, the shaping of the visual form of the city: This new field is distinct from the design of large-scale architectural projects; the urban designer must be a thoroughly trained city planner.

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.

Urban planning and social policy: The social impact of urban development programs and the application of social science concepts and methods to the solution of planning problems. This option is planned to prepare experts in developing programs to cope with social needs (relocation, anti-poverty) in collaboration with other professionals.

Quantitative methods in urban and regional studies and planning: The application of mathematical, statistical, and computer techniques to problem analysis and to policy development and implementation.



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 have at last achieved the technical potential for the creation of a society free from want.

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

Although engineers deal extensively with facts and scientific principles, they also must carry out their work as leaders of men. Their ultimate stature, therefore, often finds expression in those situations where judgment and wisdom weave the elements of scientific knowledge into the whole fabric of society. Accordingly, the educational plan at M.I.T. interlaces a sequence of studies in science, engineering, and the humanities with involvement in research, in a manner that embraces all the elements of a truly liberal education.

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

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

five, or even six years. Furthermore, the engineer and the scientist, working in concert, are setting such a pace in technological change that specialization is often outmoded several times within the span of a professional lifetime.

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

The curriculum of the freshman year and about two-thirds of the curriculum of the sophomore year are, in effect, similar for all Courses at M.I.T. The technical and professional subjects that lead to a major field begin only in the later years. Mature professional education finds its full expression in the graduate years. The student who decides early in his program on the broad field of his major may enter a department at the beginning of the sophomore year. In most instances this student may elect, for about one-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 for the one-third of the sophomore year will be credited to his total degree requirements.

The basis of choice among engineering fields should lie within — rather than outside — each student's mind and personality. When assessing the question of becoming identified with a particular engineering field during a period of study, a student is wise to choose the one which provides an immediate, potent source of motivation and inspiration rather than to attempt to foresee what his permanent area of professional activity may be. To find expression for one's gifts and to carry one's education as far as those gifts justify is the essential purpose of higher education.

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

GORDON S. BROWN

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

WILLIAM WALTHER SEIFERT, SC.D.
Assistant Dean

ROBERT PAUL GREENE, S.B.
Administrative Assistant

ROBERT HUGH SCOTT, 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

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

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

THOMAS BURNESS KING, PH.D.
Head, Department of Metallurgy

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

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

RAYMOND FREDERICK BADDOUR, 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	CHEMICAL PRINCIPLES I	5	2	5	
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					
21.01	[1]THE GREEK TRADITION	3	0	6	
21.02	[1]THE EUROPEAN TRADITION	3	0	6	
21.03T	[1]LITERATURE: LANGUAGE, FORMS, AND THE INDIVIDUAL AUTHOR *or*				
21.031	[1]LITERATURE: SELF, NATURE, AND SOCIETY *or*	3	0	6	
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY				
21.05T	[1]THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM" *or*				
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS *or*	3	0	6	
17.01T	SOCIETY AND MAN				
	Upperclass program (see pages 46–49)		32		
					68
					128

Science Distribution Requirement
At least 36 units in three fields (*see the list on pages 44–45*)

Laboratory Requirement
At least 12 units (*see page 45*)

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.011 THE GREEK TRADITION (in place of 21.01); 23.021 THE JUDAEO-CHRISTIAN TRADITION (in place of 21.02); 23.031 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.051 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T). The following subjects are offered in German for students having an adequate background in German and will be accepted in place of the Humanities subjects listed in parentheses: 23.022 THE EUROPEAN TRADITION: THE ERA OF GOETHE (in place of 21.02); 23.032 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.052 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T).

Department of Aeronautics and Astronautics

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

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

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

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

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

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

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

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

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

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

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

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

MARTEN TEODOR LANDAHL, TEKN.D.
Professor of Aeronautics and Astronautics

ROBERT LOUIS HALFMAN, S.M. *(Absent)*
Professor of Aeronautics and Astronautics

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

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

JACK LEO KERREBROCK, 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

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

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

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

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

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

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

HAROLD YEHUDA WACHMAN, PH.D.
Associate Professor of Aeronautics and Astronautics

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

JAMES ELLIOT McCUNE, PH.D. *(Absent)*
Associate Professor of Aeronautics and Astronautics

MYRON ARNOLD HOFFMAN, SC.D. *(Absent)*
Associate Professor of Aeronautics and Astronautics

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

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

WILLIAM STEPHEN LEWELLEN, PH.D.
Associate Professor of Aeronautics and Astronautics (Visiting)

FRANK KINGSLEY BENTLEY
Assistant Professor of Aeronautics and Astronautics, Emeritus
ELMER EUGENE LARRABEE, S.M.
Assistant Professor of Aeronautics and Astronautics
LAURENCE RETMAN YOUNG, SC.D.
Assistant Professor of Aeronautics and Astronautics
NORMAN DOUGLAS HAM, AER.E.
Assistant Professor of Aeronautics and Astronautics
WALTER MARK HOLLISTER, SC.D. (*Absent*)
Assistant Professor of Aeronautics and Astronautics
ROBERT WARREN SIMPSON, SC.D.
Assistant Professor of Aeronautics and Astronautics
SHEILA EVANS WIDNALL, SC.D.
Assistant Professor of Aeronautics and Astronautics
JAMES EMERSON POTTER, PH.D.
Assistant Professor of Aeronautics and Astronautics
RODNEY JACKSON MASON, JR., PH.D.
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HEINRICH JOSEF VOLK, PH.D.
Assistant Professor of Aeronautics and Astronautics

Lecturers
RAMON LUIS ALONSO, PH.D.
RICHARD HORACE BATTIN, PH.D.
ELMER JACOB FREY, PH.D.
ROBERT GOTTLIEB STERN, PH.D.

Technical Instructors
JOHN BARLEY
ALLAN RALPH SHAW

Professors Emeriti
JEROME CLARKE HUNSAKER, SC.D., ENG.D.
Professor of Aeronautical Engineering, Emeritus
OTTO CARL KOPPEN, S.B.
Professor of Flight Vehicle Engineering, Emeritus
JOHN RAYMOND MARKHAM
Professor of Aeronautical Engineering, Emeritus
SHATSWELL OBER, S.B.
Professor of Aeronautical Engineering, Emeritus
FRANK KINGSLEY BENTLEY
Assistant Professor of Aeronautics and Astronautics, Emeritus

AERONAUTICS AND ASTRONAUTICS

Aeronautics and astronautics are closely integrated phases of flight vehicle technology and its uses for transportation, national defense, scientific research, and space exploration. Aeronautics encompasses flight activities within the atmosphere from helicopters to supersonic transports, while long-range ballistic missiles, satellites, lunar vehicles, and interplanetary craft operate largely in the airless regions of astronautics. Interest in aeronautical and astronautical systems is very great today; the present high levels of support will surely continue during the foreseeable future, requiring many pioneering developments in science and engineering. It is the purpose of the Department of Aeronautics and Astronautics to prepare its graduates for effective leadership in these future advances. To serve this objective, the Department offers subjects in applied science and engineering, based on the central theme of flight, to students prepared in humanities, science, and mathematics by the core curriculum of the Institute.

The faculty of the Department is made up of individuals with high qualifications and broad interests ranging from basic science to advanced engineering. This variety of talents makes it possible for the Department to offer sound education in aeronautics and astronautics with the flexibility needed to meet student desires and to encourage maximum development of individual abilities. Engineering science electives are offered to those interested in research, while professional engineering subjects are ready for students attracted toward work in the solution of real-world problems. Faculty Counselors help each student arrange a program adapted to his individual interests, abilities, and career plans.

In order to deal effectively with the great range of subjects associated with the engineering, construction, testing, and operation of flight vehicle systems, the Department faculty is organized as a number of more or less distinct groups. Taken together, the groups provide a complex of knowledge, experience, and ability that is effective in providing deep, across-the-board education for aeronautics and astronautics. The faculty groups adapt to changing conditions but in general cover the following eleven areas: materials, structures, aeroelasticity; fluid mechanics from incompressible flow to magnetogasdynamics; propulsion from air-breathing piston engines to ion rockets; dynamics of vehicles from aircraft to space ships, including stability, flying

qualities, and control; navigation and guidance; communication, data processing, and computing; astrodynamics and experimental astronomy; man-machine systems; flight transportation; vehicle engineering; and systems engineering. Many faculty members work with more than one group, thereby helping all the faculty to understand the stringent conditions associated with research and engineering of flight vehicles and systems. Clear understanding of these conditions emphasizes the small design margins that separate success from failure and make the problems of flight among man's most difficult.

Progress in aeronautics and astronautics is and will continue to be so rapid that effective education for this field 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 to technology. Another highly effective means for insuring that teachers 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 strongly associated with research work in either academic facilities or laboratories assisted by outside sponsorship. Experience and information gained from such research is generally used 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 practicing engineers and 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 advanced 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, 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 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 Mechanical Engineering Department, conducts research on the aerodynamics of turbines, compressors, combustion, and mixing jets. The Experimental Astronomy Laboratory is engaged in the design of interplanetary navigation systems and in research and flight testing of systems for celestial observations from stations in the upper atmosphere. Simulator equipment for studying human reactions is applied in man-machine systems.

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 to develop knowledge, ingenuity, and skills is maintained for the purpose of helping students carry out experiments which they themselves conceive and design. Students who have acquired reasonable levels of skill in the Projects Laboratory usually move on to 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 Aero-

nautics and Astronautics at the end of four years. The curriculum provides great flexibility to meet the needs for 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 a tentative 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 93*)					
	Specific science and humanities and social science subjects				**128**
	The subjects 8.03, 16.20T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) 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 45) and can be used to satisfy the Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects				
16.00J	THERMODYNAMICS AND STATISTICAL MECHANICS	3	2	7	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
16.20T	SOLID MECHANICS I	4	2	6	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
3.141	SCIENCE OF MATERIALS	4	3	5	
6.43	INTRODUCTION TO ELECTRICAL SCIENCE	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:				
6.44	INTRODUCTION TO ELECTRICAL SCIENCE	4	0	8	
16.11T	AERODYNAMICS OF FLIGHT VEHICLES	3	0	6	
16.201	SOLID MECHANICS II	4	0	6	
16.30	PRINCIPLES OF AUTOMATIC CONTROL	3	0	9	
16.53	ROCKET PROPULSION				
	or	3	0	6	
16.54	AIRCRAFT ENGINES				
16.71	FLIGHT VEHICLE ENGINEERING	2	3	7	
	or				
16.73T	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] Programs of students in Course XVI may always be arranged to leave available 12 units of unrestricted elective in the first year and 24 units 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 8.03, 18.034, 16.00J and 16.20T. 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 8.03, fields in continuous media, 16.09, or, from the above list, 16.01 or 6.43.

A student who elects Course XVI at the end of his second year can still 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. FLIGHT VEHICLES (16.81) and freshman seminars meet these needs.

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 for about five months of experience in an industrial organization before the professional work of the senior year. Continuous contact with industrial problems enables students to discover and develop their aptitudes and inter-

ests to better advantage than would be possible with shorter periods of employment. The program does not interfere with the student's academic progress nor with his extracurricular activities in association with his classmates. Cooperative Course participation is also independent of the particular selection of the undergraduate program.

The cooperating companies of the aircraft industry pay the students at prevailing rates during their period of employment. The students pay their own expenses while away from the Institute.

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

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

CURRICULUM IN THE COOPERATIVE COURSE (COURSE XVI-B)

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

16.85	INDUSTRIAL PRACTICE	40 h.p.w.

At the earliest possible date each student should arrange with his Faculty Counselor a schedule (including two Summer Sessions) which permits his absence from Cambridge during the second term of his third year and assures completion of graduation requirements by the end of the fourth year.

GRADUATE STUDY IN AERONAUTICS AND ASTRONAUTICS

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

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

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

For this degree, at least one year of an approved graduate program is required, including thesis. Two terms of advanced mathematics beyond DIFFERENTIAL EQUATIONS (18.034) 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 same breadth of educational background implied by the Engineer degree.

ENGINEER IN AERONAUTICS AND ASTRONAUTICS

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

Requirements for admission to candidacy for the degree of Engineer in Aeronautics and

Astronautics are more rigorous than for the degree of Master of Science in Aeronautics and Astronautics.

DOCTOR OF SCIENCE (OR PHILOSOPHY) IN AERONAUTICS AND ASTRONAUTICS

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

DOCTOR OF SCIENCE WITH SPECIALIZATION IN THE FIELD OF INSTRUMENTATION

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

MATERIALS ENGINEER AND DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY IN MATERIALS ENGINEERING

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

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

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

Language Requirement

No language requirement is made for candidates for the Master of Science or Engineer degrees. A candidate for the Doctor of Science or Doctor of Philosophy degree must fulfill the Institute language requirement (page 75). Under "a" either plan 1 or 2 will be accepted but 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; these are described in Appendix A of this Catalogue. In addition, graduate students may earn part or all of their expenses as part- or full-time assistants. These duties, concerned with either teaching or research, provide valuable educational experience.

Department of Chemical Engineering

(Including the School of Chemical Engineering Practice)

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

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

HOYT CLARKE HOTTEL, A.B., S.M.
Carbon P. Dubbs Professor of Chemical Engineering; Director of the Fuels Research Laboratory

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

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

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

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

HAROLD SOMERS MICKLEY, SC.D.
Ford Professor of Chemical Engineering; Director of the Center for Advanced Engineering Study

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

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

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

THOMAS BRADFORD DREW, S.M. *(Absent)*
Professor of Chemical Engineering

ROBERT CLARK REID, SC.D.
Professor of Chemical Engineering

PIERRE LEONCE THIBAUT BRIAN, SC.D.
Professor of Chemical Engineering

JAN THEODOOR GERARD OVERBEEK, DR.
Professor of Chemical Engineering (Visiting)

ALLAN SACHS HOFFMAN, SC.D.
Associate Professor of Chemical Engineering

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

KENNETH ALAN SMITH, SC.D.
Assistant Professor of Chemical Engineering

ADEL FARES SAROFIM, SC.D.
Assistant Professor of Chemical Engineering; United Engineers and Constructors, Inc., Preceptor

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

LAWRENCE BOYD EVANS, PH.D.
Assistant Professor of Chemical Engineering

MAX CURTIS DEIBERT, SC.D.
Assistant Professor of Chemical Engineering

MICHAEL MODELL, SC.D.
Assistant Professor of Chemical Engineering

JON RENÉ VALBERT, SC.D.
Assistant Professor of Chemical Engineering

SAMUEL WRIGHT BODMAN, III, SC.D.
Assistant Professor of Chemical Engineering; Director of the Bound Brook Station, School of Chemical Engineering Practice

SHIOU-SHAN CHEN, PH.D.
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

WILLIAM HOWARD DALZELL, SC.D.
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

JACK BENNEY HOWARD, PH.D.
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

DUDLEY WALTER COILLET, SC.D.
Assistant Professor of Chemical Engineering (Visiting)

ALLAN STANLEY DOUGLAS
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

SAMUEL MCLAIN FLEMING, SC.D.
Assistant Professor of Chemical Engineering; Director of the Oak Ridge Station, School of Chemical Engineering Practice

CHARLES WILLIAM SELVIDGE, SC.D.
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

Administrative Officer

MARGARET SCHULER BARRETT

Technical Instructors

HAROLD HAVNER CARTER
REED CAMPBELL FULTON

Research Associates

RENE BLOCH, PH.D.
PETER HARROLD DUNDAS, PH.D.

STATIONS OF THE SCHOOL OF CHEMICAL ENGINEERING PRACTICE

Directors

SAMUEL WRIGHT BODMAN, III, SC.D., *Bound Brook*
SAMUEL MCLAIN FLEMING, SC.D., *Oak Ridge*

Assistant Directors and Instructors

RAMON LUIS ESPINO, S.M., *Bound Brook*
SIEGFRIED THEODOR MAYR, B.SC., *Oak Ridge*

Professors Emeriti

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

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

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

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

CHEMICAL ENGINEERING

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

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

The 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 93*)					
	Specific science and humanities and social science subjects				**128**
	The subjects 5.61, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement (see page 45)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
5.41	ORGANIC CHEMISTRY I	4	0	8	
5.61	PHYSICAL CHEMISTRY I	4	0	8	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
10.12	CHEMICAL ENGINEERING	3	0	5	
10.15	[1]THESIS REPORTS	0	4	0	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
	THESIS		12		
					72
	Restricted Electives				
	Chemistry (in addition to the above required subjects)			at least	**36**
	Chemical engineering (in addition to the above required subjects)			at least	**60**
	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 and THESIS)				
Total units required for the S.B. degree					**360**

[1] 10.15 is a "time-arranged" subject.

[2] Programs of students in Course X may always be arranged to leave available 12 units of unrestricted elective in each of the first and second years.

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, 5.15); a term of inorganic chemistry (5.03); and relevant laboratory subjects. Electives in chemical engineering normally include most of the following: a second term of thermodynamics (10.13); fluid mechanics (10.30); engineering operations (10.31 and 10.32); structure and properties of non-metallic substances (10.21); industrial chemistry (10.18); and industrial chemistry laboratory (10.26) or chemical engineering laboratory (10.27).

Additional opportunity for experimental research, with considerable flexibility in scheduling, is provided in 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 10.13) and physical chemistry (5.61 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, 3.00T, 5.41, 5.61, 10.12), 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 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 in Chemical Engineering, and Doctor of Science or Doctor of Philosophy in Materials Engineering. Programs for the Master of Science degree are usually arranged as a continuation of undergraduate professional training on a more mature basis. Work for the Engineer and doctoral degrees is more specific in character, and the Department offers coordinated programs in three fields: engineering operations, applied chemistry, and fuel engineering. Special programs are developed for individual cases.

Entrance Requirements for Graduate Study

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

Requirements for Advanced Degrees

The general requirements for the various degrees are specified in Section 3. 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 (10.52T)
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)
PHYSICS AND CHEMISTRY OF MEMBRANES, GELS, AND NETWORKS (10.66)
PHYSICOCHEMICAL KINETICS AND HYDRODYNAMICS (10.67)
PHYSICAL CHEMISTRY OF POLYMERS (10.68)
SYNTHETIC CHEMISTRY OF POLYMERS (10.69)

Graduate research activities in these fields include such topics 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 in Materials Engineering. 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 (10.52T)
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, N.J. 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 student's 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 10.83T; or 10.86T and 10.87T) 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.

Department of Civil Engineering

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

ARTHUR THOMAS IPPEN, PH.D.
Ford Professor of Engineering

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

ROBERT JOSEPH HANSEN, SC.D.
Professor of Civil Engineering

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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 inter-related 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 com posed 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.

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 physico-chemical 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 best facilitate 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 I.B.M. 1620/1311 Electronic Data Processing System to which students have direct access, located in a classroom equipped with closed-circuit TV for group demonstration; and an I.B.M. System/360, Model 40 which is used both for research and student course work. In addition, remote console facilities for direct communication with the I.B.M. 7094 in the M.I.T. Computation 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.

THE UNDERGRADUATE PROGRAM

Civil Engineering (Course I)

The undergraduate program of the Department offers an unusual educational opportunity for students seeking a strong base for careers in civil engineering or related fields. The program emphasizes fundamental technology as a foundation to assure subsequent professional growth.

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.

At the same time, the undergraduate program 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. The undergraduate program 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.

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 Course leads to the degree of Bachelor of Science in Civil Engineering: the curriculum requirements for the degree are given below for students entering subsequent to July 1, 1965. Other students should consult the Typical Course Schedules and their Faculty Counselors.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 93*)					
	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, 8.03 and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement[1] (see the list on page 45)				**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	PRINCIPLES OF UNCERTAINTY	3	0	6	
1.08	GEOTECHNOLOGY	3	3	6	
1.09	CIVIL ENGINEERING	0	6	12	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
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] Programs of students in Course I may always be arranged to leave available 12 units of unrestricted elective in each of the first and second years.

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
1.922J	BUILDING PROCESS	3	3	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.

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 inter-departmental 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 best reflect 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.

GRADUATE STUDY IN CIVIL ENGINEERING

The Graduate Degrees

The Department grants the following advanced degrees:

Master of Science in Civil Engineering
Civil Engineer
Doctor of Science in Civil Engineering
Doctor of Philosophy in Civil Engineering
Materials Engineer
Doctor of Science in Materials Engineering
Doctor of Philosophy in Materials Engineering

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 engineering, structures, materials, civil engineering systems, transportation, and construction management. Each of these is described briefly below.

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 educational programs in the applied earth sciences. Primary efforts are being directed toward a synthesis of fluid mechanics, soil mechanics, and geology in the areas of geomorphology, erosion, and flow in porous media. The Department's work in the applied earth sciences is based on extensive educational and research resources in soil engineering and in hydromechanics and water resources, described in more detail below.

HYDRODYNAMICS AND WATER RESOURCES

A vital area in civil engineering is represented by the application of fluid mechanics to problems in hydrology, hydraulic engineering, water-resource systems, sanitary engineering, coastal engineering, and tidal hydraulics. Subjects in hydrodynamics deal with modern developments in turbulence, boundary layers, free surface flow, wave motion, diffusion, flow in porous media, and sedimentation. The planning and development of water resources is treated from the stand-

point of the hydraulic analysis and synthesis of hydrologic systems and with both physical and economic inputs.

Water quality — the effect of man's activities on the quality of water as well as the methods of altering and improving it — is covered.

A broadly conceived research effort in the Hydrodynamics Laboratory is closely coupled to the educational offerings and at present includes the following areas: transformation and shoaling of waves in nonuniform channels, resonant oscillations in harbors, long-wave movement in navigation channels, interaction of submerged bodies and fluid interfaces, mechanics of stratified flow, dispersion, circulation and mixing processes in lakes, rivers, and estuaries, flow and dispersion in porous media, sediment transport and erosion of cohesive material, resistance and turbulence phenomena in non-Newtonian fluid suspensions, cavitation at rough boundaries, analysis and synthesis of hydrologic systems, and regional development of water resource systems.

SOILS

The civil engineer employs soil as a foundation material for a wide variety of structures, such as buildings, bridges, pavements, and retaining walls and uses soil as a construction material for such things as embankments, dams, roads, and canal linings. The graduate program in soils emphasizes the measurement of the engineering properties of soil in the laboratory and field, the development of analytical procedures for solving settlement, stability, and flow problems, and the study of the fundamental physicochemical properties which govern the engineering behavior of soils.

In addition to the basic treatments of theoretical soil mechanics, soil behavior, and soil engineering, there are advanced subjects in the areas of soil dynamics, soil technology, engineering geology, and particulate mechanics. These subjects, together with thesis research and other studies utilizing the unique laboratory facilities, offer students excellent opportunities to work closely with the staff in the study of such problems as the nature of clay-water forces, the strength behavior of stabilized soils, the shear strength of clay as influenced by environment, and stress system, the use of computers to solve stress distribution and consolidation problems, the interaction between soil and buried structures, the dynamic properties of soil, the load-settlement-pore pressure-time behavior of structures on clay deposits using large-scale models, the long term stability of clay-shales as part of project Plowshare, the investigation of tunnels and roadways for a high speed ground transportation system, and the measurement and analysis of the field performance of foundations of new and old buildings on the M.I.T. campus.

STRUCTURES

The civil engineer is often responsible for the design of structures ranging from the frames of buildings to the complete systems involved in dams, towers, radar antennas, bridges, and tanks; these must withstand various environmental influences as well as machine-produced shock, vibration, and moving loads. The graduate program is concerned with the behavior of such structures and with their conception, analysis, and design.

The research effort is closely correlated with the academic program and provides direct support through projects in the following areas: modeling techniques for the analysis and design of complex structures, the dynamic response of arches and domes to shock-type loading, the probabilistic approach to structural design, the conception of new structural systems, and computer techniques in relation to the design process.

MATERIALS

As civil engineering works become more sophisticated, the types of materials used, and the demands placed upon them, also grow in complexity. Hence the graduate program contains subjects treating concrete, cementitious substances, metals, polymers, wood, ceramics, glasses, bituminous materials and composites. In addition, subjects examining various generic types of mechanical behavior, especially time-dependent phenomena, also are presented; in both cases, close relations to the research laboratory projects are maintained.

As noted previously, advanced degrees in Materials Engineering are granted by the Department; 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 transportation, 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. In addition to the extensive facilities and research programs of the Civil Engineering Systems Laboratory, joint work is conducted with the Operations Research Center and the Computation Center.

TRANSPORTATION SYSTEMS

The essential focus of teaching and research in transportation is on system planning which necessarily depends largely upon basic knowledge of the properties of transportation systems components and the ability to analyze interaction among these components and the transportation environment. The problems which emerge are oriented to engineering design and include emphasis on rational decision-making in the face of uncertainty. Support of the academic program is provided by close relation with an extensive body of research. Subjects of instruction offered include transportation systems analysis, transport systems design, urban highway systems, flight transportation, traffic flow theory, discrete flow control, decision theory, system simulation, mathematical programming, network flow, economic analysis, probabilistic analysis, and substantive applications to highway, air, rail, and sea transport. The Transportation Systems Group 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 MANAGEMENT

Graduate study in construction management is focused on modern mathematical and computer methods of analysis and control of construction operations. Hence, such work is an integral part of the Institute's interdisciplinary activity in operations research, systems analysis, and computer-oriented information systems. In addition to graduate subjects and research in the Department, students interested in construction management may take subjects in such areas as accounting, labor relations, financial management, law, industrial dynamics, organization, and administration in the Alfred P. Sloan School of Management.

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.

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RICHARD GWYN MILLS, S.M.
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BARNEY REIFFEN, PH.D.
ROBERT HARVEY RINES, S.B., LL.B.
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HERBERT MARTIN TEAGER, SC.D.
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RONALD WILLIAM SCHAFER, S.M.
HERMAN MARTIN SCHNEIDER, S.M.
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WILLIAM L. HENKE, S.M.
JOEL ELLIOT SCHINDALL, S.M.
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LANSING HATFIELD, S.B.
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JAMES ALAN ROME, S.B.
CARLTON EDWARD SPECK, S.M.
ALTON PARKER TRIPP, JR., S.B.

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DOROTHY YOUNG

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LESTER ABRAM GIMPELSON, S.M.
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BERNARD SILVERMAN
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ELWOOD WORRAL SCHAFER, S.B.
STANLEY HARRIS ZISK, PH.D.

Professors Emeriti
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Professor of Electrical Machinery, Emeritus
RALPH GORTON HUDSON, S.B.
Professor of Electrical Engineering, Emeritus
MURRAY FRANK GARDNER, S.M.
Professor of Electrical Engineering, Emeritus
ERNST ADOLPH GUILLEMIN, PH.D.
Professor of Electrical Engineering, Emeritus
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Professor of Electrophysics, Emeritus
KARL LELAND WILDES, S.M.
Professor of Electrical Engineering, Emeritus
RICHARD HENRY FRAZIER, S.M.
Professor of Electromechanics, Emeritus
ALEXANDER SMAKULA, PH.D.
Professor of Crystal Physics, Emeritus
PARRY MOON, S.M.
Associate Professor of Electrical Engineering, Emeritus
MARCY EAGER, S.B.
Associate Professor of Electrical Engineering, Emeritus

ELECTRICAL ENGINEERING

Starting from a relatively modest beginning about one hundred years ago, the field of electrical engineering has become one of great variety and scope. 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 fifteen 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. The relevant physics and mathematics are presented, motivated, and illustrated by applications to engineering problems; but the purpose is to teach the principles and the techniques of application, rather than the applications as such.

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 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 on-the-job training in industry. By making effective use of elective time, they may also prepare themselves for graduate work in such fields as physics, mathematics, industrial management, and the social sciences. Students in Program 2 are likely to stay in research-oriented fields. Alumni of this Program have done graduate work in electrical engineering, physics, mathematics, and biology, working in such fields as plasma physics, solid-state materials and devices, mathematical logic and the theory of automata, computer programming, and the study of the electrical activity of the nervous system.

Both programs 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, 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.

Four laboratory subjects are used to teach experimental techniques. Each subject starts with experiments whose objectives are defined, but each includes a substantial component of project work in which the student defines his own objectives, has his proposal approved, and carries it out. Students with the necessary interest and ability may spend most of their laboratory time doing projects. Students with less experience are given an opportunity to gain confidence and technique before embarking on project work.

Electrical Engineering (Course VI)

THE ELECTRICAL ENGINEERING PROGRAM

This program leads to the degree of Bachelor of Science in Electrical Engineering. The curriculum provides a thorough background for graduate study or on-the-job training in industry in one of the many fields to which people with electrical engineering training have made major contributions.

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 such fields as biology, psychology, and linguistics, to develop an understanding of communications in a context which includes both men and machines.

The curriculum requirements for the Electrical Engineering Program are listed below.

1. ELECTRICAL ENGINEERING PROGRAM CURRICULUM (COURSE VI)

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 93*)					
	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, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.				
	The subjects 6.70 and 6.71 or 6.72, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
6.01	INTRODUCTORY CIRCUIT THEORY I	4	0	8	
6.02	INTRODUCTORY CIRCUIT THEORY II	4	0	8	
6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.05	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.70	EXPERIMENTAL ELECTRONICS	1	4	1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
6.72	ELECTROMAGNETIC LABORATORY	1	4	1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
8.04	MODERN PHYSICS	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	[2]THESIS		12		
					132
	Restricted Electives				
	Two of the following subjects[3]				
6.06T	FIELDS, FORCES AND MOTION	3	0	9	
6.07T	ENERGY TRANSMISSION AND RADIATION	4	0	8	
6.08T	THERMODYNAMICS AND QUANTUM STATISTICS	4	0	8	
					24
	Unrestricted Electives[4]				**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] 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.

[3] Students electing all of these subjects may use the third subject as Unrestricted Elective.

[4] Programs of students in Course VI, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the first year and 24 units in the second year.

The above requirements are not rigid. Some variations are routinely permitted, while others are considered on an individual basis. For example, after completing EXPERIMENTAL ELECTRONICS (6.70), students may meet the departmental requirement of 18 units of further experimental work by substituting any combination of 12 unit project laboratories (6.711–6.719), laboratories given as part of classroom subjects (such as 6.213T, 6.341, 6.342, 6.37T, and 6.372T), individual project work done under 6.81 registration, FEEDBACK CONTROL LABORATORY 6.214, and experimental thesis work, for some or all of ELECTRONIC CIRCUITS AND SIGNALS LABORATORY (6.71), ELECTROMAGNETIC LABORATORY (6.72), and ADVANCED ELECTRICAL ENGINEERING LABORATORY (6.73). Laboratory work done in other departments will usually be accepted. Students should note that not all of the above laboratory subjects appear on the list of Laboratory Subjects (see page 45), but that 6.70 and any one of 6.71, 6.72 or 6.711 to 6.719 do appear on that list and will satisfy the 12-unit Laboratory Requirement. Well-motivated substitutions of substantially equivalent subjects are usually approved. For example, a student with a strong physics background who plans graduate study in physics may substitute STATISTICAL MECHANICS AND THERMODYNAMICS (8.07), for 6.08T.

Students may also 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.

THE ELECTRICAL SCIENCE AND ENGINEERING PROGRAM

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. Most students take an additional subject in either probability (6.28J or 18.18) or the electrical properties of matter (6.13T). Many students take both and also elect graduate subjects in mathematics, physics, or electrical engineering during their fourth year. Since most students in this program will be doing thesis work in graduate school, twelve units of project seminar are used to satisfy the departmental requirement of a thesis or project for the Bachelor of Science degree.

To provide consistent evaluation, students in Program 2 often have common final examinations with students in Program 1. 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.

2. ELECTRICAL SCIENCE AND ENGINEERING PROGRAM CURRICULUM (COURSE VI)

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 93*)					
	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, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.				
	The subjects 6.70 and 6.71 or 6.72, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
6.013	INTRODUCTORY CIRCUIT THEORY I	4	0	8	
6.023	INTRODUCTORY CIRCUIT THEORY II	4	0	8	
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.053	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.11	[2]PROJECT SEMINAR	2	0	4	
6.12	[2]PROJECT SEMINAR	2	0	4	
6.70	EXPERIMENTAL ELECTRONICS	1	4	1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
6.72	ELECTROMAGNETIC LABORATORY	1	4	1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
8.04	MODERN PHYSICS	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
					132
	Restricted Electives				
	Two of the following subjects[3]				
6.063T	FIELDS, FORCES, AND MOTION	3	0	9	
6.073T	ENERGY TRANSMISSION AND RADIATION	4	0	8	
6.083T	THERMODYNAMICS AND QUANTUM STATISTICS	4	0	8	
					24
	Unrestricted Electives[4,5]				**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] These subjects are taken in place of the Departmental S.B. thesis requirement.

[3] Students electing all of these subjects may use the third subject as Unrestricted Elective.

[4] Programs of students in Course VI, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the first year and 24 units in the second year.

[5] Subjects in materials and probability — e.g., 6.13T, 6.28J, 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 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.

Many students get such experience in summer jobs. The VI-A programs provide another way of meeting the same objective. 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. However, each student in a VI-A program must agree to stay with one company through his Bachelor's or Master's degree.

Second-year students in good standing at the Institute, and transfer students who have completed the first two years of the Course VI program, may apply. 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.

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, International Business Machines Corporation, Honeywell, Inc., 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 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[1] at the end of the graduate year, if the student is admitted to the Graduate School. The curriculum requirements for the Bachelor of Science degree are given below.

[1] In this case, a total of four terms of industrial practice and industrial project subjects is required.

1. ELECTRICAL ENGINEERING PROGRAM CURRICULUM (COURSE VI-A)

	Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 93*)	
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, 8.03, and 18.034, which are required in the Departmental Program,	

appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.

The subjects 6.70 and 6.71 or 6.72, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.

DEPARTMENTAL PROGRAM

	Required Subjects[1]				
6.01	INTRODUCTORY CIRCUIT THEORY I	4	0	8	
6.02	INTRODUCTORY CIRCUIT THEORY II	4	0	8	
6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.05	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.70	EXPERIMENTAL ELECTRONICS	1	4	1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
6.72	ELECTROMAGNETIC LABORATORY	1	4	1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
8.04	MODERN PHYSICS	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	[2]THESIS		12		
	[3]INDUSTRIAL PRACTICE		18		
					150
	Restricted Electives				
	Two of the following subjects[4]				
6.06T	FIELDS, FORCES, AND MOTION	3	0	9	
6.07T	ENERGY TRANSMISSION AND RADIATION	4	0	8	
6.08T	THERMODYNAMICS AND QUANTUM STATISTICS	4	0	8	
					24
	Unrestricted Electives[5]				**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] 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.

[3] Credit for Industrial Practice subjects is limited to a maximum of 27 units and a minimum of 18 units.

[4] Students selecting all of these subjects may use the third subject as Unrestricted Elective.

[5] Programs of students in Course VI-A, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the first year and 24 units in the second year.

2. ELECTRICAL SCIENCE AND ENGINEERING PROGRAM CURRICULUM (COURSE VI-A)

	Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 93*)	
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, 8.03, and 18.304, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.	
The subjects 6.70 and 6.71 or 6.72, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.	

DEPARTMENTAL PROGRAM

	Required Subjects[1]				
6.013	INTRODUCTORY CIRCUIT THEORY I	4	0	8	
6.023	INTRODUCTORY CIRCUIT THEORY II	4	0	8	
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.053	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.70	EXPERIMENTAL ELECTRONICS	1	4	1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
6.72	ELECTROMAGNETIC LABORATORY	1	4	1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
8.04	MODERN PHYSICS	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	INDUSTRIAL PRACTICE		18		
	[2]INDUSTRIAL PROJECT		12		
					150
	Restricted Electives				
	Two of the following subjects[3]				
6.063T	FIELDS, FORCES, AND MOTION	3	0	9	
6.073T	ENERGY TRANSMISSION AND RADIATION	4	0	8	
6.083T	THERMODYNAMICS AND QUANTUM STATISTICS	4	0	8	
					24
	Unrestricted Electives[4,5]				**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] The Industrial Project is taken in place of the Departmental S.B. Thesis requirement.

[3] Students electing all of these subjects may use the third subject as Unrestricted Elective.

[4] Programs of students in Course VI-A, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the first year and 24 units in the second year.

[5] Subjects in materials and probability — e.g., 6.13T, 6.28J, 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 and broad 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 attack-

ing 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. For a well-prepared student, satisfactory completion of a one-year program of graduate study, which includes participation in departmental teaching or research and the completion of a satisfactory thesis, lead to the Master of Science degree. 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 Counsellor, 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. Fields 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 magneto-fluid dynamics
Energy conversion devices and systems
High-voltage radiation engineering
Operations research and system engineering
Programming languages and artificial intelligence
Radio astronomy
Solid state materials and devices
Stroboscopic photography and underwater sound

In addition, many subjects in physics and mathematics are appropriate to electrical engineering; subjects are also available in business and industrial management, economics, social science, linguistics, biology, and psychology.

Research laboratories of extraordinary range and strength are sponsored by the Department. The principle of close integration between regular graduate studies and these research laboratories has proven very effective, yielding educational values beyond those of formal study alone. Most of the research work is free from security restrictions. 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 and students 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; 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 and processes.

The *Research Laboratory of Electronics* provides a basic research environment in which faculty and students from eleven academic departments participate. The activities of the Laboratory fall into three broad categories. These are general physics, plasma dynamics, and communication sciences. The research in general physics includes microwave spectroscopy, masers, radio astronomy, molecular beam studies, microwave electronics, acoustics, and several other topics. The research in plasma dynamics ranges from basic physics to engineering applications such as microwave oscillators and amplifiers, ion propulsion, controlled thermonuclear reactions, and plasma magnetohydrodynamics.

Studies of the various aspects of communica-

tion in both living and man-made systems comprise the activities of the *Center for Communication Sciences.* The major areas of interest include processing and transmission of information, statistical communication theory, artificial intelligence, speech communication, linguistics, mechanical translation, communications biophysics, neurophysiology, cognitive information processing, circuit theory, and computer research.

Both graduate and undergraduate students in Electrical Engineering have participated in virtually all of the above research activities at one time or another.

Project MAC is an interdepartmental research effort. It supports research in such areas 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 Group* and *The Energy Conversion and Semiconductor Laboratory* are concerned with problems which range from the fundamental physics of semiconductors to the engineering problems encountered in semiconductor device development and analysis. *The Microwave 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 Molecular Science Group* is concerned with a variety of special problems which principally involve the dielectric properties of solids. 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. Additional work on crystals is carried out by the *Structure Analysis Group;* here x-ray-, and neutron-diffraction techniques are used in studying crystal properties. *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.

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, of which a number are offered to new students each year. 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.

The Graduate Record Examination, described in Section 3, is requested of all United States applicants to graduate-degree programs in electrical engineering. In addition to the general requirements for all graduate students, a candidate for an advanced degree in electrical engineering must present evidence of training in most professional areas considered essential for further study in electrical science and engineering. These areas are indicated approximately by the following Institute subjects:

INTRODUCTORY CIRCUIT THEORY I AND II (6.01, 6.02)
ELECTROMAGNETIC FIELDS AND ENERGY (6.03)
CIRCUITS, SIGNALS, AND SYSTEMS (6.05)

FIELDS, FORCES, AND MOTION (6.06T)
ENERGY TRANSMISSION AND RADIATION (6.07T)
THERMODYNAMICS AND QUANTUM STATISTICS (6.08T)
INTRODUCTION TO QUANTUM PHYSICS (8.051)
ADVANCED CALCULUS FOR ENGINEERS (18.05)

Superior achievement in undergraduate mathematics and physics is considered particularly important.

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. A detailed description of the current examination and procedures will be sent to each applicant after he has been accepted for admission.

Up to a total of 24 units of subjects which are considered prerequisites for graduate studies may be taken as part of a graduate program for credit toward the Master's degree.

The Graduate Degrees

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

The general requirements for the Master's degree are given in Section 3.

Students working for the Master's degree are expected to 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.

All of the four undergraduate programs, which are described above, 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 DEGREES

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 program for this degree is elective except for the thesis and 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

JOSEPH HENRY KEENAN, LL.D.
Professor of Mechanical Engineering, Emeritus

JACOB PIETER DEN HARTOG, PH.D., D.ENG.
Professor of Mechanical Engineering

JAMES HOLT, S.B.
Professor of Mechanical Engineering, Emeritus

EGON OROWAN, D.ENG.
Professor of Mechanical Engineering

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

STEPHEN HARRY CRANDALL, PH.D.
Professor of Mechanical Engineering

NORMAN CHRISTIAN DAHL, SC.D.
Professor of Mechanical Engineering

FRANK AMBROSE McCLINTOCK, PH.D.
Professor of Mechanical Engineering

BRANDON GARNER RIGHTMIRE, SC.D.
Professor of Mechanical Engineering

JAMES ALAN FAY, PH.D.
Professor of Mechanical Engineering

KENNETH ROBERT WADLEIGH, SC.D.
Professor of Mechanical Engineering; Dean of Student Affairs

STANLEY BACKER, SC.D.
Professor of Mechanical Engineering

RONALD FILMORE PROBSTEIN, PH.D.
Professor of Mechanical Engineering

ROBERT WELLESLEY MANN, SC.D.
Professor of Mechanical Engineering

TAU-YI TOONG, SC.D. (*Absent*)
Professor of Mechanical Engineering

HENRY MARTYN PAYNTER, SC.D. (*Absent*)
Professor of Mechanical Engineering

NATHAN HENRY COOK, SC.D.
Professor of Mechanical Engineering

JAMES COLLYER KECK, PH.D.
Ford Professor of Mechanical Engineering

KENNETH NOEL CORBETT BRAY, PH.D.
Professor of Mechanical Engineering (Visiting)

SHIH-YING LEE, SC.D.
Professor of Mechanical Engineering

AUGUSTUS RUDOLPH ROGOWSKI, S.M.
Associate Professor of Mechanical Engineering

DOUGLAS PAYNE ADAMS, S.B., A.M.
Associate Professor of Mechanical Engineering

PRESCOTT ARTHUR SMITH, S.B.
Associate Professor of Mechanical Engineering

AUGUST LUDWIG HESSELSCHWERDT, JR., S.M.
Associate Professor of Mechanical Engineering

PETER GRIFFITH, SC.D.
Associate Professor of Mechanical Engineering

STEVEN ANSON COONS (*Absent*)
Associate Professor of Mechanical Engineering

ERNEST RABINOWICZ, PH.D.
Associate Professor of Mechanical Engineering

DEANE LENT, A.B.
Associate Professor of Engineering Drawing

HERBERT HEATH RICHARDSON, SC.D.
Associate Professor of Mechanical Engineering

JOSEPH LECONTE SMITH, JR., SC.D.
Associate Professor of Mechanical Engineering

PATRICK LEEHEY, PH.D.
Associate Professor of Mechanical Engineering

THOMAS BROWN SHERIDAN, SC.D.
Associate Professor of Mechanical Engineering

ALI SUPHI ARGON, SC.D.
Associate Professor of Mechanical Engineering

DWIGHT MAYLON BILLY BAUMANN, SC.D.
Associate Professor of Mechanical Engineering

S. WILLIAM GOUSE, JR., SC.D.
Associate Professor of Mechanical Engineering

PHILIP GRAHAM HILL, SC.D.
Associate Professor of Mechanical Engineering

DAVID GORDON WILSON, PH.D.
Associate Professor of Mechanical Engineering

CHARLES ADOLPH BERG, SC.D.
Associate Professor of Mechanical Engineering

FORBES TAYLOR BROWN, SC.D.
Associate Professor of Mechanical Engineering

MARTIN DUNCAN COWLEY, PH.D.
Associate Professor of Mechanical Engineering (Visiting)

ALVE JOHN ERICKSON, SC.D.
Associate Professor of Mechanical Engineering

DEAN CHARLES KARNOPP, PH.D.
Associate Professor of Mechanical Engineering

DAVID EDWARD NEWLAND, SC.D.
Associate Professor of Mechanical Engineering

REGIS MARC NOEL PELLOUX, SC.D.
Associate Professor of Mechanical Engineering (Visiting)

EUSTRATIOS NICOLAS CARABATEAS, SC.D.
Assistant Professor of Mechanical Engineering

ROBERT ERWIN STICKNEY, PH.D.
Assistant Professor of Mechanical Engineering

ARTHUR EDWARD BERGLES, PH.D.
Assistant Professor of Mechanical Engineering

RAYMOND GORDON COOK, PH.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering

WILLIAM RUSSELL FERRELL, PH.D.
Assistant Professor of Mechanical Engineering

LEON ROBERT GLICKSMAN, PH.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering

PHILLIP GOULD, SC.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering

RICHARD JOSEPH GURSKI, SC.D.
Assistant Professor of Mechanical Engineering

JON RONALD KELLY, SC.D.
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JOHN STEWART MAULBETSCH, SC.D.
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AIN ANTS SONIN, PH.D.
Assistant Professor of Mechanical Engineering

JOSEPH GERSTMANN, PH.D.
Assistant Professor of Mechanical Engineering

ALLAN DALE PIERCE, PH.D.
Assistant Professor of Mechanical Engineering

RONALD CARL ROSENBERG, PH.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering

JOHN BASIL YANNAS, PH.D.
Assistant Professor of Mechanical Engineering

Administrative Officer

JAMES HARRISON EACKER, S.M.

Senior Lecturer

GEORGE NICHOLAS HATSOPOULOS, SC.D.

Lecturer

PHILIP ALDRICH DRINKER, PH.D.

Instructors

DAVID NEAL WORMLEY, S.M.
ROGER ALLEN HUMPHREY, S.M.
DANIEL WADE KENNEDY, S.M.
PANGAL NARAYAN NAYAK, M.E.
JENS ERIK JORGENSEN, S.M.
WALTER JOHN BORNHORST, S.M.

Technical Instructors

RALPH JOHN BOWLEY
CLARENCE WILLIAM CHRISTIANSEN
FREDERICK HAROLD ANDERSON
JOHN LEACH

Senior Research Associate

EMERY IMRE VALKO, PH.D.

Research Associates

ANDREAS BOEHRINGER, D.ENG. (*Visiting*)
COLIN CLARK, PH.D.
JOHN KENNETH DUPRESS, A.B.
MARVIN EMANUL GOLDSTEIN, PH.D.
HANS ULRICH RUDOLF, SC.D.
HISAYOSHI SATO, D.ENG.
YESHAISHU YEHUDA WINOGRAD, PH.D.

Professors Emeriti

CHARLES WILLIAM BERRY, S.B.
Professor of Heat Engineering, Emeritus

JOSEPH CAINS RILEY, S.B.
Professor of Heat Engineering, Emeritus

CHARLES FAYETTE TAYLOR, PH.B., M.E.
Professor of Automotive Engineering, Emeritus

GORDON BALL WILKES, S.B.
Professor of Heat Engineering, Emeritus

EARLE BUCKINGHAM
Professor of Mechanical Engineering, Emeritus

CARL RICHARD SODERBERG, TEKN.D., D.ENG.
Institute Professor, Emeritus; Professor of Mechanical Engineering, Emeritus

JOSEPH HENRY KEENAN, LL.D.
Professor of Mechanical Engineering, Emeritus

JAMES HOLT, S.B.
Professor of Mechanical Engineering, Emeritus

JOHN THOMAS RULE, S.B.
Professor of Engineering Graphics, Emeritus

SAMUEL CORNETTE COLLINS, PH.D., SC.D.
Professor of Mechanical Engineering, Emeritus

CARL LOUIS SVENSON, S.M.
Professor of Mechanical Engineering, Emeritus

THEODORE HOWARD TAFT, S.B.
Associate Professor of Heat Engineering, Emeritus

LAWRENCE SOUTHWICK SMITH, S.B.
Associate Professor of Applied Mechanics, Emeritus

ARTHUR LINDSAY GOODRICH, S.B.
Associate Professor of Drawing and Descriptive Geometry, Emeritus

WALTER CARL EBERHARD, S.B.
Assistant Professor of Engineering Graphics, Emeritus

MECHANICAL ENGINEERING

As he looks into the future, the mechanical engineer sees as his province all industry and all science as they are applied to man's purposes. He must lead in the development of new sources of power, transport, missiles, and spacecraft.

Undergraduate study in mechanical engineering must be planned with these objectives in mind. It will include such basic subjects as dynamics of solids and fluids, physics and mechanics of solids, thermodynamics, electrical circuit theory, and electromagnetic field theory.

In addition to these basic studies, the Mechanical Engineering Department is concerned with bridging the gap between science and basic knowledge on the one hand, and the development and design of useful devices and processes on the other. This is the art of engineering, and to teach this art is the primary object of subjects in laboratory and in engineering design. Here each student works under the critical and sympathetic eyes of men skilled in the art. Laboratory experience, which takes many forms, is intended to show how the experimental method is used in the solution of engineering problems. Design experience includes devising means to perform certain specified tasks, such as the design of a device or the synthesis of a system made up of parts having known characteristics.

The faculty and their students, undergraduate as well as graduate, carry on research and laboratory experiments on a wide range of basic subjects such as thermodynamics, heat transfer, refrigeration and cryogenics, elasticity, plasticity, kinematics and dynamics, fluid and gas dynamics, magnetofluiddynamics, biomedical problems, properties of materials, automatic control, design of complex systems, processing of materials, lubrication, and surface phenomena. All these subjects are applied in the design of a great variety of machines and devices.

A field of this width and diversification cannot be learned and mastered in all its details in four college years or even in a lifetime. The objective of our undergraduate program is to provide a broad intellectual horizon for the graduate and to inculcate such habits and skills of study that he will learn new science as it appears and take the initiative in applying it.

THE UNDERGRADUATE PROGRAMS

Mechanical Engineering (Course II)

The work in the first two years of the undergraduate curriculum lays a thorough foundation in mathematics, physics, 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.

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 propellors 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 Mechanical Engineering Department.

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 93*)		
	Specific science and humanities and social science subjects	**128**
	The subjects 2.012, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.	
	The subject 2.671T which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.	

DEPARTMENTAL PROGRAM

	Required Subjects			
2.012	MECHANICS OF SOLIDS	4	0	8
2.022	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8
2.03	DYNAMICS	3	0	6
2.201T	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
2.671T	EXPERIMENTAL ENGINEERING	1	8	3
2.731	ENGINEERING DESIGN	3	3	6
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4
8.03	ELECTRICITY AND MAGNETISM	4	0	8
18.034	DIFFERENTIAL EQUATIONS	3	0	9
	THESIS		9	
				144
	Restricted Electives[1]			
3.13T	MATERIALS SCIENCE I *or*	4	3	5
3.141	SCIENCE OF MATERIALS			
				12
	Unrestricted Electives[2]			**76**
Total units required for the S.B. degree				**369**

[1] Because of the strong emphasis upon materials in mechanical engineering and the desirability of acquiring an appropriate early background, the Department suggests 3.13T or 3.141 as an elective choice in the first or second year.

[2] Programs of students in Course II may always be arranged to leave available 12 units of unrestricted elective in the first year and 24 units in the second year. The Department recommends 8.04 and at least one subject in electrical engineering or electrical science as elective subjects.

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 93*)					
	Specific science and humanities and social science subjects.				**128**
	The subjects 2.012, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement. The subject 2.671T, which is among the restricted electives, appears on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
2.012	MECHANICS OF SOLIDS	4	0	8	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
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	
3.13T	MATERIALS SCIENCE I				
2.022	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8	
2.03	DYNAMICS	3	0	6	
2.201T	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	
2.671T	EXPERIMENTAL ENGINEERING	1	8	3	
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 students' 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 Mechanical Engineering Department.				at least **57**
	Unrestricted Electives[1]				up to **64**
Total units required for the S.B. degree					**360**

[1] Programs of students may always be arranged to leave available 12 units of unrestricted elective in each of the first and second years.

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 in Mechanical Engineering, and Doctor of Science or Doctor of Philosophy in Materials Engineering.

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 Graduate Degrees

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

The general requirements for the degree are given in Section 3 of this Catalogue.

The student working for the Master of Science in Mechanical Engineering follows a wholly elective program; his subjects are not restricted to those given by the Mechanical Engineering Department. The selection of individual subjects is restricted only by the condition that the program must be substantial and logical in the judgment of the faculty adviser. The program should be well balanced, emphasizing one or more of the analytical, economic, design, or experimental aspects of 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 Mechanical Engineering Department should in general have training equivalent to that offered by the Institute in its undergraduate programs in any of several departments of engineering or science. The graduate program encompasses study in the areas of mathematics, physics, chemistry, electrical materials, continuum and dislocation mechanics, metallurgy, ceramics, elastomers, and plastics, as well as research. In general, two years are required for completion of the degree of Materials Engineer. General requirements for the degree of Materials Engineer include a qualifying examination, as described for the Mechanical Engineer degree.

DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY IN MECHANICAL ENGINEERING OR DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY IN MATERIALS ENGINEERING

Admission to the doctoral program is granted only after the candidate has passed a qualifying examination; this should be taken as soon as possible after completing the Master's degree program. The requirements for the Doctor's degree include a Program of Advanced Study, a Minor program, a thesis, and the language requirement specified for the doctorates on page 75 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 in the field of fibrous materials.

Department of Metallurgy

THOMAS BURNESS KING, PH.D.
Professor of Metallurgy; Head of the Department
JOHN CHIPMAN, PH.D., SC.D.
Professor of Metallurgy, Emeritus
ANTOINE MARC GAUDIN, SC.D.
Richards Professor of Mineral Engineering, Emeritus
MORRIS COHEN, SC.D.
Ford Professor of Materials Science and Engineering
JOHN WULFF, D.SC.
Class of 1922 Professor of Metallurgy
CARL FREDERICK FLOE, SC.D.
Professor of Metallurgy; Vice President, Research Administration
HERBERT HENRY UHLIG, PH.D.
Professor of Metallurgy
MICHAEL BERLINER BEVER, DR. IUR., SC.D.
Professor of Metallurgy
NICHOLAS JOHN GRANT, SC.D.
Professor of Metallurgy
BENJAMIN LEWIS AVERBACH, SC.D.
Professor of Metallurgy
JOHN FRANK ELLIOTT, SC.D.
Professor of Metallurgy
CYRIL STANLEY SMITH, SC.D.
Institute Professor; Professor of Metallurgy
PHILIP LOUIS DE BRUYN, SC.D.
Professor of Metallurgy
WILLIAM DAVID KINGERY, SC.D.
Professor of Ceramics
HARRY CONSTANTINE GATOS, PH.D.
Professor of Electronic Materials
CLYDE MELVIN ADAMS, JR., SC.D.
Abex Corporation Professor of Metallurgy
WALTER ALAN BACKOFEN, SC.D.
Professor of Metallurgy
JOHN WERNER CAHN, PH.D.
Professor of Metallurgy
ROBERT EDWARD OGILVIE, SC.D.
Professor of Metallurgy
MERTON CORSON FLEMINGS, SC.D.
Associate Professor of Metallurgy
ROBERT LOUIS COBLE, SC.D.
Associate Professor of Ceramics
ROY KAPLOW, SC.D.
Associate Professor of Metallurgy
ROBERT MICHAEL ROSE, SC.D.
Associate Professor of Metallurgy
AUGUST FERDINAND WITT, PH.D.
Assistant Professor of Mineral Engineering
SIMON CHARLES MOSS, SC.D.
Assistant Professor of Metallurgy
JOHN FRANK BREEDIS, D.ENG.
Assistant Professor of Metallurgy
RONALD ALAN BROWN, PH.D.
Assistant Professor of Metallurgy
KENNETH CALVIN RUSSELL, PH.D.
Assistant Professor of Metallurgy
BERNHARDT JOHN WUENSCH, PH.D.
Assistant Professor of Ceramics
THOMAS OWENS ZIEBOLD, PH.D.
Assistant Professor of Nuclear Materials
DEREK JOHN FRAY, PH.D.
Assistant Professor of Metallurgy
DAVID JULIAN SELLMYER, PH.D.
Assistant Professor of Metallurgy
DONALD ROBERT UHLMANN, PH.D.
Assistant Professor of Ceramics
CYRIL JOSEPH MOGAB, B.S.
Assistant Professor of Ceramics
BUD CAESAR WONSIEWICZ, PH.D.
Assistant Professor of Metallurgy

Administrative Officer

DOUGLAS CRAIG JOHNSTON, S.B.

Technical Instructors

PAUL FREDERICK HUGHES
ARTHUR JEREMIAH GREGOR
PHILIP RENE LAFRANCE

Research Associates

SHIRO BAN-YA, PH.D.
JOSEPH TIBOR BLUCHER, SC.D.
TERRY FREDERICK BOWER, SC.D.
JOHN WASHBURN BRACKETT, PH.D.
BILL CORMANN GIESSEN, SC.D.
THEODOULOS ZENONOS KATTAMIS, SC.D.
HENRYK MATYJA, SC.D.
OLGA REPETYLO, DR.
STANLEY WEISS, SC.D.

Professors Emeriti

JOHN CHIPMAN, PH.D., SC.D.
Professor of Metallurgy, Emeritus
ANTOINE MARC GAUDIN, SC.D.
Richards Professor of Mineral Engineering, Emeritus
VICTOR OLIVER HOMERBERG, SC.D.
Professor of Physical Metallurgy, Emeritus
JOHN TORREY NORTON, SC.D.
Professor of the Physics of Metals, Emeritus
FREDERICK HARWOOD NORTON, SC.D.
Professor of Ceramics, Emeritus

METALLURGY

The Department of Metallurgy 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 metallurgist 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,

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 adviser, 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 a computation facility with a remote console tied to the M.I.T. Computation Center.

The curriculum requirements for the Course in Metallurgy and Materials Science are given below:

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 93*)				
	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 3.00T, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.			
	Laboratory Requirement (see page 45).			**12**
DEPARTMENTAL PROGRAM				
	Required Subjects[1]			
3.00T	THERMODYNAMICS OF MATERIALS	4	0	8
3.01T	THERMODYNAMICS AND STATISTICAL MECHANICS	4	0	8
3.02T	CHEMISTRY OF MATERIALS	3	3	6
3.11T	MECHANICS OF MATERIALS	4	0	8
3.12T	PRINCIPLES OF CRYSTALLOGRAPHY AND X-RAY DIFFRACTION	4	3	5
3.13T	MATERIALS SCIENCE I	4	3	5
3.15T	MATERIALS SCIENCE II	4	3	5
8.03	ELECTRICITY AND MAGNETISM	4	0	8
18.034	DIFFERENTIAL EQUATIONS	3	0	9
	[3]THESIS		12	
				120
	Restricted Electives			**20 to 24**
	Physical Metallurgy			
	One of the following subjects:			
3.14T	PHYSICAL METALLURGY I	4	3	5
3.144	PHYSICAL METALLURGY I	4	0	4
	Materials Processing			
	One of the following subjects:			
3.18T	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] Programs of students in Course III may always be arranged to leave available 12 units of unrestricted elective in each of the first and second years.

[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 or Materials Science can facilitate their later progress by ensuring that their second-year subjects include additional mathematics and physics as well as 3.00T and 3.11T, 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 ENGINEERING

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 adviser. 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 a remote computation console.

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 in metallurgy 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 (3.01T)
MATERIALS SCIENCE I (3.13T)

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 engineering, 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 (3.01T)
MATERIALS SCIENCE I (3.13T)

The Graduate Degrees

The Department offers the following graduate degrees: Master of Science in Metallurgy; Master of Science in Ceramics; Metallurgical Engineer; Mineral Engineer; Materials Engineer; Doctor of Science in Metallurgy; Doctor of Science in Ceramics; and Doctor of Science in Materials Engineering. Doctorate students may elect the degree of Doctor of Philosophy in these fields.

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
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus
JACOB PIETER DEN HARTOG, PH.D., D.ENG.
Professor of Mechanical Engineering
MARTIN AARON ABKOWITZ, PH.D.
Professor of Naval Architecture
JOHN HARVEY EVANS, B.ENG.
Professor of Naval Architecture
PHILIP MANDEL, B.S.
Professor of Naval Architecture
ROBERT EDWARD STARK, S.M.
Captain, U. S. Navy
Professor of Naval Construction
SHANNON CURTIS POWELL, DOTT.ING.
Associate Professor of Marine Engineering
JUSTIN ELLIOT KERWIN, PH.D.
Associate Professor of Naval Architecture
PATRICK LEEHEY, PH.D.
Associate Professor of Naval Architecture
ERNST GABRIEL FRANKEL, MAR.MECH.E.
Associate Professor of Marine Engineering
SHERMAN CLARK REED, NAV.E.
Commander, U. S. Navy
Associate Professor of Naval Engineering
NEAL ALVIN BROWN, PH.D.
Assistant Professor of Naval Architecture

Lecturer
WILLIAM AVERY BAKER, S.B.

Instructors
HALSEY CHASE HERRESHOFF, S.M.
JOHN CHARLES ADAMCHAK, S.M.
DAMON ELLIS CUMMINGS, S.M.

Research Associate
JEROME H. MILGRAM, PH.D.

Professors Emeriti
HENRY EASTIN ROSSELL, S.M.
Professor of Naval Construction, Emeritus
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus
EVERS BURTNER, S.B.
Associate Professor of Naval Architecture and Marine Engineering, Emeritus

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Naval architecture and marine engineering encompasses one of the broadest of engineering fields. 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, exploitation, 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 naval architecture and marine 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 industrial experience, and unusually close faculty-student contact all contribute to a sound and effective education.

The Department offers two programs of study for civilian students: Naval Architecture and Marine Engineering (Course XIII), with both undergraduate and graduate programs; and Shipping and Shipbuilding Management (Course XIII-B), a combination of undergraduate and graduate study, also available as a graduate program. In addition, it offers a graduate program for selected officers of the U.S. Navy, U.S. Coast Guard, and accredited foreign navies. This is designated as Naval Construction and Engineering (Course XIII-A).

THE UNDERGRADUATE PROGRAMS

Naval Architecture and Marine Engineering (Course XIII)

This curriculum is 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 program 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 ship 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 hydrodynamics, structures, oceanography, noise and vibration, hydroelasticity and management (Course XIII-B). 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 in 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 field of naval architecture and marine 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 93*)					
	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 2.012, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement (see page 45).				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
2.012	MECHANICS OF SOLIDS	4	0	8	
2.022	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8	
2.201T	FLUID MECHANICS	4	0	8	
2.403	THERMODYNAMICS	4	0	8	
3.141	SCIENCE OF MATERIALS	4	3	5	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
13.00	PRINCIPLES OF NAVAL ARCHITECTURE	4	1	7	
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	8	3	
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] Programs of students in Course XIII may always be arranged to leave available 12 units of unrestricted elective in each of the first and second years.

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 Department of Economics and the Alfred P. Sloan School of Management, as appropriate. 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, AND SHIPPING AND SHIPBUILDING MANAGEMENT

The Department offers five graduate degrees in the field of Naval Architecture and Marine Engineering: Master of Science, Naval Architect, Marine Mechanical Engineer, and Doctor of Science (or Philosophy). In addition, the Course in Naval Construction and Engineering (Course XIII-A) offers the degree of Naval Engineer and the Course in Shipping and Shipbuilding Management (Course XIII-B) leads to the degree of Master of Science in Shipping and Shipbuilding Management, as described later.

A program of graduate study in the Department is almost entirely under the control of the student. He is assisted in his planning by the Graduate Registration Officer who is his faculty adviser. An acceptable graduate program of 72 credit units plus an acceptable thesis leads to the degree of Master of Science in Naval Architecture and Marine Engineering; this program can usually be completed in one academic year if it is based on an undergraduate curriculum equivalent in scope to that offered by this Department. A two-year program leads to the degree of Naval Architect or Marine Mechanical Engineer. Students with a less broad undergraduate background usually require more time; or they may follow a program leading to a Master of Science without specification, which requires equally high standards of academic performance.

To obtain the degree of Doctor of Science in Naval Architecture and Marine Engineering usually requires a minimum of three years of graduate work if the thesis can be successfully completed in one year.

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)
STRUCTURES (13.12, 13.14, 13.15, 13.16)
MARINE ENGINEERING (13.21, 13.23)
MECHANICAL VIBRATION (13.31)
SHIP DESIGN (13.41, 13.42)
SHIPPING ECONOMICS AND OPERATIONS RESEARCH (13.92, 13.93, 13.96)
HYDROACOUSTICS (13.95)
SPECIAL PROBLEMS (13.91)

Most other departments in the Schools of Engineering and Science offer subjects which

are appropriate to graduate programs in Naval Architecture or Marine Engineering. Among such subjects are those in mathematics, physics, acoustics, dynamics, structures, mechanics of fluids and solids, controls, computers, electrical engineering, nuclear engineering, materials, gas turbines, internal combustion engines, thermodynamics, and heat transfer.

Entrance Requirements for Graduate Study

In addition to the general requirements for admission described in Section 3 of this Catalogue, the undergraduate preparation should be equal, in quality, quantity, and breadth of coverage to the Institute's undergraduate curriculum in Naval Architecture and Marine Engineering. Successful study in an acceptable program of graduate work requires a competence substantially equivalent to that represented by this curriculum in each of the following areas:

Strength of materials
Dynamics
Fluid mechanics
Heat engineering
Engineering materials
Naval architecture
Ship structures
Marine engineering
Ship design

If undergraduate preparation has been significantly less intensive in any of these areas, the deficiencies must be removed prior to the award of any of the degrees implying specification. This may be accomplished concurrently with graduate work if the deficiencies are not extensive. Undergraduate subjects so required 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 semester of full-time work.

A program for an Engineer degree ordinarily includes two subjects in the area of economics or industrial management, and at least 20 units of comprehensive design, such as PRELIMINARY DESIGN OF SHIPS (13.42), or the equivalent. A single thesis will generally be acceptable for both the Master of Science and Engineer degrees, provided it is appropriate to the specification of the latter degree.

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 twenty 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 Shipbuilding and Shipbuilding Management, previously described, may also be achieved by postbaccalaureate 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.

Graduate credit will usually not be given for those undergraduate and graduate subjects in statistics, probability theory, economics, management, accounting, and basic operations research which are prerequisite to the program. Deficiencies in these areas should be removed during the first two terms of study. A number of graduate subjects are then required in computer programming, industrial dynamics, shipping economics, decision theory, and systems engineering, followed by electives in the areas of operations, international business management, mathematical programming, transportation, advanced computer systems, and controllership. The elective program permits specialization in fields of particular interest.

Requirements for admission to the graduate program in Shipbuilding 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.

Department of Nuclear Engineering

MANSON BENEDICT, PH.D.
Professor of Nuclear Engineering; Head of the Department
IRVING KAPLAN, PH.D.
Professor of Nuclear Engineering
THEOS JARDIN THOMPSON, PH.D.
Professor of Nuclear Engineering; Director of the M.I.T. Reactor
DAVID JOHN ROSE, PH.D.
Professor of Nuclear Engineering
EDWARD ARCHIBALD MASON, SC.D.
Professor of Nuclear Engineering
ELIAS PANAYIOTIS GYFTOPOULOS, SC.D.
Professor of Nuclear Engineering
NORMAN CARL RASMUSSEN, PH.D.
Professor of Nuclear Engineering
GORDON LEE BROWNELL, 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
THOMAS HENDERSON DUPREE, PH.D.
Associate Professor of Nuclear Engineering
LAWRENCE MARK LIDSKY, PH.D.
Assistant Professor of Nuclear Engineering
FRANKLYN MILES CLIKEMAN, PH.D.
Assistant Professor of Nuclear Engineering
THOMAS OWENS ZIEBOLD, PH.D.
Assistant Professor of Nuclear Materials
SIDNEY YIP, PH.D.
Assistant Professor of Nuclear Engineering
MICHAEL JOHN DRISCOLL, SC.D.
Assistant Professor of Nuclear Engineering
ELMER EUGENE LEWIS, PH.D.
Assistant Professor of Nuclear Engineering; Postdoctoral Fellow in Engineering

Lecturers

LEON EDWARD BEGHIAN, PH.D.
SAMUEL LEVIN, S.B.

Research Associates

EDWARD JAMES BARNETT
WILLIAM NORMAN BLEY, S.M.
KUNMO CHUNG, PH.D.
LINCOLN CLARK, JR., A.B., S.M.
JAMES WATERBURY GOSNELL, M.S.

NUCLEAR ENGINEERING

The Nuclear Engineering Department 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 to reduce the capital cost of nuclear power stations and extend 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 Nuclear Engineering Department 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 in Nuclear Engineering. No undergraduate degree is offered.

In these programs attention is focussed 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 basic 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 I.B.M. Type 7094 digital computer is used extensively in research and graduate instruction. Liquid helium for low-temperature research is available from the M.I.T. Cryogenic Laboratory.

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, 8.03, 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 8.72.

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 5.61.

Engineering Fundamentals: Elementary theory of elasticity, thermodynamics of power cycles, and heat transfer, equivalent to M.I.T. subjects 2.012, 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.

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 (8.531)
NUCLEAR PHYSICS FOR ENGINEERS II (8.532)

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 (22.71T)
SELECTED TOPICS IN 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 (22.65J)
NUCLEAR PHYSICS FOR ENGINEERS I (8.531)
NUCLEAR PHYSICS FOR ENGINEERS II (8.532)

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 IN NUCLEAR ENGINEERING

The program of study leading to this degree aims to give a comprehensive knowledge of nuclear engineering and to develop competence in engineering research. General requirements for the doctorate are listed in Section 3 of this Catalogue. Before the student may start his doctoral research, he is required to pass a comprehensive general examination demonstrating competence in physics, mathematics, and engineering fundamentals.

Graduate subjects on which all candidates for the doctorate are also examined include:

NUCLEAR REACTOR PHYSICS I (22.21)
NUCLEAR PHYSICS FOR ENGINEERS I (8.531)
NUCLEAR PHYSICS FOR ENGINEERS II (8.532)
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 thermonuclear option must also be familiar with the content of:

ELECTROMAGNETIC RADIATION (8.72)
ADVANCED PLASMA PRINCIPLES (22.62)
ENGINEERING PHYSICS OF PLASMA AND PARTICLE DEVICES (22.63)
PLASMA LABORATORY (22.65J)

The doctoral examination will also include elective questions on other related 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 conversion of nuclear heat to electricity, chemical and biological effects of radiation, effect of radiation on reactor materials, fuel cycles for nuclear reactors, solvent extraction of metals, isotope separation, 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
WILBUR BAYLEY DAVENPORT, JR., SC.D.
Professor of Electrical Engineering
ARTHUR CLARKE SMITH, PH.D.
Associate Professor of Electrical Engineering
FRANK EDWARD PERKINS, SC.D.
Assistant Professor of Civil Engineering

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
HENRY MARTYN PAYNTER, SC.D.
Professor of Mechanical Engineering
CLYDE MELVIN ADAMS, JR., SC.D.
Abex Corporation Professor of Metallurgy
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, 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 two 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.

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, and $1,400 for the regular Summer Term. 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 semester 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 semesters in the humanities or social sciences, including typically a sequence of three semesters 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 four such programs, one in the Department of Economics, one in the Department of Political Science, and two in the Department of Humanities. Those in Humanities require what is essentially a second major in some branch of either science or engineering, while those in Economics and Political Science are specified as single majors, though there is 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, however, 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

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 in 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 nontechnological 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 sciences (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 40*)				*Total units*
	Specific Science Subjects			
5.01	CHEMICAL PRINCIPLES I	5	2	5
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			
21.01	[1]THE GREEK TRADITION	3	0	6
21.02	[1]THE EUROPEAN TRADITION	3	0	6
21.03T	[1]LITERATURE: LANGUAGE, FORMS, AND THE INDIVIDUAL AUTHOR			
	or			
21.031	[1]LITERATURE: SELF, NATURE, AND SOCIETY	3	0	6
	or			
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY			
21.05T	[1]THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM"			
	or			
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	6
	or			
17.01T	SOCIETY AND MAN			
	Upperclass program (*see pages 46–49*)	32		
				68
				128

Science Distribution Requirement
At least 36 units in three fields (*see page 44*)
Laboratory Requirement
At least 12 units (*see page 45*)

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.011 THE GREEK TRADITION (in place of 21.01); 23.021 THE JUDAEO-CHRISTIAN TRADITION (in place of 21.02); 23.031 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.051 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T). The following subjects are offered in German for students having an adequate background in German and will be accepted in place of the Humanities subjects listed in parentheses: 23.022 THE EUROPEAN TRADITION: THE ERA OF GOETHE (in place of 21.02); 23.032 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.052 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM": (in place of 21.05T).

Department of Economics

EDGAR CARY BROWN, PH.D.
Professor of Economics; Head of the Department

PAUL ANTHONY SAMUELSON, PH.D.
Institute Professor; Professor of Economics

CHARLES ANDREW MYERS, PH.D.
Professor of Industrial Relations

HAROLD ADOLPH FREEMAN, S.B.
Professor of Statistics

CHARLES POOR KINDLEBERGER, PH.D.
Professor of Economics; Chairman of the Faculty

MAX FRANKLIN MILLIKAN, PH.D.
Professor of Economics; Director of the Center for International Studies

PAUL NARCYZ ROSENSTEIN-RODAN, DR.RER.POL.
Professor of Economics

EVERETT EINAR HAGEN, PH.D.
Professor of Economics

SIDNEY STUART ALEXANDER, PH.D.
Professor of Economics

EVSEY DAVID DOMAR, PH.D. (*Absent*)
Professor of Economics

ROBERT LYLE BISHOP, PH.D.
Professor of Economics; Dean of the School of Humanities and Social Science

ROBERT MERTON SOLOW, PH.D.
Professor of Economics

MORRIS ALBERT ADELMAN, PH.D.
Professor of Economics

FRANCO MODIGLIANI, D.JUR., D.SOC.SCI.
Professor of Economics

MICHAEL MOISSEY POSTAN, M.A., M.SC.
Professor of Economic History (Visiting)

EDWIN KUH, PH.D.
Professor of Economics

ABRAHAM J. SIEGEL, PH.D.
Professor of Industrial Relations

RICHARD SAMUEL ECKAUS, PH.D.
Professor of Economics

FRANKLIN MARVIN FISHER, PH.D. (*Absent*)
Professor of Economics

MICHAEL BRUNO, PH.D.
Professor of Economics (Visiting)

KENNETH JOSEPH ARROW, PH.D.
Professor of Economics (Visiting)

JEROME ROTHENBERG, PH.D.
Professor of Economics

ALAN ARTHUR WALTERS, B.SC.
Professor of Economics (Visiting)

PETER ARTHUR DIAMOND, PH.D.
Associate Professor of Economics

KARL SHELL, PH.D.
Assistant Professor of Economics

CECIL DUNCAN MACRAE, PH.D.
Assistant Professor of Economics

GORDON ROBERTSON SPARKS, PH.D.
Assistant Professor of Economics

PRANAB KUMAR BARDHAN, PH.D.
Assistant Professor of Economics

ROBERT WARREN CRANDALL, PH.D.
Assistant Professor of Economics

DUNCAN KARL FOLEY, PH.D.
Assistant Professor of Economics

JOHN REES HARRIS, PH.D.
Assistant Professor of Economics

MICHAEL JOSEPH PIORE, PH.D.
Assistant Professor of Economics

MIGUEL SIDRAUSKI, PH.D.
Assistant Professor of Economics

JOHN H. WILLIAMSON, PH.D.
Assistant Professor of Economics (Visiting)

Administrative Officer

IDELLA LYMAN TAPLEY, A.B.

Instructors

PETER CHARLES PING, B.A.
DAVID EARL BLACK, B.A.
SANJIT BOSE, M.A.
DONALD GEORGE HECKERMAN, B.A.
JOSEPH EUGENE STIGLITZ, B.A.
WILLIAM EDWARD WHITELAW, B.A.

Professors Emeriti

FLOYD ELMER ARMSTRONG, LL.D.
Professor of Economics and Finance, Emeritus

DONALD SKEELE TUCKER, PH.D.
Professor of Economics, Emeritus

RALPH EVANS FREEMAN, M.A., B.LITT.
Professor of Economics, Emeritus

PAUL PIGORS, PH.D.
Professor of Industrial Relations, 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 CURRICULA
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 nontechnical 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.

The elementary subjects, ECONOMIC PRINCIPLES I and II (14.01 and 14.02), are an introduction to the whole field of economics. The intermediate subjects, PRICES AND PRODUCTION (14.03) and ECONOMIC FLUCTUATIONS AND GROWTH (14.05), deepen this knowledge — the first in industry analysis and price formation, and the second in the study of economic fluctuations and growth. Preparation for the quantitative side of economics is offered in STATISTICAL METHOD (14.381).

With this general background the student may go farther in particular fields by his choice of junior and senior electives. The program specifies that a minimum of four subjects (32 units) are to be elected in economics. The unrestricted electives make possible greater concentration in economics, more depth in science and engineering, and the further exploration of other complementary fields.

In the senior year, training in the methods of economic research is provided by participation in an ECONOMIC RESEARCH SEMINAR (14.39) in the first term and by the writing of a thesis in the second.

The curriculum requirements for the degree of Bachelor of Science in Economics are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 153*)					
	Specific science and humanities and social science subjects[1]				**128**
	The Science Distribution Requirement will be satisfied by 1.00 and 18.034, which are required in the Departmental Program, plus appropriate subjects (see page 44) totalling				**12**
	Laboratory Requirement (see page 45)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
1.00	INFORMATION SYSTEMS	3	3	6	
14.01	ECONOMIC PRINCIPLES I	3	0	5	
14.02	ECONOMIC PRINCIPLES II	3	0	5	
14.03	PRICES AND PRODUCTION	3	0	5	
14.05	ECONOMIC FLUCTUATIONS AND GROWTH	3	0	5	
14.381	STATISTICAL METHOD	3	0	6	
14.39	ECONOMIC RESEARCH SEMINAR	2	0	6	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
	THESIS		9		
					82
	Restricted Electives				
	Elective subjects in economics		32		
	Elective subjects in science or engineering		24		**56**
	Unrestricted Electives[2]				**70**
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.

[2] Programs of students in Course XIV may always be arranged to leave available 12 units of unrestricted elective in the first year.

GRADUATE STUDY IN ECONOMICS

The Department of Economics offers work leading to the degrees of Master of Science in Economics and Doctor of Philosophy in Economics.

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 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-semester 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-semester 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:
14.121T, 14.122T, 14.123, 14.124, 14.132, 14.151, 14.451T, 14.452T.

Economic history:
14.161, 14.162, 14.163, 14.164.

Monetary and Fiscal Economics:
14.462, 14.463, 14.471, 14.472, 14.474.

Economic development:
14.171, 14.172, 14.182, 14.282.

Industrial organization and policy:
14.231, 14.271, 14.272, 14.291, 14.292.

Statistics and Econometrics:
14.371, 14.372, 14.373, 14.374, 14.381, 14.383T, 14.384.

International economics:
14.581T, 14.582T, 14.584, 14.586.

Labor economics and public policy:
14.671, 14.672, 14.674, 14.691, 14.692.

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 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 in Economics

A candidate for the doctorate must prepare himself in five fields, four of which are covered by the General Examination. Economic theory, including both micro- and macroeconomics, is required as a field for all students. One other field, designated as primary, requires more intensive preparation than the remaining three, which are designated as secondary. Elective fields include advanced economic theory, monetary economics, fiscal economics, industrial organization and policy, international economics, economic development, labor economics and labor relations, economic history, statistical theory and econometrics, and others. If statistics and economic history are not among the candidate's five fields of concentration, he must also take one graduate subject in each of these areas.

No stated number of graduate subjects in the Department of Economics are required, but ordinarily the candidate will need two full academic years of work to prepare himself adequately for his General Examination and to meet the other pre-thesis requirements.

The doctoral thesis must be written in residence. As a rule it represents one year's research.

Candidates are required to 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 Humanities

RICHARD MATEER DOUGLAS, PH.D.
Professor of History; Head of the Department

HOWARD RUSSELL BARTLETT, B.S., A.M.
Professor of History

WILLIAM CHACE GREENE, M.A.
Professor of English, Emeritus

GIORGIO DIAZ DE SANTILLANA, PH.D.
Professor of the History and Philosophy of Science

CARVEL COLLINS, PH.D. (*Absent*)
Professor of English

KLAUS LIEPMANN
Professor of Music; Director of Music

ROY LAMSON, PH.D.
Professor of English

HUSTON CUMMINGS SMITH, PH.D.
Professor of Philosophy

CYRIL STANLEY SMITH, SC.D.
Institute Professor;
Professor of the History of Science and Technology

THOMAS HENRY DONALD MAHONEY, PH.D.
Professor of History

JAMES FREDERICK THOMSON, M.A.
Professor of Philosophy

ROBERT SMITH WOODBURY, S.B., A.M.
Professor of the History of Technology

GREGORY TUCKER
Professor of Music

BRUCE MAZLISH, PH.D.
Professor of History

ELLIOTT COOK CARTER, JR.
Professor of Music (Visiting)

EDWARD NEAL HARTLEY, A.M.
Professor of History;
Secretary of the Faculty; Institute Archivist

HARALD ANTON THRAP OLSEN REICHE, PH.D.
Professor of Classics and Philosophy

LYNWOOD SILVESTER BRYANT, A.M.
Associate Professor of History

THEODORE WOOD, JR., S.B., A.M.
Associate Professor of English

ROBERT REYNOLDS RATHBONE, A.M.
Associate Professor of English

IRVING SINGER, PH.D. (*Absent*)
Associate Professor of Philosophy

ROBERT ELLSWORTH MACMASTER, PH.D.
Associate Professor of History and Literature

JOSEPH DEE EVERINGHAM, A.M.
Associate Professor of English; Director of Drama

ABNER ELIEZER SHIMONY, PH.D. (*Absent*)
Associate Professor of the Philosophy of Science

JUDITH JARVIS THOMSON, PH.D.
Associate Professor of Philosophy

DAVID MAYER EPSTEIN, M.F.A.
Associate Professor of Music; Conductor
of the M.I.T. Symphony Orchestra

JERRY ALAN FODOR, PH.D.
Associate Professor of Philosophy

JERROLD JACOB KATZ, PH.D.
Associate Professor of Philosophy

WALTER FRANCIS URBACH, A.M.
Associate Professor of English

SYLVAIN BROMBERGER, PH.D.
Associate Professor of Philosophy

ALBERT RAMSDELL GURNEY, JR., M.F.A.
Associate Professor of English

LOUIS KAMPF, B.A.
Associate Professor of English

WILLIAM HARVEY YOUNGREN, PH.D.
Assistant Professor of English

HUBERT LEDERER DREYFUS, PH.D.
Assistant Professor of Philosophy

THOMAS HERBERT JACKSON, PH.D.
Assistant Professor of English

WILLIAM BRAASCH WATSON, PH.D.
Assistant Professor of History

ROBERT ADOLPH, PH.D.
Assistant Professor of English

ARTHUR DANIEL KALEDIN, PH.D.
Assistant Professor of History

WARREN JORDAN MACISAAC, PH.D.
Assistant Professor of English

TRAVIS RHODES MERRITT, PH.D.
Assistant Professor of English

NORMAN PETTIT, PH.D.
Assistant Professor of English

DAVID BIRD RALSTON, PH.D.
Assistant Professor of History

DAVID LOUIS SCHALK, PH.D.
Assistant Professor of History

ARTHUR RICHARD STEINBERG, M.A.
Assistant Professor of History and Archeology

DUNCAN MORSE NELSON, PH.D.
Assistant Professor of English
NATHAN SIVIN, PH.D.
Assistant Professor of the History of Science
GERALD BOB DWORKIN, PH.D.
Assistant Professor of Philosophy
ROBERT EDWIN HERZSTEIN, PH.D.
Assistant Professor of History
WILLIAM IRWIN THOMPSON, PH.D.
Assistant Professor of English
FRANK D. ZINGRONE, PH.D.
Assistant Professor of English

Administrative Officer
RUTH ELEANOR DUBOIS, A.B., S.B.

Lecturers
CHARLES THOMAS COLE, A.M.
JOHN COOK, MUS.B. *Organist*
WILLIAM RAYMOND CROUT, M.A.
ERCOLINO FERRETTI, B.MUS.
DAVID ALLEN PARK, PH.D. (*Visiting*)
WILLIAM McCONNELL RUDDICK, M.A.
BARRY BERNARD SPACKS, M.A.
HERTHA HILDEGARD VON DECHEND, PH.D.
RICHARD WAYNE WERTZ, B.A., B.D.

Instructors
MICHAEL LAY, M.M.
MARY KATHARINE WAKEMAN, M.A.
JOHN COWPERTHWAITE GRAVES, A.M.
MARK ALAN LEVENSKY, M.A.
NANCY ZILBOORG DWORSKY, M.A.
GEORGE JAY BORNSTEIN, M.A.
DIANE SHAVER CLEMENS, PH.D.
MARTIN DISKIN, M.A.
FRANCIS JOSEPH ESTERHILL, M.A.
SANFORD KAYE, A.B., M.A.
PETER GATES SNYDER, M.A.

Professors Emeriti
JOHN ELY BURCHARD, L.H.D., D.ARCH.
Professor of Humanities, Emeritus; Dean of the School of Humanities and Social Science, Emeritus
WILLIAM CHACE GREENE, M.A.
Professor of English, 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 two special undergraduate programs which combine the basic subjects in science and engineering with a concentrated program in the humanities; these special programs are Humanities and Engineering (Course XXI-A) and Humanities and Science (Course XXI-B). In addition, there is graduate work in philosophy leading to the Ph.D. degree.

THE UNDERGRADUATE CURRICULA

Humanities and Engineering (Course XXI-A)
Humanities and Science (Course XXI-B)

The two undergraduate Courses 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 has been described as a "double major." Because of the flexibility it provides 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 Courses 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 core curriculum in mathematics, physics, chemistry, and humanities, each of these Courses provides a program with a quality of unusual scope and balance. One part of each Course 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 disci-

plines of the Department of Humanities and the Department of Modern Languages. The student chooses one field for concentration: literature (English, American, French, German, 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 participate in either a Humanities Seminar, interdisciplinary in character, or in a History Seminar, a Literature Seminar, or a Philosophy Seminar. 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 a visiting professor. The disciplinary seminars are intended to round out the student's studies within his chosen field of humanities and to prepare him for advanced study. In addition each student receives instruction in the writing of a thesis.

Course XXI-A leads to the degree of Bachelor of Science in Humanities and Engineering, and Course XXI-B leads to the degree of Bachelor of Science in Humanities and Science. The curriculum for the first year is shown on pages 41–43; the curriculum requirements for the degrees in both Courses are summarized below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 153*)					
	Specific science and humanities and social science subjects				**128**
	Science Distribution Requirement (see page 44)				**36**
	Laboratory Requirement (see page 45)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
21.08	THESIS PREPARATION AND REPORTS	1	2	3	
	THESIS		12		
					18
	Restricted Electives				
21.07	HUMANITIES SEMINAR				
	or				
21.071	HISTORY SEMINAR				
	or	2	0	8	
21.072	LITERATURE SEMINAR				
	or				
21.073	PHILOSOPHY SEMINAR				
			10		
	Elective subjects restricted to one of the humanities disciplines: e.g., literature, philosophy, etc.		48		
	Elective subjects restricted to one of the science or engineering curricula		52		
					110
	Unrestricted Electives[1]				**56**
Total units required for the S.B. degree					**350**

[1] Programs of students in Course XXI-A and Course XXI-B may always be arranged to leave available 12 units of unrestricted elective in the first year.

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 in 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 IN 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 semester 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 comprehensive general examinations demonstrating competence in history of philosophy, philosophy of science, logic, value theory, 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
WILLIAM NASH LOCKE, PH.D.
Professor of Modern Languages
ROMAN JAKOBSON, PH.D.
Institute Professor
NOAM AVRAM CHOMSKY, PH.D.
Ferrari P. Ward Professor of Modern Languages and Linguistics
MORRIS HALLE, PH.D.
Professor of Modern Languages
MARTIN DYCK, PH.D.
Professor of German and Humanities
JAMES HINTON SLEDD, PH.D.
Professor of Linguistics (Visiting)
GEORGE HUBERT MATTHEWS, PH.D.
Associate Professor of Modern Languages
KRYSTYNA POMORSKA, PH.D.
Associate Professor of Russian
EDWARD STEPHAN KLIMA, PH.D.
Associate Professor of Modern Languages
CARL JOHN BLACK, JR., M.A.
Assistant Professor of French
CLAUDE JANE-MARIE CAREY, PH.D.
Assistant Professor of Modern Languages
RENÉ PAUL VIKTOR KIPARSKY, PH.D.
Assistant Professor of Linguistics
JOHN ROBERT ROSS, M.A.
Assistant Professor of Linguistics

Lecturers
PRIMUS BENEDICT BON, B.S., M.A.
MARGARET ZAROODNY FREEMAN, S.M.

Instructors
STELLA BERGER GREENFIELD, M.A.
RENATA HOFMAN BRIGGS
MAGDA BUKA, B.A.
MARIANNE LIEPE TEUBER, M.A.
RENATA BERG PAN, M.A.
ILONA RICARDO, M.A.
URSULA BRIGITTE McCUNE
ANNEMARIE BESTOR, M.A.
JAMES WESLEY HARRIS, M.A.
PHILIPPE MICHAUX, M.A.
LAURENCE HERBERT SCOTT, M.A.
DAVID TILESTON EDSALL, B.A.
CHRISTA LOUISE JOHNS, PH.D.
CLAIRE JEANNE KRAMSCH, M.A.
HELGA MINNA STEGEMANN, M.A.
KRISTINE FORSTER BRECHT, M.A.
ILSE GISELA KLEMPERER, B.A.

Professors Emeriti
RICHARD FELIX KOCH, A.M.
Assistant Professor of Modern Languages, Emeritus
GEORGE ALEXANDROVICH ZNAMENSKY, B.D., ED.M.
Assistant Professor of Russian, Emeritus
HERMAN KLUGMAN, PH.D.
Assistant Professor of Modern Languages, Emeritus

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 in Linguistics.

UNDERGRADUATE SUBJECTS

The Department provides instruction on several levels in German, French, and Russian. Introductory subjects aim first at familiarity with the spoken language, emphasizing pronunciation, and second at minimum essentials for a reading knowledge. The intermediate level provides for a continuation of speaking and the development of a broad reading vocabulary. The texts cover fiction, drama, and historical or descriptive works to introduce students to the genius, institutions, and social organization of the countries in question. Advanced subjects are conducted 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-semester sequence on Dante provides both language study and literary analysis. Two 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-semester subjects in French, German, and Russian, *open to graduate students only*, are designed to help each student develop rapidly the ability to read technical and scientific material in his own field whether or not he has any previous acquaintance with the language. A two-semester subject in Spanish stressing the listening, speaking, and reading skills is designed to prepare graduate students for work in Latin America. These subjects carry no credit.

The Doctoral Program in Modern Languages and Linguistics (Course XXIII)

The program of studies leading to the degree of Doctor of Philosophy in Linguistics aims to give a comprehensive knowledge of modern linguistics, with particular emphasis on its experimental, quantitative, and theoretical aspects. To enter the program, each student must satisfy the Institute requirements for admission to the Graduate School and have done well in his previous academic work. He must be formally accepted by the Department of Modern Languages and Linguistics as a candidate for the degree.

DOCTOR OF PHILOSOPHY IN LINGUISTICS

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites:

Mathematics. One full year of college mathematics.

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)
PROBLEMS OF PHONOLOGY (23.762)
SURVEY OF GENERAL LINGUISTICS I (23.781)
SEMINAR IN LINGUISTICS (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

NORMAN JUDSON PADELFORD, PH.D., LL.D.
Professor of Political Science

MAX FRANKLIN MILLIKAN, PH.D.
Professor of Economics

DANIEL LERNER, PH.D.
Professor of Sociology

EVERETT EINAR HAGEN, PH.D.
Professor of Economics

LUCIAN WILMOT PYE, PH.D.
Professor of Political Science

WILLIAM WEED KAUFMANN, PH.D.
Professor of Political Science

LINCOLN PALMER BLOOMFIELD, PH.D.
Professor of Political Science

MYRON WEINER, PH.D.
Professor of Political Science

HAROLD ROBERT ISAACS, A.B.
Professor of Political Science

FREDERICK WARD FREY, PH.D.
Professor of Political Science

WILLIAM EDGAR GRIFFITH, PH.D.
Ford Professor of Political Science

HENRY S. ROWEN, B.PHIL.
Professor of Political Science

DANKWART RUSTOW
Professor of Political Science (Visiting)

FRANK BONILLA, PH.D.
Associate Professor of Political Science

FRED CHARLES IKLÉ, PH.D.
Associate Professor of Political Science

JOSEPH WEIZENBAUM, S.M.
Associate Professor of Political Science

ALAN A. ALTSHULER, PH.D.
Associate Professor of Political Science

URI RA'ANAN, B.LITT.
Associate Professor of Political Science (Visiting)

EUGENE BERTRAM SKOLNIKOFF, M.A., S.M.
Associate Professor of Political Science

DONALD LAWRENCE MORTON BLACKMER, A.M.
Assistant Professor of Political Science; Assistant Director of the Center for International Studies

LEONARD J. FEIN, PH.D.
Assistant Professor of Political Science

JOHN SELIM SALOMA, III, PH.D.
Assistant Professor of Political Science

WILLARD RAYMOND JOHNSON, PH.D.
Assistant Professor of Political Science

FRANK CARLTON COLCORD, JR., PH.D.
Assistant Professor of Political Science

GEORGE ERIC HANSEN
Assistant Professor of Political Science

HARVEY M. SAPOLSKY
Assistant Professor of Political Science

Administrative Officer

ELIZABETH ANNA MARIA TERLINGEN, PHARM.

Lecturers

GEORGE WILLIAM ANGELL, JR., ED.D.
RICHARD HENRY BOLT, PH.D.
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.

Instructors

ROY E. FELDMAN, M.A.
ALLAN MAZUR, M.S.

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 are equipped with knowledge and skills necessary for the understanding of 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. The objectives are: (1) to examine the nature of political behavior and the political process; (2) to explore the government's role in science and technology, both in America and abroad, and in international relations; and (3) to develop familiarity with the techniques of policy formulation and decision-making on issues of public policy.

There is no rigid program of subjects of instruction in the political science curriculum. 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 a seminar on INTERNATIONAL POLITICS (17.53). Students in the comparative government field may focus on the United States to include, among other subjects, THE AMERICAN POLITICAL PROCESS (17.21), COMPARATIVE POLITICAL SYSTEMS (17.24), and a seminar on ISSUES IN CONTEMPORARY AMERICAN POLITICS (17.23). In the field of public policy, appropriate subjects are POLITICS, SOCIETY, AND POLICY-MAKING (17.12), 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 POSTWAR U.S. DEFENSE POLICY (17.31) and CURRENT U.S. DEFENSE PROBLEMS (17.32).

Each student majoring in political science writes a thesis on a subject that particularly interests him and has an opportunity for field study with a local political organization or governmental unit. 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 153)*					
	Specific science and humanities and social science subjects[1]				**128**
	The Science Distribution Requirement will be satisfied by 1.00 and 18.034, which are required in the Departmental Program, plus appropriate subjects (see page 44) totalling				**12**
	Laboratory Requirement (see page 45)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
1.00	INFORMATION SYSTEMS	3	3	6	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
	THESIS			9	
					33
	Restricted Electives				
	Elective subjects in political science			88	
	Elective subjects in science or engineering			24	
					112
	Unrestricted Electives[2]				**63**
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] Programs of students in Course XVII may always be arranged to leave available 12 units of unrestricted elective in the first year.

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 in Political Science.

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-semester subject, INTRODUCTION TO MATHEMATICAL MODELS IN THE SOCIAL SCIENCES (17.731), and one other semester 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-semester subject in science at the Institute. A student whose deficiencies are of minor extent will be permitted graduate registration while taking appropriate subjects to remove them.

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, 17.151T, 17.161, 17.162, 17.191, 17.192.

Comparative Politics:
17.211, 17.213T, 17.214T, 17.222, 17.223T, 17.225T, 17.232T, 17.242T, 17.261, 17.262T, 17.282.

Defense Policy:
17.311, 17.312, 17.321T, 17.322, 17.342T, 17.352.

Science and Public Policy:
17.412, 17.431, 17.441, 17.442.

International Relations and Foreign Policy:
17.511, 17.513, 17.514, 17.516, 17.521T, 17.522, 17.523.

Political and Economic Development:
17.611, 17.612, 17.621, 17.623, 17.631, 17.652T.

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 IN POLITICAL SCIENCE

A candidate for the doctorate in political science must prepare himself for a General Examination covering four approved fields. In addition, he must provide evidence through course work or examination of general competence in 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.

Candidates for the doctorate will be required to take a Minor in a field other than political science. Possibilities include economics, industrial relations, management, mathematics, history, philosophy, sociology, social psychology, or relevant fields in science or engineering.

General Requirements for Doctoral Candidates

No stated number of graduate subjects in the Department of 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
WALLE JETZE HARINX NAUTA, M.D., PH.D.
Professor of Neuroanatomy
JOSEPH ALTMAN, PH.D.
Associate Professor of Psychology
STEPHAN LEWIS CHOROVER, PH.D.
Associate Professor of Psychology
JERRY ALLEN FODOR, PH.D.
Associate Professor of Psycholinguistics
HERBERT DAVID SALTZSTEIN, PH.D.
Assistant Professor of Psychology
WAYNE ALLEN WICKELGREN, PH.D.
Assistant Professor of Psychology
ALAN HEIN, PH.D.
Assistant Professor of Psychology
PETER HARKAI SCHILLER, PH.D.
Assistant Professor of Psychology
WHITMAN ALBIN RICHARDS, PH.D.
Assistant Professor of Psychology

Lecturer

MERRILL FREDERICK GARRETT, PH.D.

Administrative Assistant

ROBERT IRWIN McELROY, B.A.

Research Associates

EMILIO BIZZI, M.D.
SUZANNE HAMMOND CORKIN, PH.D.
HARVEY JULES KARTEN, M.D.
JACOBO R. MEHLER, PH.D.
RITA GILLIS RUDEL, PH.D.
ARTHUR TAUB, M.D., PH.D.
THOMAS EVANS TWITCHELL, M.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.

GRADUATE STUDY IN PSYCHOLOGY (COURSE IX)

The program of studies leading to the degree of Doctor of Philosophy in Psychology 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 IN PSYCHOLOGY

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 to 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 in Management; a one-year Alfred P. Sloan Fellowship 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. It oversimplifies the task of educating men such as these to catalogue business education into quantitative or non-quantitative alternatives or between liberal and technical emphases. We want to produce men who are solidly based in the pertinent disciplines and who can think about the whole problem in management terms, from the whole range of technical data to the human element. We want them to be able to reach decisions. At his best, our young graduate has this ability to move decisively and responsibly in an increasingly complex world. The opportunities for such men in a society full of challenge, both socially and technically, are substantial and growing. This task of educating men for management is our first purpose. There is a second concern, equally important, that drives the School. We want to conduct research that produces new understanding and better solutions to management problems, and these results must be communicated to a broader audience. The net effect of these education and research goals should have their impact on other schools and on management operations in general.

WILLIAM F. POUNDS

MANAGEMENT

SLOAN SCHOOL OF MANAGEMENT

WILLIAM FRANK POUNDS, PH.D.
Professor of Management; Dean

JOHN MacDONALD WYNNE, A.B., S.M.
Associate Dean; Senior Lecturer

JOHN ELY BURCHARD, L.H.D., D.ARCH.
Professor of Humanities, Emeritus; Dean of the School of Humanities and Social Science, Emeritus

DOUGLASS VINCENT BROWN, PH.D.
Alfred P. Sloan Professor of Management

CHARLES ANDREW MYERS, PH.D.
Professor of Industrial Relations

ELTING ELMORE MORISON, A.M. (*Absent*)
Sloan Fellows Professor of Management

BILLY EARL GOETZ, PH.D.
Professor of Management

SIDNEY STUART ALEXANDER, PH.D.
Professor of Management

JAY WRIGHT FORRESTER, D.ENG.
Professor of Management

DAVID DURAND, PH.D.
Professor of Management

DONALD GEORGE MARQUIS, PH.D. (*Absent*)
Professor of Organizational Psychology and Management

FRANCO MODIGLIANI, D.JUR., D.SOC.SCI.
Professor of Finance

CARROLL LOUIS WILSON, SC.D.
Professor of Management

DANIEL MARK HOLLAND, PH.D.
Professor of Finance

EDWIN KUH, PH.D.
Professor of Finance

WARREN G. BENNIS, PH.D.
Professor of Organizational Psychology and Management

THOMAS MASON HILL, A.B., M.B.A.
Professor of Management

EDGAR HENRY SCHEIN, PH.D.
Professor of Organizational Psychology and Management

ABRAHAM J. SIEGEL, PH.D.
Professor of Industrial Relations

PAUL HAROLD COOTNER, PH.D.
Professor of Finance

ZENON SOTERIOU ZANNETOS, PH.D.
Professor of Management

MASON HAIRE, PH.D.
Professor of Organizational Psychology and Management (Visiting)

CHARLES HENRY SAVAGE, JR., D.B.A.
Professor of Management (Visiting)

LEO BENJAMIN MOORE, S.M.
Associate Professor of Management

WILLIAM LOUIS LETWIN, PH.D.
Associate Professor of Economic History

MARTIN GREENBERGER, PH.D.
Associate Professor of Management

JOHN DUTTON CONANT LITTLE, PH.D.
Associate Professor of Management

BARNARD ELLIOT SMITH, PH.D. (*Absent*)
Associate Professor of Management

WILLIAM PENFIELD TRAVIS, PH.D.
Associate Professor of Industrial History

THEODORE MARK ALFRED, PH.D.
Associate Professor of Industrial Relations

DONALD CARY CARROLL, PH.D.
Associate Professor of Management

GEOFFREY PENNISTON ELLIOTT CLARKSON, PH.D. (*Absent*)
Associate Professor of Management

GORDON MAYER KAUFMAN, D.B.A.
Associate Professor of Management

EDWARD BAER ROBERTS, PH.D.
Associate Professor of Management

DONALD EUGENE FARRAR, PH.D. (*Absent*)
Associate Professor of Finance

JAMES SUREN HEKIMIAN, D.B.A.
Associate Professor of Management

PAUL WEBSTER MACAVOY, PH.D.
Associate Professor of Management

JOHN DANIEL NYHART, A.B., L.L.B.
Associate Professor of Management

PEER OLAV SOELBERG, M.S.
Assistant Professor of Management

ARNOLD EVERETT AMSTUTZ, PH.D.
Assistant Professor of Management

DAVID ELMER BERLEW, PH.D. (*Absent*)
Assistant Professor of Management

MICHAEL JAMES BROWER, PH.D. (*Absent*)
Assistant Professor of Industrial History

WILLARD RUSSELL FEY, S.M.
Assistant Professor of Management

WILLIAM HARRIS GRUBER, PH.D.
Assistant Professor of Management

OTTO HERBERT POENSGEN, PH.D.
Assistant Professor of Management

DAVID PETER TAYLOR, M.B.A.
Assistant Professor of Industrial Relations

LEON SELIGSBERGER WHITE, PH.D.
Assistant Professor of Management
DAVID ALLEN KOLB, A.B.
Assistant Professor of Management
WILLIAM WARREN McKELVEY, S.M.
Assistant Professor of Management
DAVID BRUCE MONTGOMERY, PH.D.
Assistant Professor of Management
PETER TEMIN, PH.D.
Assistant Professor of Industrial History
WALLACE BRUCE STEWART CROWSTON, PH.D.
Assistant Professor of Management
THOMAS JOHN ALLEN, JR., PH.D.
Assistant Professor of Organizational Psychology and Management
GEORGE FRANKLIN FARRIS, PH.D.
Assistant Professor of Organizational Psychology and Management
JAY ROBERT GALBRAITH, D.B.A.
Assistant Professor of Management
MICHAEL STEWART SCOTT MORTON, D.B.A.
Assistant Professor of Management
STEWART CLAY MYERS, PH.D.
Assistant Professor of Finance
JOHN FRANKLIN PIERCE, JR., PH.D.
Assistant Professor of Management
IRWIN MARTIN RUBIN, PH.D.
Assistant Professor of Organizational Psychology and Management
JEREMY FRANK SHAPIRO, PH.D.
Assistant Professor of Management
GLEN LEE URBAN, PH.D.
Assistant Professor of Management
WILBUR GARRETT LEWELLEN, S.M.
Assistant Professor of Finance (Visiting)

Senior Lecturers

RICHARD BECKHARD, A.B.
ROBERT CROZER CASSELMAN, B.S.
HERBERT FRANKLIN GOODWIN, S.B.
STANLEY MARTIN JACKS, A.M., LL.B.
Adviser to Prelaw Students
WILLIAM A. WALLACE KREBS, JR., A.B., LL.B.
STUART MACMILLAN, PH.B., LL.B.
RICHARD STETSON MORSE, D.ENG., D.SC.
RICHARD DUNLOP ROBINSON, PH.D.
GERALD BRUCE TALLMAN, PH.D.

Lecturers

HERBERT FRAZER AYRES, S.M.
ROBERT LEON BRANDFON, PH.D.
EMANUEL KAY, PH.D.
RICHARD THOMAS MURPHY, JR., A.B., B.S., LL.B.
JOHN THOMAS ONUSKA, JR., PH.D.
DAVID SIROTA, PH.D.

Instructors

CARL VERNER SWANSON, S.B.
GEORGE ANTHONY GORRY, JR., M.S.
MALCOLM MURRAY JONES, S.M.
DAVID NORMAN NESS, B.A.
CHRISTOPHER REED SPRAGUE, S.B.
JOHN DAVID ARAM, B.S.
JOHN FRALICK ROCKART, M.B.A.

Executive Development Programs

PETER PAUL GIL, PH.D.
Director; Senior Lecturer
PRISCILLA ANN KARB, A.B.
Assistant Director

Research Associates

PAUL CAMPANIS, PH.D.
JAMES RUMRILL MILLER, III, M.B.A.
ALEXANDER LE FEVRE PUGH, III, E.E.
LEONARD MARK RAMSAIER, M.S.

Administrative Assistants

GERTRUDE ELIZABETH BURNS
ESTHER MERRILL, B.S.
MIRIAM SHERBURNE, A.B.

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

THE UNDERGRADUATE CURRICULUM

Management (Course XV)

The undergraduate Course in Management is designed for students who combine an aptitude for science and engineering with an interest in managerial careers. Successful management of enterprises in the future will demand the ability to deal with technological issues of increasing complexity, a broad comprehension of business problems, and an understanding of human behavior. Fundamental training in science and engineering has proved to be an excellent base for the study of management, and the Institute is uniquely qualified to provide a curriculum which combines science and technology with administration and the humanities.

The undergraduate program in Management rests upon those disciplines such as economics, psychology, and applied mathematics which underlie the management functions. Building on these foundations, the program seeks to give the student a broad understanding of the areas with which managers are chiefly concerned, including production, marketing, finance, and organization. Much of the work in management is quantitative, and several of the required subjects offer immediate introduction to the many rapidly developing mathematical and statistical techniques for solving problems.

The goal of the departmental program is to provide a core curriculum of the underlying disciplines and major applied fields of study and yet to permit flexibility to the student to pursue special interests or broaden his base of general knowledge. Each student is expected to elect three professional subjects in management and a minimum of three subjects in a related sequence outside the Course XV area. He has the further freedom of five or six unrestricted electives. Thus he has a range of options between a maximum program of professional management and management-related subjects and a minimum program of core subjects in management and substantial freedom to express other interests.

As an alternative to the standard program, an experimental two-year curriculum is offered for ten students who have the desire and initiative to plan much of their own program. This Undergraduate Systems Program option provides a 27-unit block in each term of the junior and senior years for research in the dynamics of management systems, contact with executives and existing corporations, study of the functional management areas, individual paper writing exercises with faculty tutors, reading of the current business press, and classroom work which is planned and implemented by the students.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Since a strong mathematical background is essential for the professional subjects of the junior and senior years, students who plan to study management should take the specified Science Distribution Subject in mathematics in their second year. Each student is expected, however, to make his own choice from the appropriate subjects of the remaining Science Distribution and Laboratory Requirement. Students who wish to continue their work in science and engineering may do so within the sequence of three subjects outside Course XV and the unrestricted electives.

The curriculum requirements for the degree of Bachelor of Science in Management are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS					
	Specific Science Subjects				
5.01	CHEMICAL PRINCIPLES I	5	2	5	
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				
21.01	[1]THE GREEK TRADITION	3	0	6	
21.02	[1]THE EUROPEAN TRADITION	3	0	6	
21.03T	[1]LITERATURE: LANGUAGE, FORMS AND THE INDIVIDUAL AUTHOR *or*				
21.031	[1]LITERATURE: SELF, NATURE, AND SOCIETY *or*	3	0	6	
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY				
21.05T	[1]THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM" *or*				
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS *or*	3	0	6	
17.01T	SOCIETY AND MAN				
	Upperclass program[2] *(see pages 46–49)*	32			
					68
					128
	The Science Distribution Requirement will be satisfied by 18.034, which is required in the Departmental Program, plus appropriate subjects (see page 44) totalling				**24**
	Laboratory Requirement (see page 45)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
15.01	ECONOMICS FOR MANAGEMENT	3	0	6	
15.02T	INDUSTRIAL STATISTICS	4	0	8	
15.04T	PSYCHOLOGY AND HUMAN ORGANIZATION	4	0	8	

15.41	FINANCIAL MANAGEMENT	3	0	6	
15.50T	MANAGEMENT INFORMATION AND CONTROL	4	0	8	
15.71	PRODUCTION MANAGEMENT	3	0	6	
15.81	MARKETING	3	0	6	
15.95	SENIOR SEMINAR IN MANAGEMENT	2	0	7	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					93
	Restricted Electives				
	Professional subjects in management[3]				27
	Subjects in a related sequence outside Course XV, at least				27
	Unrestricted Electives[4]				54
Total units required for the S.B. degree					365

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.011 THE GREEK TRADITION (in place of 21.01); 23.021 THE JUDAEO-CHRISTIAN TRADITION (in place of 21.02); 23.031 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.051 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T). The following subjects are offered in German for students having an adequate background in German and will be accepted in place of the Humanities subjects listed in parentheses: 23.022 THE EUROPEAN TRADITION: THE ERA OF GOETHE (in place of 21.02); 23.032 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.052 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T).

[2] ECONOMIC PRINCIPLES I (14.01) is required. Subjects in Field Six (Economics) and Field Eight (Labor Relations) may not be used towards the humanities and social science requirement.

[3] Students in Course XV are required to satisfy a basic computer requirement. This may be met by an appropriate professional elective, by a science elective, or by demonstrated evidence (summer or other non-credit work) that the requirement has been fulfilled.

[4] Programs of students in Course XV may always be arranged to leave available 12 units of unrestricted elective in the first year.

MANAGEMENT MINOR FOR ENGINEERS

In addition to the above, the School offers upperclass undergraduates majoring in any field of engineering or science a program known as the Management Minor. This program consists of four basic core subjects plus two optional subjects. It is described in a brochure available through departmental Faculty Counselors or at the office of the Undergraduate Program in Management, Room E52-472.

GRADUATE STUDY IN MANAGEMENT

The Alfred P. Sloan School of Management offers graduate study leading to the degrees of Master of Science and Doctor of Philosophy in Management.

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 semesters or in one year. The required curriculum for those who have done no previous work in this field includes the following subjects:

MATHEMATICS FOR MANAGEMENT (15.091, 15.092)
PROBLEMS IN AMERICAN POLITICAL ECONOMY (15.201)
PSYCHOLOGY AND HUMAN ORGANIZATION (15.331)
MANAGEMENT INFORMATION AND CONTROL (15.501)
ECONOMICS FOR MANAGEMENT I AND II (15.012, 15.014)
LABOR-MANAGEMENT RELATIONS (15.312)
FINANCIAL MANAGEMENT (15.412T)
OPERATIONS MANAGEMENT (15.712) (A)
MARKETING (15.812T)

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 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 School maintains a computation center, including an I.B.M. 1620 computer, for use in thesis and research work. The more extensive facilities of the M.I.T. Computation Center are also available. The Master's thesis usually involves intensive study of some industrial problem of significance to a participating company or to industry in general. Part-time research assistantships carrying sub-

stantial stipends and affording opportunity for direct participation in faculty research are available.

DOCTOR OF PHILOSOPHY

The doctoral program in management is designed primarily for students interested in teaching and research in management. 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 given 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 in combination with one or more primary disciplines, normally selected from the following list.

Primary disciplines	*Areas of application*
Economics	Operations management
Behavioral sciences	Marketing Finance
Quantitative studies	Organization Labor economics and labor relations Personnel administration International management Management information and controls Management information systems Industrial dynamics

General Examination

Upon prospective completion of the program of course work arranged with his committee, the student takes a general examination in four fields: his field of functional specialization, the field of his primary discipline, and two fields selected with the approval of his advisor as meaningfully related to his program.

Doctoral Thesis and Special Examination

The doctoral candidate's thesis, written in residence, normally represents a year's research. It must give evidence of the candidate's ability to design and carry out significant scholarly research in his area of specialization. The thesis is defended in an oral examination, which also covers the subject matter of his advanced work as a whole.

Entrance Requirements for Graduate Study

The general admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions.

Undergraduate preparation for this program should include: mathematics through college algebra and differential calculus; at least one year of an experimental science at the college level; and a course in principles of economics. An undergraduate course in elementary psychology is desirable. 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

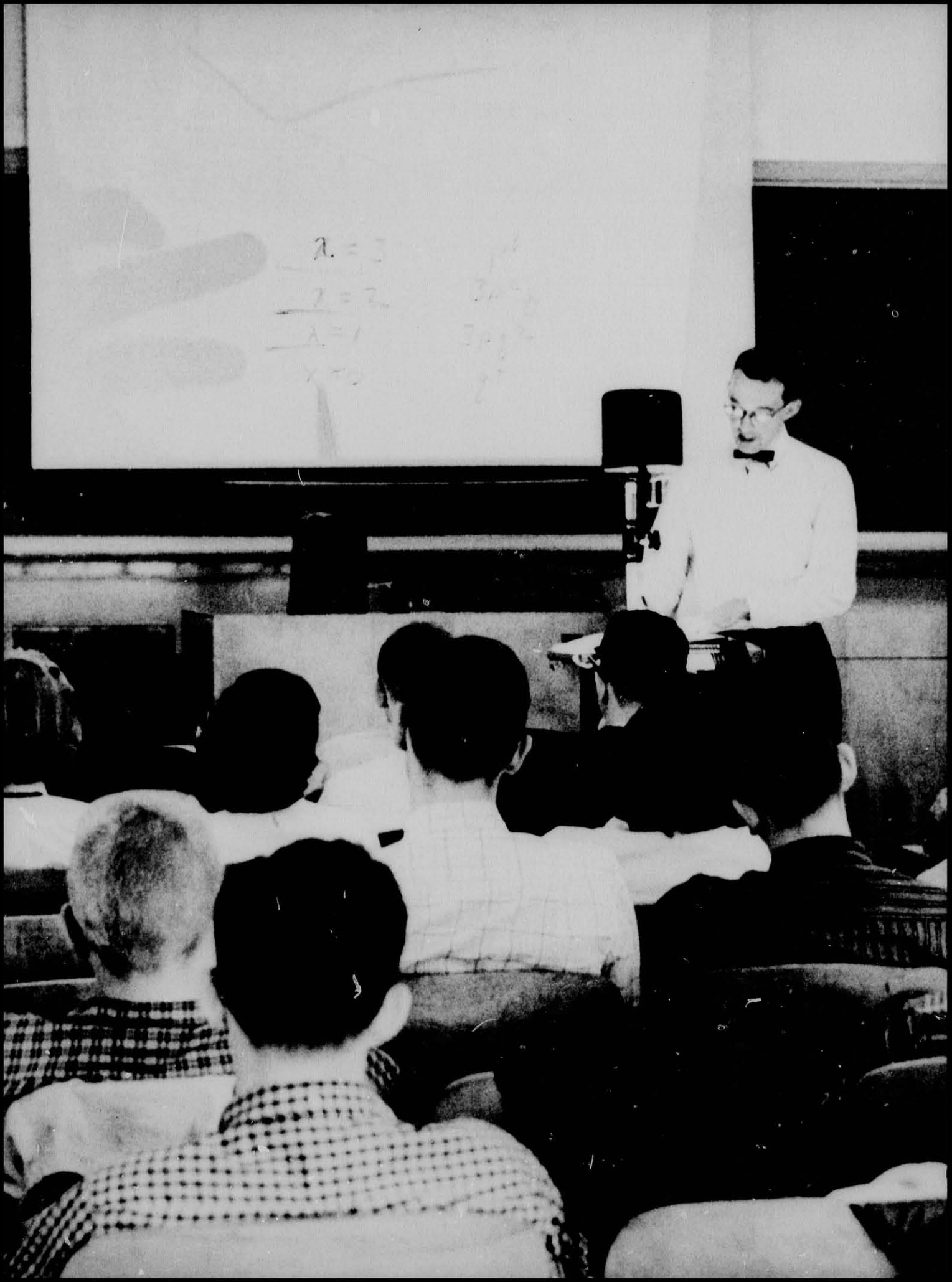
The Alfred P. Sloan School of Management provides two programs for business executives who wish to extend their knowledge of the fundamentals underlying effective management. Applicants for these programs are nominated by their companies and selected by M.I.T.

The *Sloan Fellowships in Executive Development*, available under special grants of the Alfred P. Sloan Foundation, are awarded to 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 and government (or they may apply independently); a limited number of Fellowships are awarded men from abroad. The twelve-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 Director of Executive Development 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, the investigation of the phenomena of nature and of the relationships between them. Modern science builds upon and adds to the great body of knowledge which is our heritage. Increasingly powerful and subtle instruments — themselves the product of scientific developments — are necessary for observations and measurements. Today science is one of the most exciting and rewarding of human activities because of the breadth of understanding that is being achieved, the increasing integration of scientific knowledge, and the rapidity with which new knowledge is becoming available.

The scientist, in carrying on his work, has many possibilities open to him. As an individual research worker, he can pursue knowledge at the frontiers of science. He is needed at all levels of education and often combines teaching with an active research program. Industry and government offer more and more opportunities for the scientist, either as an individual worker or as a member of a large team engaged in research or development activity. Finally, the scientist with management interests is also in demand as an administrator in research management involving scientific and engineering workers.

The School of Science at M.I.T. offers a broad educational program which prepares students to work in any of these activities. Active participation in the research being carried out by the staff provides training in many highly specialized fields and gives the prospective scientist an insight into how scientific knowledge grows.

The teaching and research activities in the School of Science may be classified, broadly speaking, into four fields — physical sciences, life sciences, earth sciences and mathematics, the latter providing a language and a tool common to all science in addition to being a highly challenging field in its own right.

The physical sciences are concerned with the structure and interaction of matter and energy. Particularly important in this category at present are studies of atomic nuclei, elementary particles, and the great concentrations of energy which can be released in nuclear reactions; electron physics and the incredibly varied ways in which the motion of electrons can be used; the structures of atoms and molecules and the electric and magnetic interaction of their various parts; the structures of liquids and solids, metals, insulators, and semiconductors; and the analysis and building up of molecular assemblages of increasing complexity.

The life sciences cover a multidisciplinary field. The most fundamental division is concerned with molecular biology and the chemistry of the molecules found in living cells. These molecules occur in a wide variety of forms, from the simplest inorganic and organic types up to the most complex — the protein molecules. The properties of these molecules, when

gathered together, govern the structure and the energy-converting powers of living systems. In cellular biology the scientist studies the structure, function, and origin of whole cells. In systems biology he examines the combined effects of aggregates of similar cells whose coordinated action determines particular activities of an entire plant or animal. Finally, psychologists, sociologists, and ecologists study the input-output relationships of the whole organism.

In nutrition the scientist studies all aspects of the qualitative and quantitative requirements of living organisms for nutrients and the ways in which food substances are utilized at the level of specific cell and organ functions. The food scientist deals with the basic constituents of food as well as the chemical, physical, and microbiological reactions and interactions which cause flavor, odor, toxicological or nutritional changes during and after processing and storage.

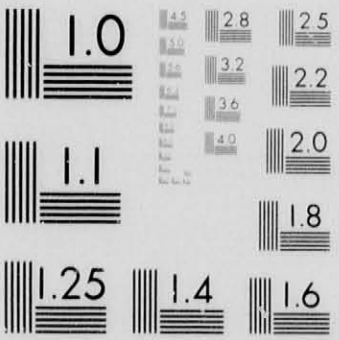
In the earth sciences a great variety of physical and chemical phenomena present themselves in complex systems that call for a penetrating application of the basic concepts of the physical sciences. Much of the field of classical physics, not related to the atom or its nucleus, was historically developed in the study of these earth science problems, and recent advances in our understanding of the earth's atmosphere, of weather prediction and control, and of the seas and oceans are continuations of this. The history and development of the earth in its present form, the dynamics of its interior and surface, its magnetic field, its electrical and chemical constitution are all studied in geophysics, geology, oceanography, and meteorology.

Planetary and space science and astrophysics extend the scope to encompass planets and moons, stars and galaxies, and the other matter and fields which occupy outer space. Many aspects of these are included in the teaching programs of the School of Science.

Mathematics, in addition to being an independent and continuously developing discipline, plays an increasingly important role in all of science. The interests of mathematicians at M.I.T. cover a broad range from such fields as topology and algebra to applied mathematics, and there is fruitful cooperation among mathematicians and other scientists and engineers. New developments in mathematics are incorporated into both the undergraduate and graduate programs, and students are encouraged to understand and work with mathematics as a unified whole.

The School of Science at M.I.T. has close and important relationships with other schools, with the surrounding community, and with the nation. The scope and variety of research activities on the campus and the continuing close contact of our staff with a wide variety of scientific problems encountered by industry and by state and national governments assure a most stimulating atmosphere for study.

JEROME B. WIESNER



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

JEROME BERT WIESNER, PH.D.
Acting Dean

JOEL ORLEN, M.A.
Administrative Officer

SCIENCE COUNCIL

IRWIN WHITING SIZER, PH.D.
Head, Department of Biology

JOHN ROSS, PH.D.
Head, Department of Chemistry

FRANK PRESS, PH.D.
Head, Department of Geology and Geophysics

WILLIAM TED MARTIN, PH.D.
Head, Department of Mathematics

HENRY GARRETT HOUGHTON, SC.D.
Head, Department of Meteorology

NEVIN STEWART SCRIMSHAW, PH.D., M.D., D.P.S.
Head, Department of Nutrition and Food Science

WILLIAM WEBER BUECHNER, PH.D., SC.D.
Head, Department of Physics

EXECUTIVE OFFICERS AND DEPUTY HEADS

JOHN WITHERS IRVINE, JR., PH.D., SC.D.
Department of Chemistry

RICHARD DONALD SCHAFER, PH.D.
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.

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	CHEMICAL PRINCIPLES I	5	2	5	
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				
21.01	[1]THE GREEK TRADITION	3	0	6	
21.02	[1]THE EUROPEAN TRADITION	3	0	6	
21.03T	[1]LITERATURE: LANGUAGE, FORMS, AND THE INDIVIDUAL AUTHOR				
	or				
21.031	[1]LITERATURE: SELF, NATURE, AND SOCIETY	3	0	6	
	or				
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY				
21.05T	[1]THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM"				
	or	3	0	6	
21.06T	[1]THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS				
	or				
17.01T	SOCIETY AND MAN				
	Upperclass program (*see pages 46–49*)	32			
					68
					128

Science Distribution Requirement
At least 36 units in three fields (*see page 44*)

Laboratory Requirement
At least 12 units (*see page 45*)

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.011 THE GREEK TRADITION (in place of 21.01); 23.021 THE JUDAEO-CHRISTIAN TRADITION (in place of 21.02); 23.031 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.051 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T). The following subjects are offered in German for students having an adequate background in German and will be accepted in place of the Humanities subjects listed in parentheses: 23.022 THE EUROPEAN TRADITION: THE ERA OF GOETHE (in place of 21.02); 23.032 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.052 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T).

Department of Biology

IRWIN WHITING SIZER, PH.D.
Professor of Biochemistry; Head of the Department
FRANCIS OTTO SCHMITT, PH.D., SC.D.
Institute Professor; Professor of Biology
JOHN MACHLIN BUCHANAN, PH.D., D.SC.
Professor of Biochemistry; in charge of the Division of Biochemistry
DAVID FLOYD WAUGH, PH.D.
Professor of Biophysics
CYRUS LEVINTHAL, PH.D.
Professor of Biophysics
SALVADOR EDWARD LURIA, M.D.
Sedgwick Professor of Biology
PATRICK DAVID WALL, M.D.
Professor of Physiology
BORIS MAGASANIK, PH.D.
Professor of Microbiology
VERNON MARTIN INGRAM, PH.D., D.SC.
Professor of Biochemistry
ALEXANDER RICH, M.D.
Professor of Biophysics
CECIL EDWIN HALL, PH.D.
Professor of Biophysics
PAUL RANDOLPH GROSS, PH.D.
Professor of Biology
MAURICE SANFORD FOX, PH.D.
Professor of Genetics
JEROME YSRAEL LETTVIN, M.D.
Professor of Communications Physiology
PHILLIPS WESLEY ROBBINS, PH.D.
Professor of Biochemistry
BERNARD SIDNEY GOULD, PH.D.
Associate Professor of Biochemistry
KURT SIEGFRIED LION, DR.ING.
Associate Professor of Applied Biophysics
EUGENE BELL, PH.D. (*Absent*)
Associate Professor of Biology
GENE MONTE BROWN, PH.D.
Associate Professor of Biochemistry
ROBERT MORRIS DOWBEN, M.D.
Associate Professor of Physiology
LLOYD ROSS FINCH, PH.D.
Associate Professor of Biology (Visiting)
CHARLES EDWARD HOLT, III, PH.D.
Assistant Professor of Biology
JOEL EDWARD BROWN, PH.D.
Assistant Professor of Physiology
SAUL ALLEN YANKOFSKY PH.D.
Assistant Professor of Microbiology
SHELDON PENMAN, PH.D.
Assistant Professor of Biophysics
JOSEPH PETER MASCARENHAS, PH.D.
Assistant Professor of Biology (Visiting)
BRUCE HERBERT POMERANZ, M.D., PH.D.
Assistant Professor of Physiology
ETHAN ROY SIGNER, PH.D.
Assistant Professor of Microbiology

Administrative Officer
DONALD DUNCAN MCNEIL, A.B.

Research Associates
CLAUDIO ALVINO, PH.D.
MARIA LEIPELT BADE, PH.D.
DWIGHT JOE BAUGHMAN, M.D., PH.D.
RONALD JAY CHANDROSS, PH.D.
BRUNO EMANUELE COLOMBO, PH.D.
ANTHONY JOHN E. COLVILLE, PH.D.
LAWRENCE KENNETH CREAMER, PH.D.
MARCELO ALBERTO DANKERT, PH.D.
ANN EDITH FARNHAM, PH.D.
LIA FISCHER-FANTUZZI, PH.D.
GIOVANNI GIANNONI, D.CH.
ANNAMARIA TORRIANI GORINI, PH.D.
FRANCO GUERRINI, PH.D.
JEREMY HAYWARD, PH.D.
JUNKO HOSODA, PH.D.
WEI-TSE HSIEH, PH.D.
YASUO IWANAMI, PH.D.
LOUIS KATZ, PH.D.
ANDREW YOSHIHISA KIMURA, PH.D.
KARL KORNACKER, PH.D.
ERNST ADOLPH KUECHLER, PH.D.
HIROSHI KUMAOKA, PH.D.
AKIRA KUNINAKA, PH.D.
FRANCOISE GROS LEVINTHAL, PH.D.
ROSA NAGEL DE ZWAIG, PH.D.
ARLAND EUGENE OLESON, PH.D.
HELEN RUTH REVEL, PH.D.
DAVID HILTON ROSCOE, PH.D.
LOUIS CRAIG SMITH, PH.D.
WERNER KARL STEUERNAGEL, E.E.
KENNETH BOIVIN TAYLOR, M.D.
MARIO TERZI, PH.D.
DAVID ROSTRON TRENTHAM, PH.D.
BERT LESTER VALLEE, M.D.
HARM OTTO VOORMA, PH.D.
MARGHERITA PIANAROSA WILLEMS, PH.D.
ANDREW WRIGHT, PH.D.

Professor Emeritus
CLAIR ELSMERE TURNER, DR.P.H., SC.D.
Professor of Public Health, Emeritus

BIOLOGY

The field of biology has undergone an impressive development during the last twenty-five years. From the conventional fields of classical botany and zoology has evolved a new field of scientific endeavor. Today biology is an exact science, utilizing physics and chemistry and surpassing both these fields in its scope and its immediate importance to man's life and health. New scientific concepts have emerged from this development; the experimental means of the classical biologist are supplemented by modern research methods. The research laboratory of today's biologist comprises electronic and optical systems of all kinds, electron microscopes, and mass spectrographs, as well as many of the methods of electrical and nuclear instrumentation.

This new approach to the biological sciences is especially at home in the M.I.T. environment, where there are important activities and facilities in all the physical sciences. The Department of Biology thus offers unusual opportunities to undergraduate, graduate, and postdoctoral students.

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 twenty 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 181*)		
	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 44) and can be used to satisfy the Science Distribution Requirement.	
	The subject 7.02 which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.	

DEPARTMENTAL PROGRAM

Required Subjects

5.41	ORGANIC CHEMISTRY I	4	0	8
5.412	ORGANIC CHEMISTRY LABORATORY I	1	5	0

(*continued*)

***Required Subjects** (continued)*

5.61	PHYSICAL CHEMISTRY I	4	0	8	
7.01	GENERAL BIOLOGY	4	0	8	
7.02	GENERAL BIOLOGY LABORATORY	1	8	3	
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	
7.031	GENETICS AND MICROBIOLOGY LABORATORY	1	6	2	
7.04	DEVELOPMENTAL BIOLOGY	2	0	4	
7.041	DEVELOPMENTAL BIOLOGY LABORATORY	1	6	2	
7.06	GENERAL PHYSIOLOGY	3	0	6	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					147

Restricted Electives

5.62	PHYSICAL CHEMISTRY II				
	or	4	0	8	
5.63	PHYSICAL CHEMISTRY III				
					12
	Unrestricted Electives[1]				**73**
Total units required for the S.B. degree					**360**

[1] Programs of students in Course VII, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the first and 24 units in the second year. A thesis is recommended but not required.

PROGRAM 2. SPECIALIZED BIOPHYSICS CURRICULUM

GENERAL INSTITUTE REQUIREMENTS (*see page 181*) — *Total units*

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 44) and can be used to satisfy the Science Distribution Requirement.

The subject 7.02, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.

DEPARTMENTAL PROGRAM

Required Subjects

5.41	ORGANIC CHEMISTRY I	4	0	8	
5.412	ORGANIC CHEMISTRY LABORATORY I	1	5	0	
5.61	PHYSICAL CHEMISTRY I	4	0	8	
7.01	GENERAL BIOLOGY	4	0	8	
7.02	GENERAL BIOLOGY LABORATORY	1	8	3	
7.05	GENERAL BIOCHEMISTRY	4	0	6	
7.051	GENERAL BIOCHEMISTRY LABORATORY	0	8	0	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
8.04	MODERN PHYSICS	4	0	8	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					120

Restricted Electives

Biology — a minimum of 27 units, including one laboratory subject, must be chosen from:

7.03	GENETICS	3	0	6	
7.031	GENETICS AND MICROBIOLOGY LABORATORY	1	6	2	
7.04	DEVELOPMENTAL BIOLOGY	2	0	4	
7.041	DEVELOPMENTAL 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 II	4	0	8	
5.63	PHYSICAL CHEMISTRY III	4	0	8	
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
					51
	Unrestricted Electives[1]				**61**
Total units required for the S.B. degree					**360**

[1] Programs of students in Course VII, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the first and 24 units in the second year. A thesis is recommended, but not required.

PROGRAM 3. NUTRITION AND FOOD SCIENCE CURRICULUM

GENERAL INSTITUTE REQUIREMENTS (*see page 181*) — *Total units*

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 44) and can be used to satisfy the Science Distribution Requirement.

The subject 7.02, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.

DEPARTMENTAL PROGRAM

Required Subjects

5.41	ORGANIC CHEMISTRY I	4	0	8	
5.412	ORGANIC CHEMISTRY LABORATORY I	1	5	0	
5.61	PHYSICAL CHEMISTRY I	4	0	8	
7.01	GENERAL BIOLOGY	4	0	8	
7.02	GENERAL BIOLOGY LABORATORY	1	8	3	
7.04	DEVELOPMENTAL BIOLOGY	2	0	4	
7.05	GENERAL BIOCHEMISTRY	4	0	6	
7.051	GENERAL BIOCHEMISTRY LABORATORY	0	8	0	
7.06	GENERAL PHYSIOLOGY	3	0	6	
7.21	GENERAL MICROBIOLOGY	3	0	6	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
20.11	FOOD SCIENCE AND TECHNOLOGY	3	0	5	
20.111	FOOD SCIENCE AND TECHNOLOGY LABORATORY	1	4	2	
20.30	BASIC NUTRITION	4	0	6	
					145

Restricted Electives

5.62	PHYSICAL CHEMISTRY II				
	or	4	0	8	
5.63	PHYSICAL CHEMISTRY III				
					12
	Unrestricted Electives[1]				**75**
Total units required for the S.B. degree					**360**

[1] Programs of students in Course VII, Program 3, may always be arranged to leave available 12 units of unrestricted elective in the first and 24 units in the second year. A thesis is recommended but not required.

GRADUATE STUDY IN BIOLOGY

The Department of Biology offers graduate work leading to the degrees of Master of Science in Biology, Biochemistry, or Biophysics, and Doctor of Philosophy in Biology in 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 the Division of Biochemistry are equipped with the most modern tools for teaching and research. Special equipment for the isolation and characterization of enzymes, a radioactivity center, and a mass spectrograph are 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 OF 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
CHARLES DUBOIS CORYELL, PH.D.
Professor of Chemistry
ISADORE AMDUR, PH.D.
Professor of Physical Chemistry
JOHN CLARK SHEEHAN, PH.D., SC.D.
Professor of Organic Chemistry
RICHARD COLLINS LORD, PH.D., SC.D.
Professor of Chemistry;
Director of the Spectroscopy Laboratory
CLARK CONKLING STEPHENSON, PH.D.
Professor of Chemistry
GEORGE HERMANN BÜCHI, D.SC.
Professor of Chemistry
CHARLES GARDNER SWAIN, PH.D.
Professor of Chemistry
DAVID NEWTON HUME, PH.D.
Professor of Chemistry
DAVID POWELL SHOEMAKER, PH.D.
Professor of Chemistry
FRANK ALBERT COTTON, PH.D., SC.D.
Professor of Chemistry
FREDERICK DAVIS GREENE, II, PH.D.
Professor of Chemistry
JOHN STEWART WAUGH, PH.D.
Professor of Chemistry
KLAUS BIEMANN, PH.D.
Professor of Chemistry
HERBERT OTIS HOUSE, PH.D.
Professor of Chemistry
EDMUND LEE GAMBLE, PH.D.
Professor of Inorganic Chemistry
IRWIN OPPENHEIM, PH.D. (*Absent*)
Professor of Chemistry
DIETMAR SEYFERTH, PH.D.
Professor of Chemistry
LOUIS HARRIS, PH.D.
Associate Professor of Physical Chemistry, Emeritus
NICHOLAS ATHANASIUS MILAS, PH.D., D.SC.
Associate Professor of Organic Chemistry, Emeritus
LAWRENCE JOSEPH HEIDT, PH.D.
Associate Professor of Physical Chemistry
CARL WESLEY GARLAND, PH.D.
Associate Professor of Chemistry
GLENN ALLEN BERCHTOLD, PH.D.
Associate Professor of Chemistry
GLEN EVERETT GORDON, PH.D. (*Absent*)
Associate Professor of Chemistry
WILLIAM ROBERT MOORE, PH.D.
Associate Professor of Chemistry
WALTER ROLLIER THORSON, PH.D.
Associate Professor of Chemistry
JAMES LLOYD KINSEY, PH.D.
Assistant Professor of Chemistry
DAVID KELMER ROE, PH.D.
Assistant Professor of Chemistry
DAVID MICHAEL HERCULES, PH.D.
Assistant Professor of Chemistry
GEORGE MCCLELLAND WHITESIDES, PH.D.
Assistant Professor of Chemistry
KERRY WOLLING BOWERS, PH.D.
Assistant Professor of Chemistry
ALAN DAVISON, PH.D.
Assistant Professor of Chemistry
JAMES WILLIAM DUBLIN, PH.D.
Assistant Professor of Chemistry
DANIEL SCHAEFFER KEMP, PH.D.
Assistant Professor of Chemistry
THAYER CARLTON FRENCH, PH.D.
Assistant Professor of Chemistry
WILLIAM BEN WALTERS, PH.D.
Assistant Professor of Chemistry
DAVID MAYER CHIPMAN, PH.D. (*Absent*)
Assistant Professor of Chemistry
ROBERT JAMES SILBEY, PH.D.
Assistant Professor of Chemistry
JEFFREY IRWIN STEINFELD, PH.D.
Assistant Professor of Chemistry

Research Associates

GRIGORIOS GERASSIMOS ARZOUMANIDIS, PH.D.
JACK CHE-MAN CHANG, PH.D.
MIROSLAV DADIC, PH.D.
IVAN GAL, PH.D.
ROBERT NICHOLAS GOURLEY, PH.D.
BERNHARD ANDREAS GUBLER, DR. SC. NAT.
THOMAS MICHAEL HARD, PH.D.
JOHN WILCOX HARVEY, PH.D.
GEORGETTE HUGEL, DR. ES SCI.

YOSHIMASA KYOGOKU, SC.D.
FUK LUEN LAM, PH.D.
DAVID BOYD LEDLIE, PH.D.
TSUNG-TEE LI, PH.D.
KRISHNA KUMAR MAHESHWARI, PH.D.
JULIO MENDEZ, PH.D.
JOHN JACOB MUELLER, PH.D.
JEFFREY YICK-PUI MUI, PH.D.
STEPHEN MEARS NAGY, SC.D.
ALEXANDER WILLIAM OXFORD, D.PHIL.
CHARLES ANTHONY PANETTA, PH.D.
PUDENS LEONARD RAGG, PH.D.
RAYMOND ERIC JOHN SEARS, PH.D.
HELMUT ANTON SEIDL, DR.RER.NAT.
CLARA BRINK SHOEMAKER, PH.D.
JON TEWKSBURY STAPLES, PH.D.
TOMOHISA TAKITA, PH.D.

Professors Emeriti

FREDERICK GEORGE KEYES, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus
EARL BOWMAN MILLARD, PH.D.
Professor of Physical Chemistry, Emeritus
WALTER CECIL SCHUMB, PH.D.
Professor of Inorganic Chemistry, Emeritus
LEICESTER FORSYTH HAMILTON, S.B.
Professor of Analytical Chemistry, Emeritus
GEORGE SCATCHARD, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus
JAMES ALEXANDER BEATTIE, PH.D.
Professor of Physical Chemistry, Emeritus
AVERY ADRIAN MORTON, PH.D.
Professor of Organic Chemistry, Emeritus
LOUIS HARRIS, PH.D.
Associate Professor of Physical Chemistry, Emeritus
AVERY ALLEN ASHDOWN, PH.D.
Associate Professor of Organic Chemistry, Emeritus
STEPHEN GERSHOM SIMPSON, PH.D.
Associate Professor of Analytical Chemistry, Emeritus
NICHOLAS ATHANASIUS MILAS, PH.D., D.SC.
Associate Professor of Organic Chemistry, Emeritus
RALPH CHILLINGWORTH YOUNG, PH.D.
Associate Professor of Inorganic Chemistry, Emeritus
CHARLES MONTGOMERY WAREHAM, S.B.
Associate Professor of Inorganic Chemistry, Emeritus

CHEMISTRY

The Department of Chemistry offers an undergraduate Course sufficiently flexible in its electives to provide excellent preparation for careers in many different areas of chemistry, and graduate programs for three advanced degrees. There are excellent opportunities for study and research in analytical, biological, inorganic, nuclear, organic, and physical chemistry and 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 nonprofessional 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 nonprofessional areas.

The Course aims to stimulate and develop the research attitude, and the curriculum includes 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 subjects 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 181*) — *Total units*

Specific science and humanities and social science subjects — **128**

The Science Distribution Requirement will be satisfied by 5.61, which is required in the Departmental Program, plus appropriate subjects (see page 44) totalling — **24**

The subjects 5.412 and 5.422, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.

DEPARTMENTAL PROGRAM

Required Subjects

5.41	ORGANIC CHEMISTRY I	4	0	8
5.412	ORGANIC CHEMISTRY LABORATORY I	1	5	0
5.42	ORGANIC CHEMISTRY II	4	0	8
5.422	ORGANIC CHEMISTRY LABORATORY II	1	5	0
5.61	PHYSICAL CHEMISTRY I	4	0	8
5.613	PHYSICAL CHEMISTRY LABORATORY I	0	4	2
5.62	PHYSICAL CHEMISTRY II	4	0	8
5.623	PHYSICAL CHEMISTRY LABORATORY II	0	4	2
5.63	PHYSICAL CHEMISTRY III	4	0	8
5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	3	0	9
5.14	ANALYTICAL CHEMISTRY	4	4	4
	THESIS[1]		12	
				120

Restricted Electives

A minimum of 52 units must be chosen from:

5.02	CHEMICAL PRINCIPLES II	5	2	5
5.04	PRINCIPLES OF INORGANIC CHEMISTRY II	2	0	4
5.065	ADVANCED INORGANIC CHEMISTRY	3	0	6
5.067	TOPICS IN THEORETICAL INORGANIC CHEMISTRY	2	0	4
5.09	RADIOCHEMISTRY	3	0	6
5.091	RADIOCHEMISTRY LABORATORY	0	3	3
5.092	SPECIAL TOPICS IN NUCLEAR CHEMISTRY	1	0	3
5.15	CHEMICAL APPLICATIONS OF SPECTROSCOPY	1	4	1
5.16	INSTRUMENTAL METHODS OF ANALYSIS	4	4	4
5.192	ELECTROCHEMISTRY	2	0	4
5.193	EQUILIBRIUM AND SEPARATION PROCESSES	3	0	6
5.194	DESIGN AND ANALYSIS OF EXPERIMENTS	2	0	4
5.195	ELECTRONIC AND MASS SPECTROMETRY	3	0	6
5.428	INTRODUCTION TO ORGANIC RESEARCH	2	9	1
5.51	ADVANCED ORGANIC CHEMISTRY: SYNTHESIS	3	0	6
5.53	MOLECULAR STRUCTURE AND REACTIVITY	3	0	6
5.54	PHYSICAL ORGANIC CHEMISTRY	3	0	6
5.55	ORGANIC CHEMISTRY: NATURAL PRODUCTS	3	0	6
5.68	KINETICS OF CHEMICAL REACTIONS	3	0	6
5.70T	INTRODUCTION TO STATISTICAL THERMODYNAMICS	3	0	6
5.71	CHEMICAL THERMODYNAMICS I	2	0	4
5.72	CHEMICAL THERMODYNAMICS II	3	0	6
5.73	INTRODUCTORY QUANTUM MECHANICS I	3	0	6
5.74T	INTRODUCTORY QUANTUM MECHANICS II	3	0	6
5.76	MOLECULAR SPECTRA AND MOLECULAR STRUCTURE	3	0	6
5.77	CHEMICAL CRYSTALLOGRAPHY	3	0	6
5.78	STATISTICAL MECHANICS	3	0	6
5.79	KINETIC THEORY	3	0	6
5.81	MAGNETIC RESONANCE	3	0	6
7.01	GENERAL BIOLOGY	4	0	8
8.03	ELECTRICITY AND MAGNETISM	4	0	8
8.04	MODERN PHYSICS	4	0	8
8.05	PHYSICS OF ATOMS AND MOLECULES I	4	0	8
8.06	PHYSICS OF ATOMS AND MOLECULES II	4	0	8
8.711	MECHANICS I	4	0	8
8.72	ELECTROMAGNETIC RADIATION	4	0	8
18.034	DIFFERENTIAL EQUATIONS	3	0	9
23.11	ELEMENTARY GERMAN	4	0	8
23.12	ELEMENTARY GERMAN	4	0	8
	Additional THESIS not exceeding		18	
				52

Unrestricted Electives[2] — **36**

Total units required for the S.B. degree — **360**

[1] The following subjects should be taken at the indicated time in preparation for the senior thesis in the appropriate field.

Analytical Chemistry: 5.16 — third year, second term.
Inorganic Chemistry: 5.04 — fourth year, first term.
Organic Chemistry: 5.53 — third year, first term; and 5.428 — third year, second term.
Physical Chemistry: 8.03 and 18.034 — prior to fourth year, first term.
Chemical Physics: 8.03 — second year, first term; 8.04 — second year, second term; 8.05 — third year, first term; 8.06 — third year, second term; and 18.034 — prior to fourth year, first term. (5.14, 5.422, and 5.63 will be waived as requirements if these subjects are taken, and 5.613 will be accepted in place of 5.422 to fulfill the Laboratory Requirement.)

[2] Programs of students in Course V may always be arranged to leave available 12 units of unrestricted elective in the first year.

GRADUATE STUDY IN CHEMISTRY

Graduate chemists have a wide choice of careers. They are needed to serve as investigators and to teach and direct investigational work in academic institutions, in industry, in endowed research institutions, and in government bureaus. Industries in particular have come to realize the desirability and even necessity of supporting fundamental scientific investigations relative to their processes, as a basis for their future development.

The Department of Chemistry offers graduate programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science in Chemistry. Details of these programs, which differ according to whether the candidate chooses to specialize in analytical, biological, inorganic and nuclear, organic, or physical chemistry or chemical physics, are recorded below.

Attainment of the Master's degree is not prerequisite to a program of study leading to a doctorate. Master's candidates may, by permission, change to the corresponding doctoral program without loss of credit.

PHYSICAL CHEMISTRY AND CHEMICAL PHYSICS

Graduate subjects cover the fundamentals of thermodynamics, statistical mechanics, kinetic theory, quantum mechanics, and molecular structure. The Minor in mathematics and physics broadens this basis. The research gives intensive specialization in a narrower field and develops experimental technique and ability to carry on independent investigations.

Research in physical chemistry and chemical physics is being carried out in the following fields, and the laboratory is especially well, often uniquely, equipped for such research:

Heat capacities and latent heats at low temperatures.
Properties of gases at low pressures.
Diffusion of gases.
Scattering and other properties of molecular beams.
Reactive collisions in highly excited systems.
Infrared, ultraviolet, and Raman spectroscopy.
Study of crystal structure by X-ray and neutron diffraction.
Study of crystal surfaces and monolayers by low-energy electron diffraction.
Charge and energy transfer processes.
Theory of energy transfer in atomic and molecular collisions.
Nuclear resonance studies of the constitution of molecules and crystals.
Lattice dynamics and low-temperature elastic constants.
Ultrasonic investigation of critical phenomena.
Theory of electronic structure of molecules and solids.
The Mössbauer effect.
Flash photolysis.
Statistical mechanics of equilibrium and transport properties.
Electron spin and quadruple resonance spectroscopy.

ORGANIC CHEMISTRY

Subjects offered in the graduate program aim to develop a sound knowledge of fundamentals and a familiarity with current progress in the most active and important branches of organic chemistry. Each student undertakes a research problem which forms the nucleus of his graduate work, and, through the experience of conducting an experimental investigation leading to the Doctor's or Master's thesis, learns the research attitude and method of approach and acquires training in the specialized techniques of research. Basic graduate subjects give a broad coverage of organic reactions and their application to synthetic and structural problems, theoretical organic chemistry, and biological chemistry.

The principal areas of research under study in the Department include investigations of natural products and physiologically active compounds (structure determination and synthesis of alkaloids, terpenes, steroids, antibiotics, peptides and vitamins); elucidation of the mechanisms of reactions and the relation of structure to reactivity; investigations directed toward the discovery and application of new synthetic methods and investigations of organometallic compounds, peroxides, photochemical transformations, mass spectrometry and model enzyme studies.

INORGANIC AND NUCLEAR CHEMISTRY

Inorganic Chemistry

Opportunities for research in inorganic chemistry, nuclear chemistry, and allied fields of interest have never been more abundant than they are today. In recent years, remarkable advances have been reported in many areas, including the utilization of the less familiar elements such as titanium, rhenium, tantalum, the rare-earth metals, uranium, and the rare gases; the isolation of small quantities of the compounds of other hitherto unknown elements such as technetium (element No. 43) and promethium (element No. 61); and the utilization of certain nonmetallic elements, such as selenium and fluorine.

Inorganic chemistry has two aspects, the preparative and the physico-chemical, which are by no means separate in practice.

In addition to the impetus which has resulted from the increased accessibility to study of new areas of the periodic table, the theoretical or physico-chemical side of inorganic chemistry has been offered challenging new means of attack on basic problems by recent developments of techniques and advances in theory. Infrared and Raman spectroscopy, visible and ultraviolet spectrometry, magnetic studies of various types including nuclear and electron resonance, as well as greatly improved methods for the determination of molecular structures are becoming a part of the inorganic chemist's body of essential techniques.

The contributions of the laboratory, therefore, will be found to include the isolation and study of numerous inorganic compounds, and physical-chemical investigations of the structures, bonding, and reactivities of inorganic compounds. Particular attention is being given to the chemistry of organometallic compounds, to the elaboration of the chemistry of some of the nontransition elements and to physico-chemical and preparative studies of the complexes of transition metals. The initiative of the student in suggesting problems in other areas is encouraged.

Nuclear Chemistry

The Institute's Laboratory for Nuclear Science provides access to outstanding facilities for research in nuclear chemistry, including a cyclotron (30-MeV He^4, 15-MeV d, and 7.5-MeV p)

and computer equipment for data analysis. The M.I.T. Research Reactor also offers excellent opportunities for production of radionuclides for decay-scheme studies or tracer applications. Rapid target-handling facilities at the cyclotron and reactor make possible studies of very short-lived species.

Students in nuclear chemistry may undertake detailed studies of nuclear reactions, fission, and nuclear levels formed in the decay of radioactive species or in direct nuclear reactions. Facilities for these investigations include large multichannel pulse-height analyzers, semiconductor and scintillation detectors, and coincidence counting equipment.

The radiochemical resources are favorable for a variety of studies of chemical properties by tracer methods, including the properties of elements at very low concentrations and the factors to be controlled in the development of new separation methods for constituents of radioactive mixtures. Other studies involve the physical-inorganic principles underlying the chemical problems of nuclear science, the application of radiotracer techniques and of solvent extraction of metal complexes to general chemical problems, and the chemical interaction of cation- and anion-exchange systems.

Investigations in earth sciences with the use of nuclear chemistry techniques, especially neutron activation analysis, are performed in cooperation with members of the Department of Geology and Geophysics.

ANALYTICAL CHEMISTRY

The graduate program provides a broad background in inorganic, physical, and organic chemistry and places emphasis upon both organic and inorganic aspects of analytical chemistry. The subjects stress principles and methods; the thesis aims at providing a varied research experience as well as specialization in a field of limited scope.

Analytical research encompasses a wide span of interests. The laboratory is unusually well-equipped for studies involving modern instrumentation, and both fundamental studies on instrumental methods and the application of these methods to analytical problems are being carried out. Research is currently underway in polarography, electrode kinetics and mechanisms, potentiostatic chromatography, flame and plasma spectroscopy, photometric and thermometric titrations, spectrofluorometry, spectrophotometry and chemistry of excited states. Other areas under active investigation include the analytical chemistry of the fission elements, complexion equilibria, organic functional group analysis, development of instrumental and chemical methods for structure elucidation of alkaloids and peptides, mass spectroscopy of organic molecules, trace metal analysis by fluorescence, chemiluminescence, and electroluminescence.

PLANETARY AND SPACE SCIENCE

A number of research fields in physical, organic, inorganic, and analytical chemistry are related to planetary and space science. These include experimental and theoretical studies of energy transfer in elastic and inelastic collisions; theoretical studies of equilibrium and transport properties of the upper atmosphere; synthesis of organometallic compounds of high thermal stability; and mass spectrometric analyses of non-terrestrial atmospheres.

Entrance Requirements for Graduate Study

The general admission requirements are those set forth in Section 3 of this Catalogue, with the following exceptions and additions:

Mathematics. Doctoral candidates with their Major in analytical, inorganic, or organic chemistry need not present DIFFERENTIAL EQUATIONS (18.034).

Professional Subjects. All candidates for admission to graduate work in this Department must present evidence of achievement in the study of the principles of analytical, inorganic, organic, and physical chemistry.

The Graduate Degrees

MASTER OF SCIENCE IN CHEMISTRY

In addition to the general requirements set forth in Section 3, the candidate must demonstrate by examination to the Department of Modern Languages and Linguistics his ability to read in either German, French, or Russian the scientific literature of his major field.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN CHEMISTRY

For the degree of Doctor of Philosophy or Doctor of Science in a field of chemistry, each candidate must fulfill the requirements listed below.

Candidates for the doctorate in any field of chemistry are encouraged to select a research supervisor during the first term of residence. Since the program of graduate subjects varies according to the candidate's major field of interest, the research supervisor will then be responsible for counselling and the registration of the student for the balance of his graduate program. In the interpretation of the depart-

mental requirements and progress toward the degree the research supervisor will consider the candidate's previous academic record and professional experience, together with his particular aims and objectives and will take a liberal attitude toward substitution of other subjects of equivalent educational and scientific value.

The program must, however, include registration for the minor requirement of at least 24 units of subjects distinct from that of his field of specialization. Candidates majoring in physical chemistry are expected to minor in mathematics or physics.

To complete the language requirement the student must pass written examinations in German and in scientific French or Russian before completing his general examination.

The comprehensive oral examination in the candidate's major field of advanced study should be taken during the third term of residence.

A series of one-hour written major examinations will be scheduled each term. The level of these examinations will correspond to the departmental graduate subjects but will not be based specifically on these subjects. The satisfactory completion of six written major examinations is required. At least three must be in the candidate's field of specialization and the remaining three may be in his or any of the fields of chemistry. Examinations will be scheduled in the various specialized areas of chemistry. No other written comprehensive examination is required. The grades on the major examinations are not entered on the student's permanent record.

The thesis must be an original research of high grade on a topic relevant to an advanced course of study. A final oral examination on the thesis is required after the thesis has been submitted and tentatively evaluated by the examiners.

Each candidate pursues a program of graduate subjects which varies according to his field of advanced study but which ordinarily includes the following subjects:

Analytical Chemistry

5.192, 5.193, 5.194, 5.195, 5.53, 5.71, and during each year of residence 5.915, 5.916, 5.951, and 5.952.

Inorganic and Nuclear Chemistry

5.065, 5.067, 5.09, 5.091, 5.092, 5.71, and additional subjects, such as X-RAYS AND CRYSTAL PHYSICS, NUCLEAR PHYSICS, X-RAY CRYSTALLOGRAPHY, and during each year of residence 5.941 and 5.942.

Organic Chemistry

5.51, 5.53, 5.54, 5.55, and during each year of residence 5.913 and 5.914.

Physical Chemistry

5.70T, 5.73, and any two subjects in advanced physical chemistry or chemical physics; and during each year of residence 5.931 and 5.932.

Inquiries should be addressed to the Chairman of the Department Committee on Graduate Students.

Teaching Assistants

The Department appoints a number of teaching assistants who are candidates for the degree of Doctor of Philosophy or Doctor of Science in Chemistry. Teaching assistants serve in the laboratories of the Department and may be asked to conduct recitation sections on a regular part-time schedule throughout the academic year. Inquiries about appointments should be addressed to the Head of the Department.

Department of Geology and Geophysics

FRANK PRESS, PH.D.
Professor of Geophysics; Head of the Department
MARTIN JULIAN BUERGER, PH.D.
Institute Professor; Professor of Mineralogy and Crystallography
ROBERT RAKES SHROCK, PH.D.
Professor of Geology
FRANCIS BITTER, PH.D.
Professor of Geophysics
PATRICK MASON HURLEY, PH.D.
Professor of Geology
HAROLD WILLIAMS FAIRBAIRN, PH.D.
Professor of Geology
WILLIAM STELLING VON ARX, SC.D.
Professor of Physical Oceanography
RAYMOND HIDE, PH.D.
Professor of Geophysics and Physics
DAYTON ERNEST CARRITT, PH.D.
Professor of Chemical Oceanography
JOHN BRACKETT HERSEY, PH.D. (*Absent*)
Professor of Oceanography
M. GENE SIMMONS, PH.D.
Professor of Geophysics
KEIITI AKI, PH.D.
Professor of Geophysics
WILLIAM FRANCIS BRACE, PH.D.
Professor of Geology
W. BARCLAY KAMB, PH.D.
Professor of Geology (Visiting)
ELY MENCHER, PH.D.
Associate Professor of Geology
WILLIAM HENRY DENNEN, PH.D.
Associate Professor of Geology
WILLIAM HAMET PINSON, JR., PH.D.
Associate Professor of Geology
JOHN WILLIS KANWISHER, PH.D.
Associate Professor of Oceanography
THEODORE RICHARD MADDEN, PH.D.
Associate Professor of Geophysics
ANTHONY FRANK GANGI, PH.D.
Associate Professor of Geophysics
DAVID ROBERT WONES, PH.D. (*Absent*)
Associate Professor of Geology
GIORGIO FIOCCO, DR.ING.
Assistant Professor of Geophysics
LEE WALLACE DEAN, III, PH.D.
Assistant Professor of Geophysics
WILLIAM CLAIR LUTH, PH.D.
Assistant Professor of Geochemistry
DAVID WILLIAM STRANGWAY, PH.D.
Assistant Professor of Geophysics
MEHMET NAFI TOKSÖZ, PH.D.
Assistant Professor of Geophysics
SHAWN BIEHLER, PH.D.
Assistant Professor of Geophysics
FREDERICK AUGUST FREY, PH.D.
Assistant Professor of Geochemistry
THOMAS FERRIS WEBSTER, PH.D.
Assistant Professor of Oceanography

Instructor

THOMAS BAYES SANFORD, B.S.

Administrative Assistant

HENRY ADAMS MORSS, JR., PH.D.

Research Associates

JAMES DOUGLAS BYERLEE, PH.D.
KI-ITI HORAI, SC.D.
MASANORI SAITO, PH.D.
JOSEPH BROUGHTON WALSH, PH.D.
JOEL S. WATKINS, PH.D.
RALPH AMBROSE WIGGINS, PH.D.
CHARLES GODDARD WING, PH.D.

Professors Emeriti

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 are not only 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. Both programs lead to the degree of Bachelor of Science in Earth Sciences.

1. GEOLOGY AND GEOCHEMISTRY PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 181*)		
	Specific science and humanities and social science subjects.	**128**
	The subjects 8.03, 12.231, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 44) and can be used to satisfy the Science Distribution Requirement.	
	Laboratory Requirement[1] (see page 45).	**12**

DEPARTMENTAL PROGRAM

	Required Subjects				
5.61	PHYSICAL CHEMISTRY I	4	0	8	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
12.231	PHYSICAL GEOLOGY	3	4	5	
12.223	CRYSTALLOGRAPHY	2	2	2	
12.232T	HISTORICAL GEOLOGY	4	4	4	
12.224	THEORETICAL MINERALOGY	2	0	4	
12.221T	LABORATORY IN MINERALS AND ROCKS	1	6	0	
12.241	PETROLOGY I	2	4	2	
12.242	PETROLOGY II	2	6	4	
12.271	STRUCTURAL GEOLOGY	3	3	6	
					111
	Restricted Electives				
	Electives are to be chosen by the student in consultation with his adviser. These may include basic science subjects more advanced than the General Institute Requirements in physics, mathematics, or chemistry, as well as 12.352, 12.701, or subjects in electrical engineering and mechanics of solids.				**54**
	Unrestricted Electives[2]				**79**
	Total units required for the S.B. degree				**384**

[1] Upon successful completion of a course of study at a regularly established field camp, students may petition for 24 units of academic credit, of which 12 units will be accepted as completing the Laboratory Requirement plus 12 units of elective credit.

[2] Programs of students in Course XII, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the first year and 24 units 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 AND PLANETARY GEOPHYSICS PROGRAM CURRICULUM

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 181*)				
	Specific science and humanities and social science subjects.			128
	The Science Distribution Requirement will be satisfied by 8.03 and 18.034 which are required in the Departmental Program, plus appropriate subjects (see page 44) totalling			12
	Laboratory Requirement (see page 45)			12
DEPARTMENTAL PROGRAM				
	Required Subjects			
8.03	ELECTRICITY AND MAGNETISM	4	0	8
8.04	MODERN PHYSICS	4	0	8
8.05	PHYSICS OF ATOMS AND MOLECULES I	4	0	8
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8
8.711	MECHANICS I	4	0	8
8.72	ELECTROMAGNETIC RADIATION	4	0	8
18.034	DIFFERENTIAL EQUATIONS	3	0	9
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9
				96
	Restricted Electives			
8.06	[1]PHYSICS OF ATOMS AND MOLECULES II *or*	4	0	8
8.08	ELECTRONICS			
				12
	Electives are chosen by the student in consultation with his adviser. They must include continuum mechanics; electives in astronomy, astro-physics, and earth and planetary science, and laboratory and/or field work.[2]			88
	Unrestricted Electives[3]			36
Total units required for the S.B. degree				384

[1] Students may take both 8.06 and 8.08 and include other subjects in their elective program.

[2] Laboratory and field experience should be obtained following the adviser's recommendations regarding field work, oceanographic studies and a thesis.

[3] Programs of students in Course XII, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the first year.

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.

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 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

In cooperation with the Department of Meteorology and the Woods Hole Oceanographic Institution, a program in oceanography is now being offered. The oceans, the atmosphere, and the solid earth are so intimately related that they must often be studied together as parts of a single system. Certain subjects of instruction in geology and in meteorology are directly applicable to oceanographic problems. Several staff members of the Woods Hole Oceanographic Institution now hold part-time faculty appointments at M.I.T. in the two cooperating departments. These oceanographers offer formal lecture subjects and are also available by appropriate arrangement for individual consultation and for thesis advising. In some cases properly qualified M.I.T. graduate students may be permitted to use the excellent facilities for oceanographic research at Woods Hole.

The program in oceanography is under the direct guidance of an interdepartmental committee representing both the Departments of Geology and Geophysics and of Meteorology; it leads to the degree of Master of Science or Doctor of Philosophy or Doctor of Science in Oceanography.

Entrance Requirements for Graduate Study

The general admission requirements are those given in Section 3 of this Catalogue.

In addition, the Department requires preparation essentially equivalent to the program of subjects leading to the degree of Bachelor of Science in Earth Sciences at the Institute. If the student is not fully prepared in certain of the required subjects, he usually will be asked to extend his preparation in these while he pursues his advanced work. The subjects to be taken for this purpose will be 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 advisers, to whom he is assigned at the time he first registers and who will generally direct the major part of his program.

The Graduate Degrees

MASTER OF SCIENCE IN GEOLOGY AND GEOPHYSICS OR MASTER OF SCIENCE IN OCEANOGRAPHY

In addition to the general and departmental requirements stated in the preceding paragraphs, the candidate for the degree of Master of Science in Geology and Geophysics or in Oceanography is required to pursue a program of advanced study and research in an area approved by his faculty advisers. Possible fields of specialization are specified above.

THE DOCTORATES

The general requirements for the degrees of Doctor of Philosophy or Doctor of Science are given in Section 3. Possible fields of specialization are indicated above. Departmental requirements for graduate work leading to these degrees are given in the following paragraphs.

The preparation and research ability of any candidate for the doctorate must be such as to satisfy the Department Committee on Graduate Students that he is qualified to undertake advanced study and research. The thesis is expected to be a publishable contribution in the field of the candidate's specialization.

Soon after the student registers in the Department as a doctoral candidate, he will be required to take a qualifying examination, which may be partly oral and partly written; this examination is intended to survey his training and attainments and to serve as a basis for certifying him for a Doctor's program.

The program of graduate work may, with the approval of 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

WILLIAM TED MARTIN, PH.D.
Professor of Mathematics; Head of the Department

RICHARD DONALD SCHAFER, PH.D.
Professor of Mathematics; Deputy Head of the Department

NORMAN LEVINSON, SC.D.
Professor of Mathematics

ERIC REISSNER, DR. ING., PH.D. (*Absent*)
Professor of Applied Mathematics

CHIA-CHIAO LIN, PH.D.
Institute Professor; Professor of Applied Mathematics

CLAUDE ELWOOD SHANNON, PH.D.
Donner Professor of Science

WARREN AMBROSE, PH.D.
Professor of Mathematics

GEORGE WILLIAM WHITEHEAD, PH.D.
Professor of Mathematics

KENKICHI IWASAWA, DR.SCI. (*Absent*)
Professor of Mathematics

ISADORE MANUAL SINGER, PH.D.
Professor of Mathematics

IRVING EZRA SEGAL, PH.D.
Professor of Mathematics

GEORGE BRINTON THOMAS, JR., PH.D.
Professor of Mathematics

BERTRAM KOSTANT, PH.D.
Professor of Mathematics

DANIEL MARINUS KAN, PH.D.
Professor of Mathematics

NESMITH CORNETT ANKENY, PH.D. (*Absent*)
Professor of Mathematics

HARVEY PHILIP GREENSPAN, PH.D.
Professor of Applied Mathematics

KENNETH MYRON HOFFMAN, PH.D.
Professor of Mathematics

LOUIS NORBERG HOWARD, PH.D.
Professor of Mathematics

DANIEL BURRILL RAY, PH.D.
Professor of Mathematics

HARTLEY ROGERS, JR., PH.D.
Professor of Mathematics

SIGURDUR HELGASON, PH.D.
Professor of Mathematics

ARTHUR PAUL MATTUCK, PH.D.
Professor of Mathematics

FRANKLIN PAUL PETERSON, PH.D.
Professor of Mathematics

MICHAEL ARTIN, PH.D.
Professor of Mathematics

DAVID JOHN BENNEY, PH.D.
Professor of Applied Mathematics

JAMES GILBERT GLIMM, PH.D.
Professor of Mathematics

JAMES RAYMOND MUNKRES, PH.D.
Professor of Mathematics

LESLIE COLIN WOODS, PH.D.
Professor of Mathematics (Visiting)

PRESCOTT DURAND CROUT, PH.D.
Associate Professor of Mathematics

GEORGE PROCTOR WADSWORTH, PH.D.
Associate Professor of Mathematics

FRANCIS BEGNAUD HILDEBRAND, PH.D.
Associate Professor of Mathematics

WILLIAM GILBERT STRANG, PH.D. (*Absent*)
Associate Professor of Mathematics

CHRISTOPHER HUNTER, PH.D.
Associate Professor of Mathematics

ALAR TOOMRE, PH.D.
Associate Professor of Mathematics

DANIEL J. KLEITMAN, PH.D.
Associate Professor of Mathematics

TAKESHI KOTAKE, DR.SCI.
Associate Professor of Mathematics

CHING-SHENG WU, PH.D.
Associate Professor of Mathematics (Visiting)

CARLO CERCIGNANI, PH.D.
Associate Professor of Mathematics (Visiting)

GERALD ENOCH SACKS
Associate Professor of Mathematics (Visiting)

RICHARD MANSFIELD DUDLEY, PH.D.
Associate Professor of Mathematics

EDWARD BALDWIN CURTIS, PH.D.
Assistant Professor of Mathematics

JOSEPH PEDLOSKY, PH.D.
Assistant Professor of Mathematics

DONALD WERNER ANDERSON, PH.D.
Assistant Professor of Mathematics

MANUEL BLUM, PH.D.
Assistant Professor of Mathematics

HUNG CHENG, PH.D.
Assistant Professor of Mathematics

BERNARD MASKIT, PH.D.
Assistant Professor of Mathematics

DANIEL GRAY QUILLEN, PH.D.
Assistant Professor of Mathematics

VICTOR BARCILON, PH.D.
Assistant Professor of Mathematics
NORMAN BLEISTEIN, PH.D.
Assistant Professor of Mathematics
ROE WILLIAM GOODMAN, PH.D.
Assistant Professor of Mathematics
VICTOR WILLIAM GUILLEMIN, PH.D.
Assistant Professor of Mathematics

Lecturer
JOHN HOWARD SMITH, PH.D.

C. L. E. Moore Instructors
EGBERT BRIESKORN, DR.RER.NAT.
ANTHONY WILLIAM KNAPP, PH.D.
RICHARD GUSTAVUS LARSON, PH.D.
JOHANNES MICHAEL AARTS, PH.D.
JOHN BRADY GARNETT, PH.D.
IRWIN KRA, PH.D.
HENRY BEN LAUFER, PH.D.
KEVIN MOR MCCRIMMON, PH.D.
RICHARD ALAN PLATEK, PH.D.

Instructors
THOMAS JOSEPH LARDNER, PH.D.
HARRY PRINCE ALLEN, PH.D.
THOMAS FULCHER BICKEL, PH.D.
THOMAS BLOOM, PH.D.
DAVID PAUL KRAINES, PH.D.
ALFRED BERRY MANASTER, PH.D.
STEPHEN KINSLEY PARROTT, PH.D.
ANDREW KAGEY SNYDER, PH.D.
MOSS EISENBERG SWEEDLER, PH.D.
LESLIE HOWARD THARP, PH.D.
FREDERIC YUI-MING WAN, PH.D.
HERBERT LOUIS WILLKE, JR., PH.D.
PHILIP OTTO KOCH, S.B.
VOLKER THOMAS PUPPE, PH.D.
DONALD RAYL WILKEN, PH.D.

Research Associates
WILLIAM GUIGNARD FARIS, PH.D.
JOHN FORBES NASH, PH.D.

Professors Emeriti
HENRY BAYARD PHILLIPS, PH.D., LL.D.
Professor of Mathematics, Emeritus
RAYMOND DONALD DOUGLASS, PH.D., SC.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 181*)

	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 44) totalling	24
	Laboratory Requirement (see page 45)	12

DEPARTMENTAL PROGRAM

	Required Subjects		
18.034	DIFFERENTIAL EQUATIONS	3 0 9	
18.21T	ANALYSIS	3 0 9	
	[1]LANGUAGE	4 0 8	
			36
	Restricted Electives		
	An integrated program of advanced mathematics subjects at the undergraduate or graduate level, including the following at least		60
	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	
	Either		
18.22T	ANALYSIS	3 0 9	
	or		
18.31	THEORY OF FUNCTIONS	3 0 9	
	or		
18.49	HARMONIC ANALYSIS AND POTENTIAL THEORY	3 0 9	
	Either		
18.24	ELEMENTARY DIFFERENTIAL GEOMETRY	3 0 9	
	or the following combination:		
18.241	INTRODUCTION TO TOPOLOGY *and*	3 0 9	
18.242	RIEMANNIAN GEOMETRY	3 0 9	
	Senior seminar in mathematics, thesis, or advanced mathematics subject at the undergraduate or graduate level		12
	Advanced professional subjects in the Schools of Science or Engineering at the undergraduate or graduate level, at least		24
		at least	96
	Unrestricted Electives[2]	up to	64
Total units required for the S.B. degree			360

CURRICULUM OF MATHEMATICS PROGRAM 2 — *Total units*

GENERAL INSTITUTE REQUIREMENTS (*see page 181*)

	Specific science and humanities and social science subjects	128
	The Science Distribution Requirement will be satisfied by 8.03 and 18.034, which are required in the Departmental Program, plus appropriate subjects (see page 44) totalling	12
	Laboratory Requirement (see page 45)	12

DEPARTMENTAL PROGRAM

	Required Subjects		
8.03	ELECTRICITY AND MAGNETISM	4 0 8	
18.034	DIFFERENTIAL EQUATIONS	3 0 9	
18.21T	ANALYSIS	3 0 9	
18.651	INTRODUCTION TO APPLIED MATHEMATICS	3 0 9	
	[1]LANGUAGE	4 0 8	
			60
	Restricted Electives		
	An integrated program of advanced mathematics subjects at the undergraduate or graduate level, including the following, at least		48
	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	
	Either		
18.22T	ANALYSIS *or*	3 0 9	
18.652	INTRODUCTION TO APPLIED MATHEMATICS	3 0 9	
	Either		
18.60	INTRODUCTION TO FLUID MECHANICS *or*	3 0 9	
18.66	INTRODUCTION TO ELASTICITY	3 0 9	
	Senior seminar in mathematics, thesis, or advanced mathematics subject at the undergraduate or graduate level		12
	Advanced professional subjects in the Schools of Science or Engineering at the undergraduate or graduate level, at least		24
		at least	84
	Unrestricted Electives[2]	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.

[2] Programs of students in Course XVIII may always be arranged to leave available 12 units of unrestricted elective in the first year.

Transfer from one program to the other may be made at any time. In either program the minimum algebra requirement is the one-semester subject LINEAR ALGEBRA (18.20), but students wishing more work in algebra as undergraduates should take the two-semester subject sequence in MODERN ALGEBRA (18.25, 18.26). For students following Program 1, the minimum requirement in geometry is the one-semester subject ELEMENTARY DIFFERENTIAL GEOMETRY (18.24), but students wishing more work in geometry should take instead the two one-semester 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 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)
MECHANICS I (8.711)

GRADUATE STUDY IN MATHEMATICS

On the graduate level, the Department offers programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science in Mathematics.

Students may select their programs from a broad range of subjects, descriptions of which appear elsewhere in this Catalogue. Numerous informal seminars supplement the basic program. There are also a weekly Mathematics Colloquium sponsored by M.I.T., Brandeis, and Harvard and a weekly Colloquium on Applied Mathematics and Mechanics, each of which brings guest lecturers from other institutions.

Candidates whose primary interest is in the field of pure mathematics will ordinarily take most of their subjects in the Mathematics Department. In addition to their advanced specialization, they will be encouraged to acquire breadth by taking basic subjects in analysis, algebra, geometry, and topology.

Candidates 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.

The Graduate Degrees

MASTER OF SCIENCE IN MATHEMATICS

For the Master's degree, a student must take not less than 72 units including four 12-unit graduate ("A") subjects offered by the Department as well as submitting an acceptable thesis. In addition, either as an undergraduate or as a graduate student, each student is expected to have completed four subjects (or their equivalents) from the following group:

METHODS OF APPLIED MATHEMATICS FOR ENGINEERS (18.15)
PROBABILITY (18.18)
LINEAR ALGEBRA (18.20)
or
MODERN ALGEBRA (18.26)
ANALYSIS (18.21T, 18.22T)
ELEMENTARY DIFFERENTIAL GEOMETRY (18.24)
or
RIEMANNIAN GEOMETRY (18.242)
INTRODUCTION TO TOPOLOGY (18.241)
MODERN ALGEBRA (18.25)
INTRODUCTION TO FUNCTIONS OF A COMPLEX VARIABLE (18.27, 18.28)
INTERMEDIATE DIFFERENTIAL EQUATIONS (18.29)
INTRODUCTION TO FLUID MECHANICS (18.60)
INTRODUCTION TO APPLIED MATHEMATICS (18.651, 18.652)
INTRODUCTION TO ELASTICITY (18.66)

Of the four subjects elected from this group, two may be counted for credit towards the Master's degree if taken while the student is a graduate student at M.I.T.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN MATHEMATICS

The general requirements for the Doctor of Philosophy and Doctor of Science degrees are those set forth in Section 3. As soon as possible after beginning graduate work, each student who plans to take a doctorate in mathematics should elect one of the following two plans of study:

Plan A, Qualifying Examination. A written qualifying examination on topics in algebra (primarily linear algebra), intermediate real analysis (based on a syllabus comparable to the current 18.21T–18.22T) 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 evi-

dence 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, General Examination. A written examination consisting of two parts; the first on Methods of Applied Mathematics (based on 18.653–18.654), and the second on application to physical subjects (based on 18.651–18.652, 18.60, and 18.66–18.67). The examination will be held in February, and students should apply at the Graduate Office by December 15 to take it, usually in their second graduate year. This written examination, together with an oral examination to be arranged with a prospective thesis supervisor selected by the student, constitutes the general examination under Plan B. The requirement of a written examination may be waived by petitioning the Departmental Graduate Committee; approval requires that the student's grades and general academic performance show proficiency in the methods of applied mathematics and in their application to specific physical subjects. The prospective thesis supervisor may also require further evidence of the candidate's readiness to perform research work.

It is expected that students planning to do doctoral theses in elasticity, fluid dynamics, and related fields will in most cases elect to follow Plan B.

Students in both Plan A and Plan B will take additional subjects, chosen in consultation with an adviser, from the Department's 12-unit graduate ("A") subjects other than those included in the qualifying examination.

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.

The Minor program may be in any field, including mathematics, in which the Institute offers advanced work. It should be started early in the student's graduate career.

Doctoral candidates are required to demonstrate proficiency in two foreign languages, which are usually chosen from French, German, and Russian. The language requirements should also be fulfilled early in the student's program.

Before the student begins work on his thesis, he is asked to submit to the Departmental Graduate Committee a brief general outline on the proposed thesis, carrying the approval of the faculty member who is his thesis adviser. When the Committee has approved the thesis proposal, the Department names two faculty members to work with the student and his adviser. The thesis is expected to represent original research and to meet the standards ordinarily required for publication in one of the standard journals devoted to research in mathematics or in a closely allied field.

Fellowships and Assistantships

Fellowships and teaching and research assistantships are available to graduate students in mathematics. Detailed information about these opportunities may be obtained from the Department.

Department of Meteorology

HENRY GARRETT HOUGHTON, SC.D.
Professor of Meteorology; Head of the Department
HURD CURTIS WILLETT, PH.D.
Professor of Meteorology
JULE GREGORY CHARNEY, PH.D.
Alfred P. Sloan Professor of Meteorology
VICTOR PAUL STARR, PH.D.
Professor of Meteorology
HENRY MELSON STOMMEL, PH.D.
Professor of Oceanography
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
JAMES MURDOCH AUSTIN, SC.D.
Associate Professor of Meteorology; Director of the Summer Session
DELBAR POULEUR KEILY, S.B.
Associate Professor of Meteorology
FREDERICK SANDERS, SC.D.
Associate Professor of Meteorology
REGINALD EDWARD NEWELL, SC.D.
Associate Professor of Meteorology

Technical Instructor
GARDNER PERRY, III, S.B.

Senior Research Associates
PAULINE MORROW AUSTIN, PH.D., SC.D.
ALAN COGSWELL BEMIS, A.B., S.M.

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:

19.14	LONG-RANGE WEATHER 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 II
19.64	DYNAMIC METEOROLOGY II
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, I.B.M. card equipment, and the high-speed computing facilities of the Computation Center.

The Meteorological Instrumentation Laboratory contains standard and specialized instrumentation and special test equipment. Laboratory facilities are available for research in physical meteorology, especially in the fields of cloud and precipitation physics. The Fluid Dynamics Laboratory contains apparatus that models atmospheric and oceanic circulations. When appropriate, arrangements can usually be made to enable qualified students to make use of the excellent research facilities at the Woods Hole Oceanographic Institution.

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, the Blue Hill Meteorological Observatory of Harvard University, and the Boston offices of the United States Weather Bureau. Close contact with the scientific personnel of these institutions is maintained through joint seminars and symposia as well as by more informal means.

OCEANOGRAPHY

In cooperation with the Department of Geology and Geophysics and the Woods Hole Oceanographic Institution, a graduate program in oceanography is now being offered. The equations that describe the motions of the atmosphere are the same as those for the oceans. The oceans and the atmosphere are closely coupled both mechanically and thermally so that they must often be considered as parts of a single system. Many of the subjects of instruction in meteorology are thus directly applicable to oceanography. Subjects in oceanography are now offered and more are planned. Certain subjects given by the Department of Geology and Geophysics are also directly applicable to the geological aspects of oceanography. Several staff members of the Woods Hole Oceanographic Institution hold part-time faculty appointments at M.I.T. They give formal subjects and are also available for individual consultation and serve as thesis advisers. Arrangements may often be made for M.I.T. graduate students to use the excellent facilities for oceanographic research at Woods Hole.

Entrance Requirements for Graduate Study

Although an undergraduate program of the type described above is considered the best preparation for graduate study, it is not required; graduates of recognized institutions who present evidence of sound preparation in physics and mathematics and who meet the general requirements for admission to the Graduate School (see Section 3 of this Catalogue) may be admitted. However, training substantially equivalent to that provided by SYNOPTIC METEOROLOGY I (19.43) and INTRODUCTION TO THEORETICAL METEOROLOGY (19.601) will make it possible for students to pursue a more advanced program of studies immediately after admission. Applicants with no previous training in meteorology will generally be required to take these subjects during their graduate study and therefore must expect to be in residence for a somewhat longer period.

The advanced subjects offered by the Department lead to the degrees of Master of Science in Meteorology, Master of Science in Oceanography, Doctor of Philosophy in Meteorology, Doctor of Philosophy in Oceanography, Doctor of Science in Meteorology, and Doctor of Science in Oceanography.

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 IN METEOROLOGY OR OCEANOGRAPHY

The general requirements for the degrees of Doctor of Science and Doctor of Philosophy are given in Section 3. Candidates for the doctorate in meteorology or in oceanography are required to demonstrate their ability to read scientific literature in English and in two other modern languages, one of which must be German or Russian. The second language must be one in which there is important meteorological or oceanographic literature. Among others, German or Russian (if not chosen as the first language), French, Norwegian, Swedish, Spanish, and Japanese satisfy this requirement. Alternatively, the language requirement may be satisfied by demonstrating substantial competence in speaking and reading either German or Russian.

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; Executive Officer
ROBERT SAMUEL HARRIS, PH.D.
Professor of Nutritional Biochemistry
SEYMOUR J. GRAY, PH.D., M.D.
Professor of Clinical Nutrition (Visiting)
LEO FRIEDMAN, PH.D.
Professor of Nutrition and Food Safety
PAUL MEDFORD NEWBERNE, D.V.M., PH.D.
Professor of Nutritional Pathology
HAMISH NISBET MUNRO, M.D., D.SC.
General Foods Professor of Physiological Chemistry
JOHN BRUTON STANBURY, M.D.
Professor of Experimental Medicine
JOHN THEODORE ROOSEVELT NICKERSON, PH.D.
Professor of Food Technology
CECIL GORDON DUNN, PH.D.
Associate Professor of Industrial Microbiology
GEORGE WOLF, D.PHIL.
Associate Professor of Physiological Chemistry
ABRAHAM DANIEL RUBENSTEIN, M.D.
Associate Professor of Epidemiology (Visiting)
EMILY LIPPINCOTT WICK, PH.D.
Associate Professor of Food Chemistry; Associate Dean of Student Affairs
MARCUS KAREL, PH.D.
Associate Professor of Food Engineering
SANFORD ARTHUR MILLER, PH.D.
Associate Professor of Nutritional Biochemistry
GERALD NORMAN WOGAN, PH.D.
Associate Professor of Food Toxicology
ZEKI BERK, PH.D.
Associate Professor of Food Engineering (Visiting)
LESLIE J. DEGROOT, M.D.
Associate Professor of Experimental Medicine
RICHARD ISAAC MATELES, SC.D.
Associate Professor of Biochemical Engineering
JUAN MARCELO NAVIA, PH.D.
Associate Professor of Nutritional Biochemistry
RICHARD J. WURTMAN, M.D.
Associate Professor of Metabolism and Endocrinology
JANIS Z. GABLIKS, PH.D.
Assistant Professor of Cell Biology
PHILLIP ISSENBERG, PH.D.
Assistant Professor of Food Science
GERALD SILVERMAN, PH.D.
Assistant Professor of Food Microbiology
STEVEN ROBERT TANNENBAUM, PH.D.
Assistant Professor of Food Science
SAMUEL ISSAC SHIBKO, PH.D.
Assistant Professor of Nutrition and Food Safety
DANIEL I. C. WANG, PH.D.
Assistant Professor of Biochemical Engineering
BOBBY JOE PAYNE, PH.D.
Assistant Professor of Pathology
VERNON ROBERT YOUNG, PH.D.
Assistant Professor of Physiological Chemistry
JAMES WALLACE DRYSDALE, PH.D.
Assistant Professor of Physiological Chemistry
THEODORE PETER LABUZA, PH.D.
Assistant Professor of Food Engineering
EDWIN D. BRANSOME, M.D.
Assistant Professor of Metabolism and Endocrinology

Administrative Officer

JOHN PAUL KARLE, B.S., M.A.

Senior Lecturer

JOHN EVERETT GORDON, PH.D., M.D.

Lecturers

AARON M. ALTSCHUL, PH.D. (*Visiting*)
GUILLERMO ARROYAVE, PH.D. (*Visiting*)
MOISES BEHAR, M.D. (*Visiting*)
DAVID BAIRD COURSIN, M.D. (*Visiting*)
CHARLEY ELMER GILMORE, D.V.M.
RONALD DUNCAN HUNT, D.V.M.
HARRY LEWIS JACOBS, PH.D. (*Visiting*)
ARNOLD JOHN LEHMAN, PH.D., M.D. (*Visiting*)
CHARLES MERRITT, JR., PH.D. (*Visiting*)
H. A. B. PARPIA, PH.D. (*Visiting*)

Research Associates

BANTVAL SURENDRA BALIGA, PH.D.
LEROY D. CAGNONE, D.D.S.
JOHN B. DAS, M.D.
LUIGI DE LUCA, PH.D.
JOHN EVERETT HARRIS, PH.D.
CHARLES E. HUNT, D.V.M.
MADHUKAR G. KARMARKAR, PH.D.
WALTER J. LOESCHE, D.M.D.
THOMAS J. MOORE, M.D.
JOAQUIN MOURIZ, M.D.
ABRAHAM EDWARD NIZEL, D.M.D., M.S.D.
YUCHIO OCHI, M.D.
ADRIANNE ELLEFSON ROGERS, M.D.
WARREN IRA SCHAEFFER, PH.D.
MICHA THEINER, PH.D.

NUTRITION AND FOOD SCIENCE

It is only during this century that nutrition and food science have evolved as relatively independent sciences. Originating in chemistry, physics, physiology, biochemistry, microbiology, and engineering, they are today integrated sciences serving as focal points for developments in many disciplines. Developments in nutrition and in food science, in turn, have both fundamental and practical implications in other biological and physical sciences; in medicine, dentistry, engineering, and agriculture; and in industry.

Problems associated with the increasing world population and with the rapid application of scientific and technological discoveries by 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 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 foods and nutrition and for ways of applying such information for human welfare. 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: research in government, private and industrial laboratories; product and process development in the food and related industries; work with international agencies; and university teaching and research.

UNDERGRADUATE SPECIALIZATION IN NUTRITION AND FOOD SCIENCE

Although this Department does not offer an undergraduate curriculum, the opportunity for specialization in nutrition or food science is offered within the curriculum in Life Sciences (Course VII, Program 3). This curriculum (described on page 184) emphasizes fundamental subjects in the physical and biological sciences. These, together with the subjects prescribed under the General Institute Requirements (page 181), provide the undergraduate student with a broad background in the basic sciences essential for an understanding of nutrition and food science. Introductory subjects in nutrition and in food science are taken during the senior year and, although most of the specialized training in these fields must be obtained at the graduate level, selection from among elective subjects allows an opportunity for limited specialization, depending upon the student's interest and anticipated career.

GRADUATE STUDY (COURSE XX)

The Department of Nutrition and Food Science offers advanced programs leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Nutrition, in Food Science and Technology, and in Biochemical Engineering.

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 control. 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.

NUTRITION

Research in nutrition and physiological chemistry emphasizes the use of nutritional, environmental, and endocrine variations in the study of metabolic processes in man and in various laboratory animals. Current research projects include: biochemical, morphological and physiological effects of malnutrition; 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; protein digestion and biological availability of amino acids in foods; utilization and metabolism of synthetic compounds as energy sources; functions of vitamins A and E; metabolism of amino acids and related compounds; 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.

FOOD SCIENCE

Research in food toxicology, food chemistry, and flavor chemistry is concerned with the occurrence of toxic substances in foods, composition of foods, and components contributing to the organoleptic properties of foods. Current research projects include isolation and identification of fat soluble toxic compounds and toxic compounds produced by molds; biochemical and physiologic effects of other potential toxic substances found in foods, effects of processing on the nutritive value of foods; isolation and identification of the components contributing to the flavor of various foods; and sensory 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 radiations on foods and on microorganisms; factors influencing storage-stability of frozen, dehydrated and freeze-dehydrated foods; rheology of foods and its relation to heat transfer and flow characteristics; stress and strain characteristics of foods during drying; ecological factors affecting the growth of microorganisms of public health significance; factors causing deterioration of processed foods; viability and mutation of microorganisms under conditions of outer space.

In biochemical engineering and industrial microbiology current research projects include continuous culture of microorganisms; microbial synthesis of amino acids; anaerobic growth of microorganisms; dynamics of microbial growth, computer simulation of microbial systems; continuous centrifugation; and automatic control of nutrient concentration.

SPECIAL PROGRAMS

Veterinary Pathology and Physiological Chemistry

A program is offered for veterinary graduates wishing to obtain a doctorate in animal pathology and physiological chemistry. This program satisfies a part of the requirements for the Board examinations of the American College of Veterinary Pathology. Special fellowships are available.

Food Control 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.

Food Toxicology

A program of training in food toxicology is offered for those qualified for admission as candidates for a degree in either nutrition or in food science and technology. This research area is concerned with the occurrence of toxic substances in food and with problems of evaluating the potential hazard to man of foods produced by new processes; with the use of toxic substances such as herbicides, insecticides, growth-promoting chemicals, preservatives, and new packaging materials; or made from new sources of food not previously used for human consumption. Research on new approaches to evaluating the wholesomeness and safety of foods and food components is directed toward understanding the mechanism of action involved and providing means of predicting potential hazard.

Oral Science

Research in disorders of the teeth and soft tissues of the mouth requires a thorough knowl-

edge 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.

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 or Doctor of Philosophy in Nutrition. 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.

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 NUTRITION; 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 Nutrition 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 Nutrition, 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 microorganisms, chemical engineering, or industrial management, again depending on the individual student's interests.

DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE IN NUTRITION; DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY

The choice of subjects in programs for the degree of Doctor of Philosophy or Doctor of Science in Nutrition and for the degree of Doctor of Philosophy or Doctor of Science in Food Science and Technology depends on each student's background, his aptitudes, and his future plans. 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.

DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE IN BIOCHEMICAL ENGINEERING

No rigid sequence of graduate subjects is specified for the degree of Doctor of Philosophy or Doctor of Science in Biochemical Engineering. Advanced studies are recommended in the fields of biochemistry, microbiology, enzymology, and chemical engineering, coordinated with studies of problems in the modern fermentation industry. Programs must be approved by an interdepartmental committee which includes representatives from the Departments of Nutrition 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 post-doctoral 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

WILLIAM WEBER BUECHNER, PH.D., SC.D.
Professor of Physics; Head of the Department

GEORGE GRAHAM HARVEY, PH.D.
Professor of Physics; Executive Officer; Associate Director of the Research Laboratory of Electronics

GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D., D.ENG.
Professor of Physics, 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

PHILIP MCCORD MORSE, PH.D., SC.D.
Professor of Physics; Director of the Computation Center; Director of the Operations Research Center

BERTRAM EUGENE WARREN, SC.D.
Professor of Physics

NATHANIEL HERMAN FRANK, SC.D.
Professor of Physics

ROBLEY DUNGLISON EVANS, PH.D. (*Absent*)
Professor of Physics

JERROLD REINACH ZACHARIAS, PH.D., L.H.D., SC.D.
Institute Professor; Professor of Physics

BRUNO BENEDETTO ROSSI, PH.D.
Institute Professor; Professor of Physics

VICTOR FREDERICK WEISSKOPF, PH.D., SC.D.
Institute Professor; Professor of Physics

ALBERT GORDON HILL, PH.D.
Professor of Physics

WILLIAM PHELPS ALLIS, SC.D.
Professor of Physics

MARTIN DEUTSCH, PH.D., SC.D.
Professor of Physics

MILTON STANLEY LIVINGSTON, PH.D., SC.D.
Professor of Physics; Director of the Cambridge Electron Accelerator

HERMAN FESHBACH, PH.D.
Professor of Physics

CLIFFORD GLENWOOD SHULL, PH.D.
Professor of Physics

GEORGE EDWARD VALLEY, JR., PH.D.
Professor of Physics; Undergraduate Planning Professor

BERNARD TAUB FELD, PH.D. (*Absent*)
Professor of Physics

FRANCIS EUGENE LOW, PH.D.
Professor of Physics

DAVID HENRY FRISCH, PH.D.
Professor of Physics

MALCOM WOODROW PERSHING STRANDBERG, PH.D.
Professor of Physics

LASZLO TISZA, PH.D.
Professor of Physics

FELIX MARC HERMANN VILLARS, D.SC.
Professor of Physics

PETER THEODORE DEMOS, PH.D.
Professor of Physics; Director of the Laboratory for Nuclear Science

CHARLES HARD TOWNES, PH.D., D.LITT., SC.D., DOTT.ING., LL.D.
Institute Professor; Professor of Physics

RAYMOND HIDE, PH.D.
Professor of Geophysics and Physics

ANTHONY PHILIP FRENCH, PH.D.
Professor of Physics

SANBORN CONNER BROWN, PH.D.
Professor of Physics; Associate Dean of the Graduate School

ROBERT ALLAN SMITH, PH.D.
Professor of Physics; Director of the Center for Materials Science and Engineering

HARALD ANTON ENGE, DR.PHIL.
Professor of Physics

PHILIP MORRISON, PH.D.
Professor of Physics

ROBERT INSLEE HULSIZER, JR., PH.D.
Professor of Physics; Director of the Science Teaching Center

ALI JAVAN, PH.D.
Professor of Physics

ARTHUR KENT KERMAN, PH.D.
Professor of Physics

GEORGE FRED KOSTER, PH.D.
Professor of Physics

LOUIS SHREVE OSBORNE, PH.D.
Professor of Physics

IRWIN ABRAHAM PLESS, PH.D. (*Absent*)
Professor of Physics

BENJAMIN LAX, PH.D.
Professor of Physics; Director of the National Magnet Laboratory

GEORGE BERNARD BENEDEK, PH.D.
Professor of Physics

BERNARD FLOOD BURKE, PH.D.
Professor of Physics

GEORGE WHIPPLE CLARK, PH.D.
Professor of Physics

KENNETH ALAN JOHNSON, PH.D.
Professor of Physics

JOHN GORDON KING, PH.D.
Professor of Physics

HERBERT SAGE BRIDGE, PH.D.
Professor of Physics; Associate Director of the Center for Space Research

LEE GRODZINS, PH.D.
Professor of Physics

KERSON HUANG, PH.D.
Professor of Physics

KARL UNO INGARD, PH.D. (*Absent*)
Professor of Physics

EARLE LEONARD LOMON, PH.D.
Associate Professor of Physics

STANISLAW OLBERT, PH.D.
Associate Professor of Physics

HENRY WAY KENDALL, PH.D.
Associate Professor of Physics

GEORGE BEKEFI, PH.D.
Associate Professor of Physics

WILLIAM BERTOZZI, PH.D.
Associate Professor of Physics

JEROME ISAAC FRIEDMAN, PH.D.
Associate Professor of Physics

ICKO IBEN, JR., PH.D.
Associate Professor of Physics

LAWRENCE ROSENSON, PH.D.
Associate Professor of Physics

RICHARD HOUZET LEMMER, D.SC., PH.D. (*Absent*)
Associate Professor of Physics

ARON MYRON BERNSTEIN, PH.D.
Associate Professor of Physics

DANIEL KLEPPNER, PH.D.
Associate Professor of Physics

KENNETH WILLIAM BILLMAN, PH.D.
Assistant Professor of Physics

ALAN JAY LAZARUS, PH.D.
Assistant Professor of Physics

CLIVE HOWE PERRY, PH.D.
Assistant Professor of Physics

RAYMOND ANGELO ALVAREZ, JR., PH.D.
Assistant Professor of Physics

HALE VAN DORN BRADT, PH.D.
Assistant Professor of Physics

THOMAS ALEXANDER BELOTE, PH.D.
Assistant Professor of Physics

GORDON PAUL GARMIRE, PH.D. (*Absent*)
Assistant Professor of Physics

RAINER WEISS, PH.D.
Assistant Professor of Physics

JOHN BRAYTON BRONZAN, PH.D.
Assistant Professor of Physics

RAYMOND YU CHIAO, PH.D.
Assistant Professor of Physics

WILLIAM EDWIN DORENBUSCH, PH.D.
Assistant Professor of Physics

JOHN CHARLES INGRAHAM, PH.D.
Assistant Professor of Physics

STANLEY BENEDICT KOWALSKI, PH.D.
Assistant Professor of Physics

JAN KUPERUS, PH.D.
Assistant Professor of Physics

WILLIAM HENRY MOORE, PH.D.
Assistant Professor of Physics

JAMES WILCOX OVERBECK, PH.D.
Assistant Professor of Physics

POPAT-LAL MULJI-BHAI PATEL, PH.D.
Assistant Professor of Physics

JACOBO RAPAPORT, PH.D.
Assistant Professor of Physics

CARL MARX SHAKIN, PH.D.
Assistant Professor of Physics

VIGDOR LOUIS TEPLITZ, PH.D.
Assistant Professor of Physics

TERENCE LESLIE WATTS, PH.D.
Assistant Professor of Physics

RICHARD KUMEO YAMAMOTO, PH.D.
Assistant Professor of Physics

PETER DONALD DE CICCO, PH.D.
Assistant Professor of Physics

IRA STEPHEN GERSTEIN, PH.D.
Assistant Professor of Physics

WILLIAM JOHN KOSSLER, PH.D.
Assistant Professor of Physics

JAMES DAVID LITSTER, PH.D.
Assistant Professor of Physics

HERBERT WILLIAM SCHNOPPER, PH.D.
Assistant Professor of Physics

CECIL EDWARD JONES, PH.D.
Assistant Professor of Physics

ROBERT JOHN KOLENKOW, PH.D.
Assistant Professor of Physics

DAVID CECIL MILLER, PH.D.
Assistant Professor of Physics

GEORGE LEONARD SISCOE, PH.D.
Assistant Professor of Physics

Administrative Officer

EDWARD SENTMAN ARENTZEN, S.M.

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.

LEO SARTORI, PH.D.

EDWIN FLORIMAN TAYLOR, PH.D.

WILLIAM ERNEST TURCHINETZ, PH.D.

Instructors

WILLIAM BASSICHIS, PH.D.

JONATHAN VAUGHAN GREENMAN, PH.D.

ALAN DOUGLAS MacKELLAR, PH.D.

ERIC RICHARD COSMAN, PH.D.

WALTER EDGAR DANIELS, PH.D.

STEPHEN GEORGE KUKOLICH, SC.D.

Research Associate

LEONARD SOL KISSLINGER, PH.D.

Professors Emeriti

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

ARTHUR COBB HARDY, SC.D.
Professor of Optics and Photography, Emeritus

PHYSICS

The progress of physics during the first half of the twentieth century has been unprecedented in the history of science. The great advances of quantum theory and the theory of relativity have enabled physics to move far beyond the conventional areas of mechanics, sound, heat, light, electricity, and magnetism; these advances have led to a remarkably complete understanding of the structure of atoms, molecules, and matter in bulk, of electronics and gas discharges, and of atomic and molecular spectra and the nature of light. The discovery of radioactivity, of cosmic rays and "strange" particles, and of nuclear fission and fusion has led to an increased understanding of the atomic nucleus and its structure. The rapidly expanding field of high-energy physics provides all the excitement and challenge of the unknown and partially understood which have characterized the periods of great discoveries of physics in the past. As a result of recent work, the fundamental laws governing the nature of matter and energy are partly understood, and great progress in these matters is bound to be made in the foreseeable future.

Along with this remarkable advance in basic knowledge has come, with unprecedented speed, a widespread application of new principles and methods to practical problems in a variety of fields. New methods of electronics have revolutionized communications and instrumentation and have led to new high-speed digital computers, which find everwidening realms of applicability. Relatively old fields such as fluid dynamics have become revitalized. Physical tools acquired from researches in X-ray, electron, and neutron diffraction, electron microscopy, and modern optical spectroscopy have opened entirely new experimental approaches to problems in chemistry, metallurgy, and biology, as well as in technology as a whole. Applied nuclear physics, with its use of artificial radioactive tracers, plays a similar role in a multitude of scientific and technological disciplines. The day has passed when physics, or any branch of it, can be considered as merely of academic interest. The broad knowledge of physical principles and methods prepares a man uniquely and powerfully to tackle new problems of industry and modern technology.

The Physics Department is aware of the vital importance of maintaining an active research program of 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 Physics Department.

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 new 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 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 the neutron diffraction studies.

The extensive facilities of the Computation Center are available for research that involves the use of high speed computation.

UNDERGRADUATE CURRICULA FOR THE CLASSES OF 1967 AND 1968

also for the Classes of 1969 and 1970 in Course IV-A

The curricula on the following pages specify the requirements for the Bachelor's degree in each Course. The curricula for all students in the Classes of 1969 and 1970 (except Course IV-A, leading to the B.Arch. degree), are given under each department in the regular edition of the General Catalogue for 1966–67.

Due to the changes in curricula effective for the Class of 1969 and later classes, the curricula on the following pages have been revised to agree with subject changes in the General Catalogue for 1966–67. In some cases the Departmental Requirements have been revised to conform more closely to the new curricula, but alternative subjects which are acceptable during the transition period have been indicated. In all cases subjects not listed in the catalogue under the Description of Subjects have been indicated by a double dagger (‡) to show that they have been discontinued beginning in September, 1966, or earlier. For information concerning these discontinued subjects, students should consult the General Catalogues for 1965–66 or 1964–65 (and for Course IV-A, the General Catalogue for 1963–64).

Students should note that, effective in September, 1966, the name of Course XV has been changed to *Management*, with a corresponding change in the specification of the S.B. degree.

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.

SCHOOL OF ARCHITECTURE AND PLANNING

DEPARTMENT OF ARCHITECTURE

Architecture (Course IV-A)

(Classes of 1967, 1968, and 1969.)

			Total units
GENERAL INSTITUTE REQUIREMENTS[4]			
‡8.01T	[1]PHYSICS I	5 0 6	
‡8.02T	[1]PHYSICS II	5 0 6	
8.03	[2]ELECTRICITY AND MAGNETISM	4 0 8	
	or		
‡8.03	[2]PHYSICS	4 1 5	
	or		
‡8.031	[2]PHYSICS	4 1 5	
8.04	[2]MODERN PHYSICS	4 0 8	
	or		
‡8.04	[2]PHYSICS	4 1 5	
	or		
‡8.041	[2]PHYSICS	4 1 5	
‡18.01	[1]CALCULUS	3 0 6	
‡18.02	[1]CALCULUS	3 0 6	
‡21.01	[1]THE GREEK TRADITION	3 0 5	
‡21.02	[1]THE EUROPEAN TRADITION	3 0 5	
‡21.03	THE NATURE OF LITERATURE	3 0 5	
	or		
‡21.04	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3 0 5	
‡21.05	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3 0 5	
	or		
‡21.06	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3 0 5	
	or		
‡17.01	SOCIETY AND MAN	3 0 5	
	[1]*Freshman electives*	12	
	[3]*Humanities and social science electives*	32	
			136 or 140
DEPARTMENTAL PROGRAM[5]			
	Required subjects		
2.701	ARCHITECTURAL GEOMETRY I	0 4 2	
2.702	ARCHITECTURAL GEOMETRY II	0 4 2	
	Visual Design		
‡4.021	FORM AND DESIGN	2 4 4	
‡4.022	FORM AND DESIGN	2 4 4	
4.04	LIGHT AND COLOR	0 9 11	
	Architectural Design		
4.121	ARCHITECTURAL DESIGN	2 5 5	
4.122	ARCHITECTURAL DESIGN	2 5 5	
4.131T	ARCHITECTURAL DESIGN	0 6 6	
4.132T	ARCHITECTURAL DESIGN	0 6 6	
4.141	ARCHITECTURAL DESIGN	0 12 8	
4.142	ARCHITECTURAL DESIGN	0 12 8	
4.151	ARCHITECTURAL DESIGN	0 12 8	
4.153	THESIS RESEARCH	0 6 0	
	Structures		
4.30	STRUCTURES I	3 3 6	
4.31	STRUCTURES II	2 2 4	
4.32	STRUCTURES III	2 2 4	
4.33	STRUCTURES IV	2 2 2	
4.34	STRUCTURES V	2 0 4	
	Technology		
‡4.40J	BUILDING PROCESS	3 3 4	
4.41	MATERIALS	3 2 3	
4.42	MATERIALS	3 2 3	
4.43	ENVIRONMENTAL CONTROL — ACOUSTICS	3 0 5	
2.644	ENVIRONMENTAL CONTROL — AIR CONDITIONING	3 0 5	
	History		
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 THESIS	3 0 5	
		18	**298**
	Elective subjects		**30**
Total units required for the B.Arch. degree			**468**

[1] Subjects of the first-year program.

[2] 8.03 (4–0–8) and 8.04 (4–0–8) or 8.03 (4–1–5) and 8.04 (4–1–5) are normally taken. 8.041, if selected in place of 8.04 (4–1–5), must be followed by ‡8.051 (4–0–5) or 8.051 (4–0–8) (or 8.05).

[3] See Section 2 of the General Catalogue for 1966–67 for the humanities and social science program. ECONOMIC PRINCIPLES I (14.01) is required. In Field Ten (Visual Arts) the following subjects may not be used in satisfaction of the humanities and social science requirements: 4.61, 4.62, 4.63, and 4.64.

[4] *General Institute Requirements.* Class '67: omit 21.03 or 21.04 *and* 21.05 or 21.06 or 17.01. Add ‡21.03 MODERN WESTERN IDEAS AND VALUES (3–0–5) *or* ‡14.003 THE MODERN WORLD AND SOCIAL SCIENCE (3–0–5) *and* ‡21.04 MODERN WESTERN IDEAS AND VALUES (3–0–5) *or* ‡14.004 THE MODERN WORLD AND SOCIAL SCIENCE (3–0–5), ‡2.721 GRAPHICAL CONCEPTS (0–4–2), and 2.722 DESCRIPTIVE GEOMETRY (0–4–2). Change freshman electives to 22 and total units to 158.

Class '68: total units are 136.

Class '69: omit 8.03 (4–1–5) or 8.031 and 8.04 (4–1–5) or 8.041. Add 8.03 ELECTRICITY AND MAGNETISM (4–0–8) and 8.04 MODERN PHYSICS (4–0–8). Total units are 140.

[5] *Departmental Program.* Class '67: omit 2.701, 2.702, 4.121 (2–5–5), 4.122 (2–5–5) 4.131T, 4.132T, and 4.30 (3–3–6). Add ‡4.121 ARCHITECTURAL DESIGN (2–4–6), ‡4.122 ARCHITECTURAL DESIGN (2–4–6), ‡4.131 ARCHITECTURAL DESIGN (0–9–9), ‡4.132 ARCHITECTURAL DESIGN (0–9–9), and ‡4.30 STRUCTURES I (3–3–4). Change Required Subjects total to 296 and Elective Subjects total to 14.

Class '68: omit 4.121 (2–5–5), 4.122 (2–5–5), 4.131T, 4.132T, and 4.30 (3–3–6). Add ‡4.121T ARCHITECTURAL DESIGN (2–7–7), ‡4.122T ARCHITECTURAL DESIGN (0–9–7), ‡4.131 ARCHITECTURAL DESIGN (0–9–9), ‡4.132 ARCHITECTURAL DESIGN (0–9–9), and ‡4.30 STRUCTURES I (3–3–4). Change Required Subjects total to 316 and Elective Subjects total to 16.

‡ Discontinued September, 1966, or earlier.

Architecture (Course IV-A)

(Class of 1970)

			Total Units
GENERAL INSTITUTE REQUIREMENTS			
	Specific Science Subjects		
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	
			48
	Humanities and Social Science Subjects		
21.01	THE GREEK TRADITION	3 0 6	
21.02	THE EUROPEAN TRADITION	3 0 6	

Humanities and Social Science Subjects (Continued)

21.03T	[1]LITERATURE: LANGUAGE, FORMS, AND THE INDIVIDUAL AUTHOR		
	or		
21.031	[1]LITERATURE: SELF, NATURE, AND SOCIETY	3 0 6	
	or		
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY		
21.05T	[1]THE TWENTIETH CENTURY: REVOLUTION, WAR AND "TOTALISM"		
	or		
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3 0 6	
	or		
17.01T	SOCIETY AND MAN		
	Upperclass program[2]	32	
			68
			116

Science Distribution Requirement[3]

At least 12 units

The subject 4.30, which is required in the Departmental Program, appears in the list of Science Distribution Subjects and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirement

At least 12 units **12**

DEPARTMENTAL PROGRAM

Required Subjects

Visual Design

‡ 4.021T	FORM AND DESIGN	2 4 6	
4.04	LIGHT AND COLOR	0 9 11	
			32

Architectural Design

4.121	ARCHITECTURAL DESIGN	2 5 5	
4.122	ARCHITECTURAL DESIGN	2 5 5	
4.131T	ARCHITECTURAL DESIGN	0 6 6	
4.132T	ARCHITECTURAL DESIGN	0 6 6	
4.141	ARCHITECTURAL DESIGN	0 12 8	
4.142	ARCHITECTURAL DESIGN	0 12 8	
4.151	ARCHITECTURAL DESIGN	0 12 8	
4.153	THESIS RESEARCH	0 6 0	
			114

Structures

4.30	STRUCTURES I	3 3 6	
4.31	STRUCTURES II	2 2 4	
4.32	STRUCTURES III	2 2 4	
4.33	STRUCTURES IV	2 2 2	
			34

Building Technology

4.402J	BUILDING PROCESS	3 3 6	
4.41	MATERIALS	3 2 3	
4.42	MATERIALS	3 2 3	
4.43	ENVIRONMENTAL CONTROL — ACOUSTICS	3 0 5	
2.644	ENVIRONMENTAL CONTROL — AIR CONDITIONING	3 0 5	
			44

History

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	
			32
	THESIS		**18**
	Unrestricted Electives[4]		**48**
Total units required for the B.Arch. degree			**450**

[1] The following subjects are offered in French for students having an adequate background in French and will be accepted in place of the Humanities subjects listed in parentheses: 23.031 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.051 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T). The following subjects are offered in German for students having an adequate background in German and will be accepted in place of the Humanities subjects listed in parentheses: 23.032 THE NATURE OF LITERATURE (in place of 21.03T or 21.031); 23.052 THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (in place of 21.05T).

[2] (*See Section 2 of the 1966-67 Catalogue.*) ECONOMIC PRINCIPLES I (14.01) is required. In Field Ten (Visual Arts), the following subjects may not be used to satisfy the Humanities and Social Sciences requirement: 4.61, 4.62, 4.63, and 4.64.

[3] 5.01 CHEMICAL PRINCIPLES I (5-2-5) may be used to satisfy the Science Distribution Requirement.

[4] Programs of students in Course IV-A may always be arranged to leave available 12 units of unrestricted electives in each of the first and second years.

‡Discontinued September 1966, or earlier.

SCHOOL OF ENGINEERING

					Total units
GENERAL INSTITUTE REQUIREMENTS					
‡5.01	[1]GENERAL CHEMISTRY	4	2	5	
‡5.02	[1]GENERAL CHEMISTRY	4	2	5	
‡8.01T	[1]PHYSICS I	5	0	6	
‡8.02T	[1]PHYSICS II	5	0	6	
8.03	[2]ELECTRICITY AND MAGNETISM	4	0	8	
	or				
‡8.03	PHYSICS	4	1	5	
	or				
‡8.031	PHYSICS	4	1	5	
8.04	[2]MODERN PHYSICS	4	0	8	
	or				
‡8.04	PHYSICS	4	1	5	
	or				
‡8.041	[2]PHYSICS	4	1	5	
‡18.01	[1]CALCULUS	3	0	6	
‡18.02	[1]CALCULUS	3	0	6	
‡18.03	CALCULUS	3	0	6	
‡18.04	DIFFERENTIAL EQUATIONS	3	0	6	
‡21.01	[1]THE GREEK TRADITION	3	0	5	
‡21.02	[1]THE EUROPEAN TRADITION	3	0	5	
‡21.03	THE NATURE OF LITERATURE	3	0	5	
	or				
‡21.04	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3	0	5	
‡21.05	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3	0	5	
	or				
‡21.06	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	5	
	or				
‡17.01	SOCIETY AND MAN	3	0	5	
	[1]*Freshman electives*				12
	[3]*Humanities and social science electives*				32
					176 or 180

[1] Subjects of the common first-year program.

[2] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[3] See Section 2 of the General Catalogue for 1966–67 for the humanities and social science program.

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

Aeronautics and Astronautics (Course XVI)

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see left*)					**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) *or* ‡8.031 and ‡8.041 must be taken.

DEPARTMENTAL PROGRAM

	Required subjects				
‡16.81	FLIGHT VEHICLES	3	0	6	
‡3.14	ENGINEERING MATERIALS	4	2	4	
‡16.20	SOLID MECHANICS I	4	0	6	
‡2.401	THERMODYNAMICS OF FLUID FLOW	3	0	6	
16.01	DYNAMICS	4	2	6	
6.43	INTRODUCTION TO ELECTRICAL SCIENCE	4	2	6	
	or				
‡6.43	INTRODUCTION TO ELECTRICAL SCIENCE	4	2	4	
16.62	EXPERIMENTAL PROJECTS	2	6	4	
	or				
‡16.62	EXPERIMENTAL PROJECTS I	2	4	4	
					72 to 74
	Elective subjects				
	Specified				
16.02	AERODYNAMICS	4	2	6	
	or				
16.03	GASDYNAMICS	4	2	6	
	At least three subjects chosen from the following:				
16.201	SOLID MECHANICS II	4	0	6	
‡16.11	FLIGHT VEHICLE AERODYNAMICS AND DYNAMICS	4	0	5	
	or				
16.11T	AERODYNAMICS OF FLIGHT VEHICLES	3	0	6	
6.44	INTRODUCTION TO ELECTRICAL SCIENCE	4	0	8	
	or				
‡6.44	INTRODUCTION TO ELECTRICAL SCIENCE	4	0	6	
16.30	PRINCIPLES OF AUTOMATIC CONTROL	3	0	9	
16.53	ROCKET PROPULSION	3	0	6	
	or				
16.54	AIRCRAFT ENGINES	3	0	6	
16.71	FLIGHT VEHICLE ENGINEERING	2	3	7	
	or				
‡16.73	SPACE SYSTEMS ENGINEERING	2	3	7	
	or				
16.73T	SPACE SYSTEMS ENGINEERING	4	0	8	
					40 to 48
	[2]*Unspecified*				**72 to 58**
Total units required for the S.B. degree					**360**

[1] 8,041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] Students may include a thesis as part of the elective requirement.

‡ Discontinued September, 1966, or earlier.

The Cooperative Course (Course XVI-B)

The curriculum is the same as for Course XVI, except for the addition of required plant work:

16.85	INDUSTRIAL PRACTICE	40 h.p.w.

DEPARTMENT OF CHEMICAL ENGINEERING
Chemical Engineering (Course X)

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)		**176 or 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) *or* ‡8.031 and ‡8.041 must be taken.

DEPARTMENTAL PROGRAM

	Required subjects	
5.41	ORGANIC CHEMISTRY I	4 0 8
5.61	PHYSICAL CHEMISTRY I	4 0 8
	or	
‡5.61	PHYSICAL CHEMISTRY I	4 0 4
10.12	CHEMICAL ENGINEERING	3 0 5
10.15	*THESIS REPORTS	0 4 0
	THESIS	12
		44 to 48
	Elective subjects	
	In specified areas:	
	Chemistry	at least 30
	Chemical engineering	at least 60
	Professional minor	at least 24
	Laboratory work (within the above electives or partially in addition thereto)	at least 28
	Unspecified elective subjects as needed to fulfill the total unit requirement of	**140 to 132**
Total units required for the S.B. degree		**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

* 10.15 is a "time-arranged" subject.

‡ Discontinued September, 1966, or earlier.

Materials Science and 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)

Students interested in this course should consult their Faculty Counselors to arrange their programs.

DEPARTMENT OF CIVIL ENGINEERING
Civil Engineering (Course I)

With the exception of the General Institute Requirements, the program for the classes now at the Institute is essentially the same as that for the classes entering in 1965 or thereafter.

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)		**176 to 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are taken except when plans for further study clearly indicate the need for the subject matter of ‡8.031 and ‡8.041. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.

DEPARTMENTAL PROGRAM

	Required subjects (*alternative subjects in parentheses*)	
1.00	INFORMATION SYSTEMS	3 3 6
	(‡1.15 COMPUTER APPROACHES TO ENGINEERING PROBLEMS	2 2 2)
1.01	ENGINEERING MECHANICS	4 0 8
	(‡2.01 MECHANICS OF SOLIDS	3 0 5)
1.02	ENGINEERING MATERIALS	3 3 6
	(‡3.14 ENGINEERING MATERIALS	4 2 4)
1.03	ENGINEERING ANALYSIS	4 0 8
	(‡2.02 DYNAMIC SYSTEMS	3 0 6)
1.04	STRUCTURAL ANALYSIS AND DESIGN I	3 3 6
	(‡1.511 STRUCTURAL ANALYSIS AND DESIGN I	3 2 5)
1.05	FLUID DYNAMICS	3 3 6
1.06	SOIL MECHANICS	3 3 6
	(‡1.06 PARTICULATE MECHANICS	3 2 5)
1.07	PRINCIPLES OF UNCERTAINTY	3 0 6
	(‡6.27J PROBABILISTIC SYSTEMS ANALYSIS	3 0 6)
1.08	GEOTECHNOLOGY	3 3 6
	(‡1.01 GEOTECHNICAL SCIENCES	3 3 6)
1.09	CIVIL ENGINEERING	0 6 12
		104 to 123
	Elective subjects	
	In specified areas	
	An approved program of subjects in science, engineering science, and other appropriate areas, such that these subjects and the required subjects total 123 units.	**19 to 0**
	Unspecified	**61 to 57**
Total units required for the S.B. degree		**360**

[1] 8.041, is selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF ELECTRICAL ENGINEERING

Electrical Engineering (Course VI)

1. ELECTRICAL ENGINEERING PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)		**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are prescribed. ECONOMIC PRINCIPLES I (14.01) is recommended as one of the humanities and social science electives.

DEPARTMENTAL PROGRAM

	Required subjects[2]	
6.01	INTRODUCTORY CIRCUIT THEORY I	4 0 8
6.02	INTRODUCTORY CIRCUIT THEORY II	4 0 8
6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4 0 8
6.05	CIRCUITS, SIGNALS AND SYSTEMS	4 0 8
6.70	EXPERIMENTAL ELECTRONICS	1 4 1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1 4 1
6.72	ELECTROMAGNETIC LABORATORY	1 4 1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1 4 1
8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 8
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 9
	THESIS	12
		108
	Elective subjects	
	Specified	
	Two of the following subjects:	
6.06T	FIELDS, FORCES, AND MOTION	3 0 9
6.07T	ENERGY TRANSMISSION AND RADIATION	4 0 8
6.08T	THERMODYNAMICS AND QUANTUM STATISTICS	4 0 8
		24
	Unspecified	**52 to 48**
Total units required for the S.B. degree		**360**

[1] 8.041 must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

‡ Discontinued September, 1966, or earlier.

2. ELECTRICAL SCIENCE AND ENGINEERING PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A3*)		**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are prescribed. ECONOMIC PRINCIPLES I (14.01) is recommended as one of the humanities and social science electives.

DEPARTMENTAL PROGRAM

	Required subjects	
6.013	INTRODUCTORY CIRCUIT THEORY I	4 0 8
6.023	INTRODUCTORY CIRCUIT THEORY II	4 0 8
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4 0 8
6.053	CIRCUITS, SIGNALS AND SYSTEMS	4 0 8

(*continued*)

6.11	[2]PROJECT SEMINAR	2 0 4
6.12	[2]PROJECT SEMINAR	2 0 4
‡6.13	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	3 0 6
	or	
6.13T	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	4 0 8
6.70	EXPERIMENTAL ELECTRONICS	1 4 1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1 4 1
6.72	ELECTROMAGNETIC LABORATORY	1 4 1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1 4 1
8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 8
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 9
18.18	PROBABILITY	3 0 9
		129 to 132
	Elective subjects	
	Specified	
	Two of the following subjects:	
6.063T	FIELDS, FORCES AND MOTION	3 0 9
6.073T	ENERGY TRANSMISSION AND RADIATION	4 0 8
6.083T	THERMODYNAMICS AND QUANTUM STATISTICS	4 0 8
		24
	Unspecified	**31 to 24**
Total units required for the S.B. degree		**360**

[1] 8.041 must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] 6.11 and 6.12 PROJECT SEMINAR satisfy the S.B. thesis requirement.

‡ Discontinued September, 1966, or earlier.

Electrical Engineering (Course VI-A)

1. ELECTRICAL ENGINEERING PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)		**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are prescribed. ECONOMIC PRINCIPLES I (14.01) is recommended as one of the humanities and social science electives.

DEPARTMENTAL PROGRAM

	Required subjects	
6.01	INTRODUCTORY CIRCUIT THEORY I	4 0 8
6.02	INTRODUCTORY CIRCUIT THEORY II	4 0 8
6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4 0 8
6.05	CIRCUITS, SIGNALS AND SYSTEMS	4 0 8
6.70	EXPERIMENTAL ELECTRONICS	1 4 1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1 4 1
6.72	ELECTROMAGNETIC LABORATORY	1 4 1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1 4 1
8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 8
	or	
‡8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 5
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 9
	or	
‡18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 6
	THESIS[2]	12
		102 to 108
	Elective subjects	
	Specified	
	Two of the following subjects:	
‡6.06	FIELDS, FORCES, AND MOTION	3 0 6
	or	

6.06T	FIELDS, FORCES, AND MOTION	3	0	9
6.07T	ENERGY TRANSMISSION AND RADIATION	4	0	8
6.08T	THERMODYNAMICS AND QUANTUM STATISTICS	4	0	8
				21 to 24
	Unspecified[2,3]			**61 to 48**
Total units required for the S.B. degree				**360**

[1] 8.041 must be followed by ‡8.051 (4–0–5) or 8.051 (4–0–8) (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] Students who go on for the S.M. degree and receive the S.B. and S.M. degrees simultaneously may substitute 12 units of additional elective for the S.B. thesis.

[3] Industrial practice subjects must be taken by students in this Course VI-A curriculum; elective credit for these subjects is limited to a maximum of 27 units and a minimum of 18 units.

‡ Discontinued September, 1966, or earlier.

2. ELECTRICAL SCIENCE AND ENGINEERING PROGRAM CURRICULUM

	Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)	**176 or 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are prescribed. ECONOMIC PRINCIPLES I (14.01) is recommended as one of the humanities and social science electives.

DEPARTMENTAL PROGRAM

Required subjects

6.013	INTRODUCTORY CIRCUIT THEORY I	4	0	8
6.023	INTRODUCTORY CIRCUIT THEORY II	4	0	8
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
6.053	CIRCUITS, SIGNALS AND SYSTEMS	4	0	8
‡6.13	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	3	0	6
	or			
6.13T	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	4	0	8
6.70	EXPERIMENTAL ELECTRONICS	1	4	1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1
6.72	ELECTROMAGNETIC LABORATORY	1	4	1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	8
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9
	or			
‡18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6
18.18	PROBABILITY	3	0	9
	[2]*Industrial project subject*			12
				126 to 132

Elective subjects

Specified

Two of the following subjects:

6.063T	FIELDS, FORCES AND MOTION	3	0	9
6.073T	ENERGY TRANSMISSION AND RADIATION	4	0	8
6.083T	THERMODYNAMICS AND QUANTUM STATISTICS	4	0	8
				24
	[2]*Unspecified*			**34 to 24**
Total units required for the S.B. degree				**360**

[1] 8.041 must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] Industrial practice and industrial project subjects must be taken by students in this Course VI-A curriculum; credit for these subjects is limited to a maximum of 30 units and a minimum of 18 units. The industrial project subject satisfies the S.B. thesis requirement.

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF MECHANICAL ENGINEERING

Mechanical Engineering (Course II)

1. ENGINEERING PROGRAM CURRICULUM

For the S.B. degree in Mechanical Engineering

	Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)	**176 or 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) *or* ‡8.031 and ‡8.041 must be taken.

DEPARTMENTAL PROGRAM

Required subjects

‡2.01	MECHANICS OF SOLIDS	3	0	5
‡2.02	DYNAMIC SYSTEMS	3	0	6
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	4	0	8
‡3.14	ENGINEERING MATERIALS	4	2	4
	or			
3.141	SCIENCE OF MATERIALS	4	3	5
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4
2.731	ENGINEERING DESIGN	3	3	6
2.671	EXPERIMENTAL ENGINEERING	2	4	2
	THESIS			12
				113 to 115

Elective subjects

In specified areas:

Thermodynamics

2.404T	STATISTICAL MECHANICS AND KINETIC THEORY	4	0	8
	or			
2.50	HEAT AND MASS TRANSFER	3	0	6

Electrical Engineering

6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
	or			
6.14	ELECTRONIC NETWORKS AND DEVICES	4	2	6
	or			
‡6.42J	ELECTROMECHANICAL COMPONENTS AND SYSTEMS	3	2	5
	or			
6.48J	ELECTROMECHANICAL COMPONENTS AND SYSTEMS	4	2	6
				19 to 24
	Unspecified (except that total THESIS units may not exceed 18)			**52 to 41**
Total units required for the S.B. degree				**360**

[1] 8.041, if selected, must be followed by 8.051 (4–0–8) (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

‡ Discontinued September, 1966, or earlier.

2. ENGINEERING SCIENCE PROGRAM CURRICULUM

For the S.B. degree in Mechanical Engineering

	Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)	**176 or 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are prescribed.

DEPARTMENTAL PROGRAM

Required subjects

‡2.01	MECHANICS OF SOLIDS	3	0	5

‡2.02	DYNAMIC SYSTEMS	3 0 6
2.03	DYNAMICS	3 0 6
2.211	FLUID DYNAMICS	3 0 6
2.212	FLUID DYNAMICS	3 0 6
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3 2 4
2.403	THERMODYNAMICS	4 0 8
2.404T	STATISTICAL MECHANICS AND KINETIC THEORY	4 0 8
‡3.14	ENGINEERING MATERIALS	4 2 4
	or	
3.141	SCIENCE OF MATERIALS	4 3 5
8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 8
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 9
2.861	ENGINEERING DESIGN AND MANUFACTURE	4 4 4
2.671	EXPERIMENTAL ENGINEERING	2 4 2
	THESIS	12
		143 to 145

Elective subjects

In specified areas:
Electrical Engineering

6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4 0 8
	or	
6.14	ELECTRONIC NETWORKS AND DEVICES	4 2 6
	or	
‡6.42J	ELECTROMECHANICAL COMPONENTS AND SYSTEMS	3 2 5
	or	
6.48J	ELECTROMECHANICAL COMPONENTS AND SYSTEMS	4 2 6
		10 or 12

Unspecified (except that total THESIS units may not exceed 18) **36 to 28**

Total units required for the S.B. degree **365**

[1] 8.041 must be followed by 8.051 (4–0–8) (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

‡ Discontinued September, 1966, or earlier.

The Cooperative Course (Course II-B)

For the S.B. degree 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

CURRICULUM FOR DEGREE OF BACHELOR OF SCIENCE
(Class of 1968)

GENERAL INSTITUTE REQUIREMENTS (*see page A4*) *Total units* **180**

PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) must be taken.

DEPARTMENTAL PROGRAM

Required subjects

‡2.01	MECHANICS OF SOLIDS	3 0 5
‡2.02	DYNAMIC SYSTEMS	3 0 6
	THESIS	12
		29

Elective subjects

In Specified Areas:
Five of the following subjects:

3.141	SCIENCE OF MATERIALS	4 3 5
	or	
3.13T	MATERIALS SCIENCE I	
2.03	DYNAMICS	4 0 8
2.201	FLUID MECHANICS	4 0 8
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3 2 4
2.403	THERMODYNAMICS	4 0 8
	or	
2.404T	STATISTICAL MECHANICS AND KINETIC THEORY	4 0 8
	or	
2.50	HEAT AND MASS TRANSFER	3 0 6
	or	
2.60	APPLIED THERMODYNAMICS	3 0 6
2.671	EXPERIMENTAL ENGINEERING	2 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 programs, 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 Mechanical Engineering Department at least **57**

at least **111**

Unspecified:

up to **40**

Total units required for the S.B. degree **360**

The Undergraduate Honors Course

(See the General Catalogue for 1966-67)

DEPARTMENT OF METALLURGY

Metallurgy (Course III-A)

GENERAL INSTITUTE REQUIREMENTS (*see page A4*) *Total units* **176 or 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are preferred.

DEPARTMENTAL PROGRAM

Required subjects

‡3.00	THERMODYNAMICS I	4 0 6
‡3.01	[2] HEAT AND FLUID FLOW	4 3 6
3.03T	CHEMICAL METALLURGY	3 0 6
‡3.20	THERMODYNAMICS II	4 0 4
	or	
3.01T	THERMODYNAMICS AND STATISTICAL MECHANICS	4 0 8
‡3.31	MATERIALS SCIENCE I	4 3 5
	or	
3.13T	MATERIALS SCIENCE I	4 3 5
3.12T	PRINCIPLES OF CRYSTALLOGRAPHY AND X-RAY DIFFRACTION	4 3 5
3.81	[2] PRINCIPLES OF MATERIALS SEPARATION	4 3 5
‡2.01	MECHANICS OF SOLIDS	3 0 5
5.62	[2] PHYSICAL CHEMISTRY II	4 0 8
	THESIS	12
		108 to 112

Elective subjects

Unspecified (except that total THESIS units may not exceed 18) **79 to 71**

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

[1] ‡8.041, if selected in place of ‡8.04 (4–1–5) must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] Class '68: omit ‡3.01, 3.81 (new 3.08), and 5.62; add science or engineering subjects (37).

‡ Discontinued September, 1966, or earlier.

Materials Science (Course III-B)

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)		**176 or 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are preferred.

DEPARTMENTAL PROGRAM

Required subjects

‡3.00	THERMODYNAMICS I	4	0	6
‡3.20	THERMODYNAMICS II	4	0	4
	or			
3.01T	THERMODYNAMICS AND STATISTICAL MECHANICS	4	0	8
‡3.31	MATERIALS SCIENCE I	4	3	5
	or			
3.13T	MATERIALS SCIENCE I	4	3	5
‡3.51	MATERIALS SCIENCE II	4	3	5
	or			
3.15T	MATERIALS SCIENCE II	4	3	5
‡2.01	MECHANICS OF SOLIDS	3	0	5
5.62	[2]PHYSICAL CHEMISTRY II	4	0	8
6.14	[2]ELECTRONIC NETWORKS AND DEVICES	4	2	6
8.051	[2]INTRODUCTION TO QUANTUM PHYSICS	4	0	8
	THESIS		12	
				98 to 102

Elective subjects

Specified

3.18T	MATERIALS PROCESSING	4	3	5
	or			
3.188	MATERIALS PROCESSING	4	0	4
	SCIENCE OR ENGINEERING SUBJECT		12	

Unspecified (including additional THESIS units, not exceeding 18) as needed to fulfill the total elective unit requirement of **89 to 81**

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

[1] 8.041, if selected, must be followed by 8.051 or (8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] Class '68: omit 5.62, 6.14, and 8.051; add science or engineering subjects (36).

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

Naval Architecture and Marine Engineering (Course XIII)

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A4*)		**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) *or* ‡8.031 and ‡8.041 must be taken.

DEPARTMENTAL PROGRAM

Required subjects

13.00	PRINCIPLES OF NAVAL ARCHITECTURE	4	1	7
13.10	SHIP STRUCTURAL ANALYSIS AND DESIGN	4	0	8
13.20	ENERGY CONVERSION SYSTEMS AND COMPONENTS	4	0	8
13.30	MECHANICAL VIBRATION	3	0	5
13.40	INTRODUCTORY SHIP DESIGN	1	8	3
‡2.01	MECHANICS OF SOLIDS	3	0	5
‡2.02	DYNAMIC SYSTEMS	3	0	6
2.201	FLUID MECHANICS	4	0	8
2.403	THERMODYNAMICS	4	0	8
‡3.14	ENGINEERING MATERIALS	4	2	4
14.01	[2]ECONOMIC PRINCIPLES I	3	0	5
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9
	THESIS		9	
				136

Elective subjects

Unspecified, except that a minimum of three subjects in engineering or science must be included and that a single beginning subject in a foreign language may not be taken for degree credit. **48[2] to 44[2]**

Total units required for the S.B. degree **360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68 take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] 14.01 may be used in partial fulfillment of the humanities requirement only with the approval of the Faculty Counselor; in such a case the elective requirement will be increased to 56 to 52 units.

‡ Discontinued September, 1966, or earlier.

Shipping and Shipbuilding Management (Course XIII-B)

The undergraduate curriculum requirements are the same as for Course XIII, except that the 9 units of undergraduate thesis are allotted to additional professional subjects, and that concentration in Economics (Field 6) and Labor Relations (Field 8) of the humanities program is not permitted.

The graduate requirement is 72 units of graduate study plus an acceptable thesis.

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

			Total units
GENERAL INSTITUTE REQUIREMENTS			
‡5.01	[1]GENERAL CHEMISTRY	4 2 5	
‡5.02	[1]GENERAL CHEMISTRY	4 2 5	
‡8.01T	[1]PHYSICS I	5 0 6	
‡8.02T	[1]PHYSICS II	5 0 6	
8.03	[2]ELECTRICITY AND MAGNETISM	4 0 8	
	or		
‡8.03	PHYSICS	4 1 5	
	or		
‡8.031	PHYSICS	4 1 5	
8.04	[2]MODERN PHYSICS	4 0 8	
	or		
‡8.04	PHYSICS	4 1 5	
	or		
‡8.041	[2]PHYSICS	4 1 5	
‡18.01	[1]CALCULUS	3 0 6	
‡18.02	[1]CALCULUS	3 0 6	
‡18.03	CALCULUS	3 0 6	
‡18.04	DIFFERENTIAL EQUATIONS	3 0 6	
‡21.01	[1]THE GREEK TRADITION	3 0 5	
‡21.02	[1]THE EUROPEAN TRADITION	3 0 5	
‡21.03	THE NATURE OF LITERATURE	3 0 5	
	or		
‡21.04	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3 0 5	
‡21.05	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3 0 5	
	or		
‡21.06	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3 0 5	
	or		
‡17.01	SOCIETY AND MAN	3 0 5	
	[1]*Freshman electives*		12
	[3]*Humanities and social science electives*		32
			176 or 180

[1] Subjects of the common first-year program.

[2] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[3] See Section 2 of the General Catalogue for 1966–67 for the humanities and social science program.

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF ECONOMICS

Economics (Course XIV)

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see left*)			**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are normally taken; but ‡8.031 and ‡8.041 will be accepted for Class '67.

DEPARTMENTAL PROGRAM			
	Required subjects		
14.01	ECONOMIC PRINCIPLES I	3 0 5	
14.02	ECONOMIC PRINCIPLES II	3 0 5	
14.03	PRICES AND PRODUCTION	3 0 5	
14.05	ECONOMIC FLUCTUATION AND GROWTH	3 0 5	
14.381	STATISTICAL METHOD	3 0 6	
14.39	ECONOMIC RESEARCH SEMINAR	2 0 6	
	THESIS	9	
			58
	Elective subjects		
	Specified		
	Subjects in engineering or science	24	
	Economics elective subjects	32	
	Unspecified	70 to 66	
			126 to 122
Total units required for the S.B. degree			**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF HUMANITIES

Humanities and Engineering (Course XXI-A) and Humanities and Science (Course XXI-B)

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A10*)			**176 to 180**
	[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) or ‡8.031 and ‡8.041 are taken according to the science or engineering curriculum being pursued in conjunction with humanities.		
DEPARTMENTAL PROGRAM			
	Required subjects		
21.08	THESIS PREPARATION AND REPORTS	1 2 3	
	THESIS	12	
			18
	Elective subjects		
	Specified		
21.07	[3]HUMANITIES SEMINAR	2 0 8	
	or		
21.071	HISTORY SEMINAR	2 0 8	
	or		
21.072	LITERATURE SEMINAR	2 0 8	
	or		
21.073	PHILOSOPHY SEMINAR	2 0 8	
	Elective subjects restricted to one of the science or engineering curricula	52[2]	
	Elective subjects restricted to one of the humanities disciplines: e.g., literature, philosophy, etc.	48	
	Unspecified	56 to 52	
			166 to 162
Total units required for the S.B. degree			**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] The student who intends to obtain a second S.B. degree in one of the science or engineering Courses by continuing his studies at M.I.T. in a fifth year and the student who plans to enter upon graduate study in science or engineering should carry at least 88 units. The additional units will be drawn from the 56 to 52 units of unrestricted elective subjects.

[3] Class '67: take 21.07.

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF POLITICAL SCIENCE

Political Science (Course XVII)

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A10*)			**176 to 180**
	[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are normally taken. If work in nuclear and atomic physics is to form part of a student's program in a science or engineering field, ‡8.031 and ‡8.041[1] are taken. Students may use 16 units of political science subjects as part of the required 32 units of humanities and social science electives.		
DEPARTMENTAL PROGRAM			
	Required subjects		
	THESIS	9	
			9
	Elective subjects		
	Specified		
	Elective subjects in a particular field of engineering or science	24	
	Political science elective subjects	88	
	Unspecified	63 to 59	
			175 to 171
Total units required for the S.B. degree			**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

‡ Discontinued September, 1966, or earlier.

ALFRED P. SLOAN SCHOOL OF MANAGEMENT

Management (Course XV)

					Total units
GENERAL INSTITUTE REQUIREMENTS					
‡5.01	[1]GENERAL CHEMISTRY	4	2	5	
‡5.02	[1]GENERAL CHEMISTRY	4	2	5	
‡8.01T[1]	PHYSICS I	5	0	6	
‡8.02T[1]	PHYSICS II	5	0	6	
8.03	[2]ELECTRICITY AND MAGNETISM	4	0	8	
	or				
‡8.03	[2]PHYSICS	4	1	5	
	or				
‡8.031	[2]PHYSICS	4	1	5	
8.04	[2]MODERN PHYSICS	4	0	8	
	or				
‡8.04	[2]PHYSICS	4	1	5	
	or				
‡8.041	[2]PHYSICS	4	1	5	
‡18.01	[1]CALCULUS	3	0	6	
‡18.02	[1]CALCULUS	3	0	6	
‡18.03	CALCULUS	3	0	6	
‡18.04	DIFFERENTIAL EQUATIONS	3	0	6	
‡21.01	[1]THE GREEK TRADITION	3	0	5	
‡21.02	[1]THE EUROPEAN TRADITION	3	0	5	
‡21.03	THE NATURE OF LITERATURE	3	0	5	
	or				
‡21.04	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3	0	5	
‡21.05	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3	0	5	
	or				
‡21.06	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	5	
	or				
‡17.01	SOCIETY AND MAN	3	0	5	
	[1]*Freshman electives*		12		
	[3]*Humanities and social science electives*		32		
					176 to 180

DEPARTMENTAL PROGRAM					
	Required subjects				
15.01	ECONOMICS FOR MANAGEMENT	3	0	6	
‡15.02	INDUSTRIAL STATISTICS	3	0	6	
	or				
15.02T	INDUSTRIAL STATISTICS	4	0	8	
‡15.04	PSYCHOLOGY AND HUMAN ORGANIZATION	3	0	6	
	or				
15.04T	PSYCHOLOGY AND HUMAN ORGANIZATION	4	0	8	
15.41	FINANCIAL MANAGEMENT	3	0	6	
‡15.50	MANAGERIAL INFORMATION AND CONTROL	3	0	6	
	or				
15.50T	MANAGERIAL INFORMATION AND CONTROL	4	0	8	
15.71	PRODUCTION MANAGEMENT	3	0	6	
15.81	MARKETING	3	0	6	
15.95	SENIOR SEMINAR IN MANAGEMENT	2	0	7	
					72 to 81

Elective subjects	
Specified	
Subjects in science or engineering making up a program minimally totaling	72
Unspecified	48 to 35
	120 to 107
Total units required for the S.B. degree	[4]**368**

[1] Subjects of the common first-year program.

[2] PHYSICS 8.03 (4–1–5) and 8.04 (4–1–5) are taken except when plans for further work clearly indicate the need for the subject matter of 8.031 and 8.041; 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[3] See Section 2 of the General Catalogue for 1966–67 for the humanities and social science program. ECONOMIC PRINCIPLES I (14.01) is required. Subjects in Field Six (Economics) and Field Eight (Labor Relations) may not be used in satisfaction of the humanities and social science sequence requirement.

[4] In exceptional cases this total may be reduced by the School within the General Institute Requirements.

‡ Discontinued September, 1966, or earlier.

SCHOOL OF SCIENCE

GENERAL INSTITUTE REQUIREMENTS		Total units
‡5.01	[1]GENERAL CHEMISTRY	4 2 5
‡5.02	[1]GENERAL CHEMISTRY	4 2 5
‡8.01T	[1]PHYSIC I	5 0 6
‡8.02T	[1]PHYSICS II	5 0 6
8.03	[2]ELECTRICITY AND MAGNETISM	4 0 8
	or	
‡8.03	PHYSICS	4 1 5
	or	
‡8.031	PHYSICS	4 1 5
8.04	[2]MODERN PHYSICS	4 0 8
	or	
‡8.04	PHYSICS	4 1 5
	or	
‡8.041	[2]PHYSICS	4 1 5
‡18.01	[1]CALCULUS	3 0 6
‡18.02	[1]CALCULUS	3 0 6
‡18.03	CALCULUS	3 0 6
‡18.04	DIFFERENTIAL EQUATIONS	3 0 6
‡21.01	[1]THE GREEK TRADITION	3 0 5
‡21.02	[1]THE EUROPEAN TRADITION	3 0 5
‡21.03	THE NATURE OF LITERATURE	3 0 5
	or	
‡21.04	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3 0 5
‡21.05	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3 0 5
	or	
‡21.06	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3 0 5
	or	
‡17.01	SOCIETY AND MAN	3 0 5
	[1]*Freshman electives*	12
	[3]*Humanities and social science electives*	32
		176 or 180

[1] Subjects of the common first-year program.

[2] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[3] See Section 2 of the General Catalogue for 1966–67 for the humanities and social science program.

‡ Discontinued September, 1966, or earlier

DEPARTMENT OF BIOLOGY

Life Sciences (Course VII)

		Total units
GENERAL INSTITUTE REQUIREMENTS *(see left)*		**176 or 180**
	[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are prescribed.	
DEPARTMENTAL PROGRAM		
	Required subjects *(alternative subjects in parentheses)*	
7.01	GENERAL BIOLOGY	4 0 8
	(‡7.01 GENERAL BIOLOGY 4 1 6)	
7.02	GENERAL BIOLOGY LABORATORY	1 8 3
	(‡7.02 GENERAL BIOLOGY LABORATORY 1 6 2)	
7.03	GENETICS	3 0 6
7.031	GENETICS AND MICROBIOLOGY LABORATORY	1 6 2
7.04	DEVELOPMENTAL BIOLOGY	2 0 4
7.041	DEVELOPMENTAL BIOLOGY LABORATORY	1 6 2
7.05	GENERAL BIOCHEMISTRY	4 0 6
7.051	GENERAL BIOCHEMISTRY LABORATORY	0 8 0
7.06	GENERAL PHYSIOLOGY	3 0 6
7.21	GENERAL MICROBIOLOGY	3 0 6
5.41	ORGANIC CHEMISTRY I	4 0 8
	(‡5.41 ORGANIC CHEMISTRY I 4 0 4) *and* (‡5.42 ORGANIC CHEMISTRY II 4 0 4)	
5.412	ORGANIC CHEMISTRY LABORATORY I	1 5 0
5.14	[1]ANALYTICAL CHEMISTRY	3 6 3
5.61	PHYSICAL CHEMISTRY I	4 0 8
5.62	PHYSICAL CHEMISTRY II	4 0 8
		147
	Elective subjects	
	[2]*Unspecified*	**37 to 33**
Total units required for the S.B. degree		**360**

[1] Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8). Omit 5.14. Add Elective (12 units).

[2] Students may elect THESIS (12 units) as one of their elective subjects.

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF CHEMISTRY

Chemistry (Course V)

1. CHEMISTRY PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A13*)		**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are prescribed.

DEPARTMENTAL PROGRAM

	Required subjects (*alternative subjects in parentheses*)			
5.41	ORGANIC CHEMISTRY I	4	0	8
	(‡5.41 ORGANIC CHEMISTRY I	4	0	4)
5.412	ORGANIC CHEMISTRY LABORATORY I	1	5	0
5.42	ORGANIC CHEMISTRY II	4	0	8
	(‡5.42 ORGANIC CHEMISTRY II	4	0	4)
5.422	ORGANIC CHEMISTRY LABORATORY II	1	5	0
	(‡5.422T ORGANIC CHEMISTRY LABORATORY II	1	5	1)
5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	3	0	9
5.61	PHYSICAL CHEMISTRY I	4	0	8
5.613	PHYSICAL CHEMISTRY LABORATORY I	0	4	2
5.14	ANALYTICAL CHEMISTRY	4	4	4
5.62	PHYSICAL CHEMISTRY II	4	0	8
5.623	PHYSICAL CHEMISTRY LABORATORY II	0	4	2
5.63	PHYSICAL CHEMISTRY III	4	0	8
	[2]LANGUAGE	4	0	8
	(LANGUAGE	3	0	5)
	[2]LANGUAGE	4	0	8
	(LANGUAGE	3	0	5)
	THESIS		12	
			129 to 144	
	Elective subjects		**55 to 36**	
Total units required for the S.B. degree			**360**	

[1] Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] The language should be ELEMENTARY GERMAN (23.11 and 23.12) or INTERMEDIATE GERMAN (23.13) and ADVANCED GERMAN (23.14).

‡ Discontinued September, 1966, or earlier.

2. CHEMICAL PHYSICS PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A13*)		**176 or 180**

[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are recommended.

DEPARTMENTAL PROGRAM

	Required subjects (*alternative subjects in parentheses*)			
5.41	ORGANIC CHEMISTRY I	4	0	8
	(‡5.41 ORGANIC CHEMISTRY I	4	0	4)
5.412	ORGANIC CHEMISTRY LABORATORY II	1	5	0
5.42	ORGANIC CHEMISTRY II	4	0	8
	(‡5.42 ORGANIC CHEMISTRY II	4	0	4)
5.61	PHYSICAL CHEMISTRY I	4	0	8
5.613	PHYSICAL CHEMISTRY LABORATORY I	0	4	2
5.62	PHYSICAL CHEMISTRY II	4	0	8
5.623	PHYSICAL CHEMISTRY LABORATORY II	0	4	2
8.05	PHYSICS OF ATOMS & MOLECULES I	4	0	8
8.06	PHYSICS OF ATOMS & MOLECULES II	4	0	8
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9
	THESIS		12	
			106 to 114	
	Elective subjects			
	In specified areas:			
8.711	MECHANICS I	4	0	8
	or			
8.72	ELECTROMAGNETIC RADIATION	4	0	8
	Two terms of one intermediate language, or certification of the equivalent by the Department of Modern Languages.			
	One additional laboratory subject in chemistry or physics.			
	Unspecified subjects (including additional THESIS units, not exceeding 18) as needed to fulfill the total elective unit requirement of		**78 to 66**	
Total units required for the S.B. degree			**360**	

[1] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

‡ Discontinued September, 1966, or earlier.

DEPARTMENT OF GEOLOGY AND GEOPHYSICS

Geology and Geophysics (Course XII)

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A13*)		**176 or 180**
[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are taken except when plans for further study clearly indicate the need for the subject matter of PHYSICS ‡8.031 and ‡8.041.		
DEPARTMENTAL PROGRAM		
Required subjects		
THESIS		**15**
Elective subjects		
Specified		
Basic science and engineering subjects more advanced than the General Institute Requirements (mathematics, physics, chemistry, and approved engineering subjects) (4 or 5 subjects depending on units)	40 to 45	
Earth science subjects: a combination of subjects selected from at least two of the following categories: geosciences (geology and/or geochemistry, and/or geophysics; meteorology; and oceanography)	30	
Professional electives (9 or 8 subjects)	[2]72 to 67	
Unspecified	32 to 28	
	174 to 170	
Total units required for the S.B. degree		**365**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] Successful completion of a course of study at a regularly established field camp will carry 24 units of academic credit in Earth Science subjects.

[3] To this total must be added appropriate field experience, generally obtained in the summer, unless a course of study has been successfully completed at a regularly established field camp (see footnote 2).

‡ Discontinued September, 1966, or earlier.

Geology and Geophysics (Five-Year Course) (Course XII-A)

The undergraduate curriculum requirements are the same as for Course XII, except that the 15 units of undergraduate thesis are allotted to additional professional subjects.

The graduate requirement is 66 units of graduate study plus an acceptable thesis.

DEPARTMENT OF MATHEMATICS

Mathematics (Course XVIII)

CURRICULUM OF MATHEMATICS PROGRAM 1

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A13*)			**176 or 180**
[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are prescribed.			
DEPARTMENTAL PROGRAM			
Required subjects			
18.21T	ANALYSIS	3 0 9	
	or		
‡18.21	ANALYSIS	3 0 9	
	[2]LANGUAGE (two terms)	16	
	or		
	[2]LANGUAGE (one term)	12	
			28 to 24
Elective subjects			
Specified			
An integrated program of advanced mathematics subjects at the undergraduate or graduate level, including the following		at least 60	
either			
18.20	LINEAR ALGEBRA *or*	3 0 9	
‡18.20	LINEAR ALGEBRA	3 0 6	
	or the following combination:		
18.25	MODERN ALGEBRA *and*	3 0 9	
18.26	MODERN ALGEBRA	3 0 9	
either			
18.22T	ANALYSIS *or*	3 0 9	
‡18.22	ANALYSIS *or*	3 0 9	
18.31	THEORY OF FUNCTIONS *or*	3 0 9	
18.49	HARMONIC ANALYSIS AND POTENTIAL THEORY	3 0 9	
either			
18.24	ELEMENTARY DIFFERENTIAL GEOMETRY *or*	3 0 9	
‡18.24	ELEMENTARY DIFFERENTIAL GEOMETRY	3 0 6	
	or the following combination:		
18.241	INTRODUCTION TO TOPOLOGY *and*	3 0 9	
18.242	RIEMANNIAN GEOMETRY	3 0 9	
Senior seminar in mathematics, thesis, or advanced mathematics subject at the undergraduate or graduate level		12	
Advanced professional subjects in the Schools of Science or Engineering at the undergraduate or graduate level		at least 41	
Unspecified subjects as needed to fulfill the elective unit requirement of			**156**
Total units required for the S.B. degree			**360**

CURRICULUM OF MATHEMATICS PROGRAM 2

	Total units
GENERAL INSTITUTE REQUIREMENTS (*see page A13*)	**176 or 180**
[1]PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are prescribed.	

DEPARTMENTAL PROGRAM

	Required subjects		
18.21T	ANALYSIS	3 0 9	
	or		
‡18.21	ANALYSIS	3 0 9	
18.651	INTRODUCTION TO APPLIED MATHEMATICS	3 0 9	
	[2]LANGUAGE (two terms)	16	
	or		
	[2]LANGUAGE (one term)	12	
			40 to 36
	Elective subjects		
	Specified		
	An integrated program of advanced mathematics subjects at the undergraduate or graduate level, including the following	at least 48	
	either		
18.20	LINEAR ALGEBRA *or*	3 0 9	
‡18.20	LINEAR ALGEBRA	3 0 6	
	or the following combination:		
18.25	MODERN ALGEBRA *and*	3 0 9	
18.26	MODERN ALGEBRA	3 0 9	
	either		
18.22T	ANALYSIS *or*	3 0 9	
‡18.22	ANALYSIS *or*	3 0 9	
18.652	INTRODUCTION TO APPLIED MATHEMATICS	3 0 9	
	either		
18.60	INTRODUCTION TO FLUID MECHANICS *or*	3 0 9	
‡18.60	INTRODUCTION TO FLUID MECHANICS *or*	3 0 6	
18.66	INTRODUCTION TO ELASTICITY	3 0 9	
	or		
‡18.66	INTRODUCTION TO ELASTICITY	3 0 6	
	Senior seminar in mathematics, thesis, or advanced mathematics subject at the undergraduate or graduate level	12	
	Advanced professional subjects in the Schools of Science or Engineering at the undergraduate or graduate level	at least 41	
	Unspecified subjects as needed to fulfill the elective unit requirement of		**144**
	Total units required for the S.B. degree		**360**

[1] Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] 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 unspecified elective subjects for the language requirement.

‡Discontinued September, 1966, or earlier.

DEPARTMENT OF PHYSICS

Physics (Course VIII)

GENERAL INSTITUTE REQUIREMENTS (*see page A13*) — *Total units* **176 or 180**

[1] PHYSICS 8.03 (4–0–8) and 8.04 (4–0–8) *or* ‡8.031 and ‡8.041 are prescribed but PHYSICS ‡8.03 (4–1–5) and ‡8.04 (4–1–5) are acceptable, when completed with good grades, in the case of students transferring to Course VIII.

DEPARTMENTAL PROGRAM

	Required subjects		
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 9	
8.05	[2]PHYSICS OF ATOMS AND MOLECULES I	4 0 8	
8.08	ELECTRONICS	4 0 8	
8.09	EXPERIMENTAL ATOMIC PHYSICS I	0 6 6	
8.06	[2]PHYSICS OF ATOMS AND MOLECULES II	4 0 8	
8.10	EXPERIMENTAL ATOMIC PHYSICS II	0 6 6	
8.711	MECHANICS I	4 0 8	
8.11	EXPERIMENTAL PHYSICS	2 0 2	
8.72	ELECTROMAGNETIC RADIATION	4 0 8	
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4 0 8	
	THESIS	12	
			124
	Elective subjects		
	Specified		
	One additional subject in the Mathematics Department		
	Unspecified subjects as needed to fulfill the total elective unit requirement of		**60 to 56**
	Total units required for the S.B. degree		**360**

[1] 8.041 must be followed by 8.05 (or 8.051). Class '68: take 8.03 (4–0–8) and 8.04 (4–0–8).

[2] In special cases 8.051 (4–0–8) and 8.053 (4–0–8) will be accepted in place of 8.05 and 8.06.

‡ Discontinued September, 1966, or earlier.

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 Science Teaching 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 41–43.

In the second year it is recommended that the student take INTRODUCTORY CIRCUIT THEORY I (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 which will be useful in his subsequent laboratory subjects. Omission of this subject from a student's second-year curriculum will necessitate added effort on his part in connection with his third-year laboratory work. Adequate elective time is made available in the second year and students may wish to take a mathematics subject beyond 18.034 at this time.

The departmentally prescribed subjects 8.05, 8.06, 8.08, 8.09, and 8.10 are normally taken in the third year. Students interested in molecular and solid state physics may prefer to substitute INTRODUCTION TO SOLID-STATE PHYSICS (8.44) for ELECTRONICS (8.08). Part of the elective time available in the second term of the third year may be used effectively in a variety of ways. For example, a student may take 8.07 or 8.72 to obtain greater flexibility in his fourth-year program; he may elect INTRODUCTION TO NUCLEAR PHYSICS (8.053) if his interests lie in this direction. Each student is urged to explore with his Faculty Counselor various possibilities of electing those subjects which are best suited to his individual needs at this stage of his studies.

In the fourth year students generally undertake 8.11, 8.07, and the theoretical sequence 8.711 and 8.72. A relatively large amount of elective time thus becomes available in this year and can be used effectively in a wide variety of ways. EXPERIMENTAL PHYSICS (8.11) is designed to enable the student to come face to face with the challenge of exploring a problem in experimental physics in the same spirit in which 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 8.11 to enable him to obtain the competence in experimental work which he needs to embark successfully on his future professional career.
2. A corresponding sequence of lecture (and recitation) subjects. In this sequence the theoretical subjects 8.711 and 8.72 are designed to recapitulate and organize the essentials of classical theoretical physics and also to provide a solid theoretical springboard for much of the student's future education in physics.

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 181*)	
Specific science and humanities and social science subjects	**128**
The Science Distribution Requirement will be satisfied by 8.03 and 18.034, which are required in the Departmental Program, plus appropriate subjects[1] (see page 44) totalling	**12**

(*continued*)

GENERAL INSTITUTE REQUIREMENTS (*continued*)

The subject 8.09, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 45) and can be used to satisfy the Laboratory Requirement.

DEPARTMENTAL PROGRAM

Required Subjects

18.034	DIFFERENTIAL EQUATIONS	3	0	9	
8.03	ELECTRICITY AND MAGNETISM	4	0	8	
8.04	MODERN PHYSICS	4	0	8	
8.05	PHYSICS OF ATOMS AND MOLECULES I	4	0	8	
8.06	PHYSICS OF ATOMS AND MOLECULES II	4	0	8	
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8	
8.08	ELECTRONICS	4	0	8	
8.09	EXPERIMENTAL ATOMIC PHYSICS I	0	6	6	
8.10	EXPERIMENTAL ATOMIC PHYSICS II	0	6	6	
8.11	EXPERIMENTAL PHYSICS	2	0	2	
8.711	MECHANICS I	4	0	8	
8.72	ELECTROMAGNETIC RADIATION	4	0	8	
	[2]THESIS		12		
					148

Restricted Electives

Two subjects given by the Department of Mathematics beyond 18.034 — **24**

Unrestricted Electives[3] — **48**

Total units required for the S.B. degree — **360**

[1] Students may find it advantageous to elect 6.01 INTRODUCTORY CIRCUIT THEORY I (4–0–8) or 6.14 ELECTRONIC NETWORKS AND DEVICES (4–2–6), in the second term of the second year. Either of these subjects 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] Programs of students in Course VIII may always be arranged to leave available 12 units of unrestricted elective in each of the first and second years.

GRADUATE STUDY IN PHYSICS

The Department of Physics offers graduate work leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Physics. No stated curriculum of subjects of instruction is required for any of these degrees; instead, individual curricula are chosen in consultation with the Registration Officer, in accordance with certain broad principles.

Subjects of study include work in almost all of the experimental fields described in the paragraphs above, and in the various branches of theoretical physics as well. Graduate students are expected to gain real familiarity with several of the branches of physics, not merely with one specialty. They will be well prepared for either academic work or industrial research, since the training includes a broad and thorough understanding of both the fundamentals of physics and its advanced applications.

A number of 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. The following subjects or their equivalents are also required but are not credited in fulfillment of degree requirements:

PHYSICS OF ATOMS AND MOLECULES I AND II (8.05, 8.06)
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)
ELECTRONICS (8.08)

Twenty-four units in the following advanced undergraduate subjects may be credited toward, and are required for, advanced degrees:

EXPERIMENTAL PHYSICS (8.11)
MECHANICS I (8.711)
ELECTROMAGNETIC RADIATION (8.72)

Deficiencies in subjects required for admission or for advanced degrees may be removed while the student is engaged in graduate work.

The Graduate Degrees

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 IN PHYSICS

For the degree of Doctor of Philosophy or of Doctor of Science, the Physics Department 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.

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

JAMES LAWRENCE PETTIGREW, M.S.
Major, U. S. Air Force
Associate Professor of Aerospace Studies

RICHARD E. BRUBAKER, M.S.
Major, U. S. Air Force
Associate Professor of Aerospace Studies

Instructors

THOMAS PHILIP NAGLE
Technical Sergeant, U. S. Air Force

EARL SYLVESTER RASMUSSEN
Staff Sergeant, U. S. Air Force

CENTER FOR INTERNATIONAL STUDIES

MAX FRANKLIN MILLIKAN, PH.D.
Director

DONALD LAWRENCE MORTON BLACKMER, A.M.
Assistant Director

DRAMA

JOSEPH DEE EVERINGHAM, A.M.
Director of Drama

INTERDEPARTMENTAL LABORATORIES

Center for Materials Science and Engineering

ROBERT ALLAN SMITH, PH.D.
Director

Center for Space Research

JOHN VINCENT HARRINGTON, SC.D.
Director

HERBERT SAGE BRIDGE, PH.D.
Associate Director

Computation Center

PHILIP McCORD MORSE, PH.D., SC.D.
Director

FERNANDO JOSÉ CORBATÓ, PH.D.
Deputy Director

WILLIAM BRUNNER KEHL, A.M.
Associate Director

Laboratory for Nuclear Science

PETER THEODORE DEMOS, PH.D.
Director

FREDERIC JOHN EPPLING, PH.D.
Associate Director

National Magnet Laboratory

BENJAMIN LAX, PH.D.
Director

ARTHUR JAY FREEMAN, PH.D.
Associate Director

DONALD THOMAS STEVENSON, PH.D.
Assistant 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

RALPH ALLEN SAYERS
Assistant Director

Spectroscopy Laboratory

RICHARD COLLINS LORD, PH.D., SC.D.
Director

CAMBRIDGE ELECTRON ACCELERATOR OF HARVARD UNIVERSITY AND THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MILTON STANLEY LIVINGSTON, PH.D., SC.D.
Director

JOINT CENTER FOR URBAN STUDIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND HARVARD UNIVERSITY

DANIEL P. MOYNIHAN
Director

LLOYD RODWIN, PH.D.
Chairman of the Faculty Committee

DEPARTMENT OF MILITARY SCIENCE

JACK RICHARD SHIELDS, B.S.
Lieutenant Colonel, Ordnance Corps
Professo. of Military Science; Head of the Department

JOHN DANIEL BLANKENSHIP, B.ED.
Captain, Infantry
Associate Professor of Military Science

Instructors

DAVID JOSEPH PAWELSKI, B.S.
Sergeant Major, U. S. Army

THADDUS McCOLLUM STRICKLAND
Staff Sergeant, U. S. Army

HENRY L. WHALEN
Master Sergeant, U. S. Army

Administrative Assistant

ROBERT SEAGRAVE SIMPSON
Staff Sergeant, U. S. Army

MUSEUMS

HERBERT LYNES BECKWITH, M.ARCH.
Chairman of the Committee on the Technology Museum

MUSIC

KLAUS LIEPMANN
Director of Music

JOHN DEAN CORLEY, JR., M.MUS.
Assistant Director of Music

DAVID M. EPSTEIN, M.F.A.
Conductor of the M.I.T. Symphony Orchestra

JOHN SANFORD OLIVER, B.MUS.
Assistant Director of the Glee Club

JOHN COOK, MUS.B.
Organist

DEPARTMENT OF NAVAL SCIENCE

ROBERT EDWARD STARK, S.M.
Captain, U. S. Navy
Professor of Naval Science; Head of the Department;
Professor of Naval Construction

JOSEPH ALLEN MATTHEWS, B.S.
Commander, U. S. Navy
Associate Professor of Naval Science

LEO HARVEY CRAIGLOW, JR., A.B.
Lieutenant, U. S. Navy
Assistant Professor of Naval Science

ROBERT M. CLIFFORD, B.S.
Lieutenant Junior Grade, U. S. Navy
Assistant Professor of Naval Science

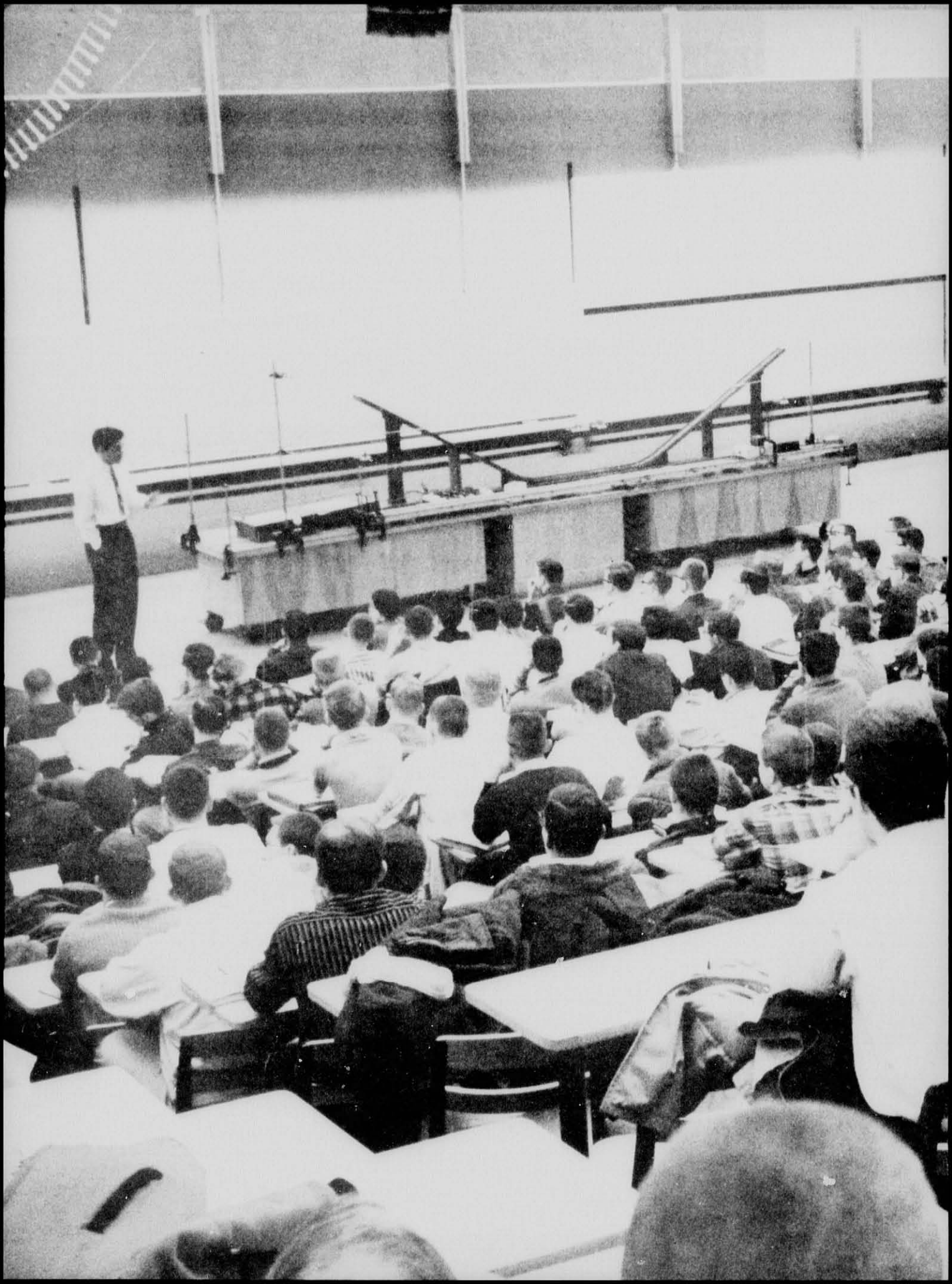
Instructors

ROBERT CHARLES KELLY
Chief Yeoman, U. S. Navy

NORMAND O. HAMEL
Chief Storekeeper, U. S. Navy

FREDERICK P. PETERKIN
Staff Sergeant, U. S. Marine Corps

TERRY L. WARD
Yeoman Second Class, U. S. Navy



DESCRIPTIONS OF SUBJECTS

The subjects and descriptions given in this Section are subject to change. The final list of subjects to be given in 1966–67 will be published with the class schedules prior to the beginning of each term.

"T" at the end of a subject number indicates that (1) a change has been made in the content or units of the subject or (2) the number was previously assigned to a different subject.

"J" at the end of a subject number indicates that the subject is a joint offering of more than one department.

"(A)" following the name of a subject indicates that it is an approved subject for a graduate degree.

"(R)" following the name of a subject indicates that it is restricted to special groups because of content; all subjects open only to special groups are so noted at the end of the description of the subject.

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

1. The number(s) of prerequisite subjects, if any. Numbers in italics indicate subjects which may be taken simultaneously with the subject described.
2. The year classification (and term) for which the subject is normally scheduled. This is indicated as follows: "1" is a first-year subject only, and not accepted for upperclass credit; "U" is an undergraduate subject above the first year; "G" is a graduate subject.
3. The time distribution of the subject, showing in sequence the units allotted to: recitation and lecture; laboratory, 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 (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 application 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, XIV, *and* XVII*; others admitted by permission of instructor.*)
Walton

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.: 5.01, 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 noncrystalline phases; thermodynamics of phase relationships and structural change; elasticity, microplasticity, viscoelasticity, and fracture; corrosion. Application of principles to structural metals, cementitious materials, structural ceramics, wood, asphalt, and polymers. Mechanical properties of composite materials, including Portland cement concrete, asphalt-aggregate mixtures, and reinforced plastics. Laboratory work on the common techniques used in the study of microstructure and in the determination of mechanical properties.
Jones, Williamson

1.03 *Engineering Analysis*
Prereq.: 18.034
Year: U (1) 4–0–8
The mathematical formulation of physical problems arising in engineering and the solution and interpretation of the associated equations. Topics selected from classical dynamics and vibrations, electrical circuit theory, heat transfer, fluid mechanics, modern physics, wave phenomena. Mathematical subject matter to include linear, ordinary and partial differential equations, Fourier series, Bessel functions, Legendre polynomials, vector analysis and complex variables. Emphasis on the correspondence between mathematical operations and their physical counterparts and the analogies between different physical systems.
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 and of reinforced concrete elements. Design of tension, compression, bending, and combined stress members using standard steel sections. Study of built-up sections and connections. Design of reinforced concrete beams and columns with attention given to both straight line and ultimate strength theories. Consideration of shear, diagonal tension, bond, and anchorage.
Sturman

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.
R. V. Whitman

1.07 *Principles of Uncertainty*
Prereq.: 18.034
Year: U (1, 2) 3–0–6
The elementary notions of probability including events, random variables, distributions, expectation, and derived

distributions. Simple stochastic processes with engineering applications. Statistical treatment of experimental data with emphasis on appropriate use of the information contained therein. Formulation, estimation, and evaluation of probabilistic models of civil engineering systems and their environments; the role of such models in engineering design, analysis, and rational decision. Examples and case studies chosen from fields of structures, transportation, materials, hydrology, water resources, etc.
Bisbee, 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, sedimentary, and metamorphic rocks; soils. Alluvial, glacial, eolian, lacustrine, marine, and colluvial sediments. Rock defects; faults; weathered zones. Air photos and geologic maps. Field trips. *Hirschfeld*

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. *Lambe*

1.10 *Civil Engineering Laboratory*
Prereq.: ——
Year: U (1) 0–6–6
A program designed to introduce the student to the experimental solution of problems in the major disciplines of civil engineering. Student work on three or more 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 nonlinear algebraic and transcendental equations.
Connor

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. *Z. M. Elias*

1.143 *Mathematical Optimization Techniques I* (A)
Prereq: 1.141
Year: G (1) 3–0–6
A survey of mathematical background and algorithms for the solution of optimization problems encountered in the design and operation of engineering systems. Applications including project scheduling, resource allocation, warehousing/shipping problems, and traffic prediction control. Introduction to linear programming. Simplex algorithm. Duality theorems and economic interpretations. Minimal cost transportation problem and variants. Bounded variable simplex algorithm. Network interpretations. Maximal flow and shortest route algorithms. Applications to project scheduling: CPM and PERT. *Hershdorfer*

1.144 *Mathematical Optimization Techniques II* (A)
Prereq.: 1.143
Year: G (2) 3–0–6
Continuation of 1.143. Dynamic programming and sequential decision processes. Integer linear programming. Decomposition of linear programs. Primal-dual algorithms. Introduction to graph theory. *Hershdorfer*

1.148 *Decision Theories in Engineering and Planning* (A)
Prereq.: 1.07, 1.144
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. Definitions of rationality; behaviorist approaches to decision-making; Schoeffler's model; the statistical decision theory model; subjective probabilities and Bayesian decision theory; relaxation of information requirements in applying Bayesian decision theory in practical situations; sequential decision models — statistical and dynamic programming; problems of generating alternatives; Alexander's method for structuring the search process; hierarchical structure; economics of problem-solving. Research seminar with extensive student contributions. (*Permission of instructor required.*)
Manheim

1.15 *Computer Laboratory*
Prereq.: ——
Year: 1 (2) 1–3–2
Introduction to the use of information-processing machines for the solution of engineering and related problems. Principles of digital computers with emphasis on programming languages and their relation to the problem of man-machine communication. Limited treatment of related topics including time sharing, teleprocessing, on-line computation, and analog computers. Extensive laboratory experience in formulating problems for computer solution and in programming with machine, assembly, procedure-oriented, and problem-oriented languages. (*Note: 1.15 is limited to first-year students. Students planning to enter Course 1 should register for 1.00.*) (*Limited enrollment.*)
Perkins

1.151 *Computer Approaches to Engineering Problems*
Prereq.: ——
Year: G (1) 3–2–4
Accelerated treatment of material covered in 1.00. Principles and engineering applications of programming

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systems and languages. Man-machine communications and organization of computer systems. Problem-oriented languages and integrated systems. Real-time systems, computer-aided design, graphical data processing. Extensive laboratory experience in computer programming and project application of information systems to civil engineering problems. (*Primarily for Course* 1 *graduate students; others admitted by permission of instructor.*) *Logcher*

1.152 *Civil Engineering Computer Systems Seminar* (A)
Prereq.: 1.00 or 1.151
Year: G (2) 2–2–5
Computer software and hardware capabilities required for the solution of civil engineering problems. Topics to include operating systems, memory organization, dynamic memory allocation, data structures, problem-oriented languages, executive routines, time-sharing systems, graphical input/output, organizational and economic considerations, systems planning and evaluation. Current research on the development of civil engineering computer systems. *Roos*

1.154 *Simulation Methods* (A)
Prereq.: 1.07, 1.151
Year: G (1) 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. *Walton*

1.16J *Special Studies in Systems Engineering* (A)
(same subject as 2.191J, 6.604J, 16.362J)
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 trade-offs 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. (Projects for 1966 were: Group 1 — An integrated urban transportation system; Group 2 — A manned satellite inspection and retrieval system.) *Bisbee, Baumann, Seifert, Li*

1.21 *Fundamentals of Transportation Systems* (A)
Prereq.: ——
Year: G (1) 3–0–6
Technological and operating characteristics of highway, air, rail, and other transportation systems; energy requirements, propulsion, resistances, speed, capacity, flexibility, performance, and cost. Consideration of optimum use of modes and combinations of transportation systems. Elements of planning, design, and engineering of transportation facilities; data procurement; prediction of demand; design of ways, terminals, and control systems. Applications to real situations. *Bone*

1.212 *Urban Highway Systems* (A)
Prereq.: 1.21
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. *Bone*

1.213 *Transportation Systems Analysis* (A)
Prereq.: 1.151, 1.21
Year: G (1) 3–0–6
Techniques of systems engineering applied to the project evaluation of engineered facilities associated with land, air, and marine transportation. Mathematical models of simple transportation processes. Techniques for predicting demand for transportation systems. The hierarchical structure of the project planning and engineering phases and the development of a framework for project evaluation under conditions of goal optimization and sub-optimization. Computer-aided techniques of searching for alternatives. Characteristics of the various modes and models for prediction of vehicle performance and operating costs as well as initial and continuing costs associated with the physical facilities. Evaluation of measures of effectiveness and their use in decision making. Application to components of overall systems. *Breuning*

1.214 *Transportation Systems Design* (A)
Prereq.: 1.143, 1.213
Year: G (2) 3–0–6
Study of information systems for use in the planning and design of transport projects. Simulation as a tool for investment planning and scheduling over regional and interregional systems. Linear programming models of multimodal networks. Synthesis of optimal and near-optimal systems. Use of dynamic programming for project scheduling and priorities in multi-stage decision processes. Applications to case examples. *Breuning*

1.221J *Flight Transportation* (A)
(Same subject as 6.671J, 15.483J, 16.751J)
Prereq.: 1.21
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, Reintjes, Farrar, R. H. Miller

1.222J *Flight Transportation Seminar*
(Same subject as 6.672J, 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, Reintjes, Farrar, Browne*

1.23 *Flight Transportation Facilities* (A)
Prereq.: 1.21 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. *Bisbee*

1.252 *Advanced Topics in Discrete Flow Control* (A)
Prereq.: 1.251
Year: G (1) 3–0–6
Control classification, controllability for the unsaturated and the saturated cases. Time-dependent inputs with strong peaking and the application of Pontryagin's maximum principle to the priority selection problem. Signal control of intersections, arteries, and grids, the use of von Stein's approach and the mathematical programming formulation of signal progression. Special topics from recent research literature varying from year to year. Emphasis on model formulation and analysis. (*Permission of instructor required.*) *Bisbee*

1.261 *Advanced Transportation Planning I* (A)
Prereq.: 1.21
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, trade-offs 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.: 1.21
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
Construction and interpretation of flow nets for isotropic and anisotropic, homogeneous and non-homogeneous soils. Solution of the one-dimensional consolidation equation for various initial and boundary conditions; introduction to consolidation in three dimensions. Stress distributions within elastic half-space. Rankine and Coulomb solutions for active and passive pressure. Derivation of Terzaghi bearing capacity equation and factors. Slope stability analysis. *Luscher*

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. *R. V. Whitman*

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*

1.322T *Soil Technology* (A)
Prereq.: 1.06
Year: G (1) 3–0–6
Mineralogy of clay minerals and the principles of colloidal chemistry and their application to an understanding of the behavior of clay soils. Study of the following topics: chemical and mineralogical composition of soils, interparticle electrical forces, nature of adsorbed water, concepts of soil fabric and soil structure and their use in interpretation and prediction of the engineering behavior of clay with particular reference to the effects of environment (temperature, pore fluid composition, etc.). *Ladd*

1.331 *Soil Dynamics* (A)
Prereq.: 1.03, 1.06
Year: G (1) 3–0–6
Fundamentals of dynamic soil behavior as applied to explosion effects, earthquake effects, and foundation vibrations. Stress-strain-time behavior of soils for conditions of rapid stress change; analysis of dynamic stresses and strains in soil-like masses. Wave propagation in one dimension for elasto-plastic and visco-elastic materials; introduction to wave propagation phenomena in three dimensions; application to explosion effects problems. Cratering and near-crater ground motions. Earthquake ground motions; stability of slopes and earth dams subjected to earthquake loadings. Theories of vibration of mass resting upon elastic half space; application to foundation vibration problems. *R. V. Whitman*

1.34 *Seminar on Physics of Soil Systems* (A)
Prereq.: ——
Year: G (1) 2–0–4
Discussion of current research on the physics of soil systems. In some years primary emphasis on clay-water systems; other years, on granular systems. *Staff*

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1.361 ***Advanced Soil Mechanics*** **(A)**
Prereq.: 1.06
Year: G (1) 3–0–6
Consideration of principles of soil mechanics including: soil composition, effective stress, influence of fluid flow on soil behavior, pore pressures developed in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems. *Lambe*

1.362 ***Earth Structures*** **(A)**
Prereq.: 1.361
Year: G (2) 3–0–6
Stability of natural and cut slopes. Design of earth dams and embankments including site exploration, excavation and drainage, considerations of stability and seepage, specifications, and construction control. Field measurements of settlement, pore pressures, seepage, etc. Case studies. *Staff*

1.364 ***Foundations*** **(A)**
Prereq.: 1.361
Year: G (2) 3–0–6
Types of foundations and retaining structures including excavations, footings, piles, retaining walls, and bulkheads. Considerations of exploration, economics, construction operations, and design. Emphasis on settlement and bearing capacity analyses and methods of field measurements. Model tests and case studies. *Lüscher*

1.37T ***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*

1.38T ***Engineering Geology*** **(A)**
Prereq.: 1.06, 1.08
Year: G (2) 3–3–6
Advanced physical geology covering rock and transported and residual soils with discussion of geologic origin, physical properties, influence on required subsurface exploration program and engineering design, and measures for treating undesirable conditions, including case studies. Laboratory work on identification of minerals and rocks, air photo analysis, and interpretation of geologic maps and structural sections. *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: 1 (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.
Williamson, Jones

1.401 ***Physics of Materials***
Prereq.: ——
Year: 1 (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. 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 (1, 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 multi-phase systems. Reference to present and anticipated materials. Laboratory primarily concerned with structure-composition-mechanical property interactions. *Jones*

1.451 ***Mechanics of Layered Systems*** **(A)**
Prereq.: 1.02, 1.03
Year: G (1) 3–0–6
Concepts of layered systems with emphasis on analysis of flexible and rigid pavements. Formulation of equations for stresses and displacements in semi-infinite bodies and in double and multi-layer systems subjected to various loadings. Analysis of thermal stresses, stresses in reinforcement, effects of anisotropy. Nonelastic behavior of paving materials, including linear viscoelastic effects. Introduction to engineering design methods.
Moavenzadeh

1.452 ***Design and Behavior of Pavement Systems*** **(A)**
Prereq.: 1.02, 1.03
Year: G (2) 3–0–6
Principles of engineering design of flexible and rigid pavements for highways and airfields. Detailed study of properties of highway materials; emphasis on physical and chemical factors influencing behavior of particulate systems and composites. Discussions of environmental effects, pavement strengthening methods, evaluation procedures. *Moavenzadeh*

1.46 ***Concrete and Cementitious Materials*** **(A)**
Prereq.: 1.02
Year: G (2) 3–2–4
Advanced study of Portland cement concrete and other cementitious materials used in construction. Emphasis on mechanical behavior and durability as related to composition of binders, types and amounts of aggregates, nature of processing and hardening, structure and microstructure of final composite. Rheology of mixtures, thermodynamic effects and chemical reactions in setting, fracture mechanisms. Effects of additives. Laboratory work devoted to illustration of principles, study of structure, measurement of properties. *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*

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. *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. Individual and group study of topics arranged by the instructor in charge. Special reading assignments, consultation, and original investigations in the Materials Research Laboratory. *McGarry*

1.501T *Structural Mechanics*
Prereq.: 1.01 or 2.012
Year: G (1) 3–1–6
Elementary analysis of stress, strain, and deflection of typical structural members. Elastic and plastic behavior of both statically determinate and indeterminate arrangements. Elementary consideration of plates and shells and of buckling and dynamic response of structures. 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*

1.502T *Naval Structural Engineering*
Prereq.: 1.501
Year: G (2) 3–0–5
Application of the principles of elementary structural mechanics, and of behavior of materials to analysis and design of typical naval structural arrangements. Laboratory work with models to illustrate behavior of typical structural types. (*Primarily for selected officers of the U.S. Navy and Coast Guard.*) *Mirabelli*

1.51 *Structural Analysis and Design*
Prereq.: 1.04, 18.034
Year: U (2) 3–2–5
Analysis of continuous structural systems and design of complete structures. Stiffness matrix formulation for rigid-jointed structures. Equilibrium, compatibility, and force-deformation equations. Development of structural matrices using the connectivity matrix. Analysis of arches, curved beams, and simple structures using variable depth members. Small deflection theory of plates. Boundary conditions for rectangular plates. The Navier solution. Stiffened plates. Theory of elastic stability. Elastic and inelastic stability of straight columns. The column curve. Solutions to the stability problem. Lateral stability of beams. Built-up columns and columns of variable stiffness. Plate stability. Limit analysis of continuous beams and simple frames. Plastic moment capacity of various shapes. Equilibrium and mechanism methods. Design of structural systems. Multi-story steel frames, industrial buildings, floor grids. Reinforced concrete structural systems. Floor slabs, building frames. Design of key portions of reinforced concrete and steel building frames. *Sturman*

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*

1.522 *Experimental Design of Shell Structures* (A)
Prereq.: 1.521
Year: G (2) 1–4–1
Use of experimental and approximate analytical techniques for the design of typical shell type structures. Consideration of problems of instability, stress distribution and ultimate strength in relation to the assumed form and its possible modifications. Presentation and use of analytical methods where possible, but with emphasis on the experimental method of design. One or more case studies developed by the class. *R. J. Hansen*

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*

1.541 *Behavior of Reinforced Concrete Structures* (A)
Prereq.: 1.51
Year: G (1) 3–0–6
Consideration of the actual behavior and strength of various concrete structural members and panels involving a critical comparison of present theory and accepted

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design procedures with significant experimental and analytical investigations, and with current design specifications. Flexural behavior of reinforced concrete beams including thorough discussion of shear, diagonal tension, and bond; behavior of both short and long columns; buckling of columns, flat and curved panels, and slender flexural members; behavior of shear walls, deep beams, and prestressed members. *Holley*

1.542 *Advanced Reinforced-Concrete and Prestressed-Concrete Design* (A)
Prereq.: 1.541
Year: G (2) 2–0–4
Application of theory and characteristic behaviors discussed in 1.541 to design of civil engineering structures such as slabs, precast decking, rigid frames, arches, prestressed concrete tanks, continuous prestressed concrete girders, etc. *Holley*

1.551 *Advanced Structural Design* (A)
Prereq.: 1.51
Year: G (1) 3–0–6
General principles of structural design. Factor of safety. Probabilistic approach to design. Ultimate versus elastic design. Stress control and erection of indeterminate structures. Economics and preliminary planning of structures. Approximate analysis for preliminary design of indeterminate structures. Application of computers to design. *Litle*

1.552 *Advanced Design of Metal Structures* (A)
Prereq.: 1.51
Year: G (2) 3–0–6
Consideration of structural behavior and design of typical metal structures and structural components. Lectures covering material properties, comprehensive review of methods of plastic analysis and design, discussion of background for and basis of code design, code requirements for both elastic and plastic design, and construction considerations. Illustration by comprehensive design problems involving the student in the use of computers and physical models as design tools. *Litle*

1.561 *Advanced Structural Mechanics* (A)
Prereq.: 1.51
Year: G (1) 3–0–6
Introduction to the mechanics of continuous bodies: analysis of stress and strain, stress equilibrium equations and elastic stress-strain relations using matrix-tensor notation. Discussion of the "generalized plane stress" case. Development of the Saint-Venant Theory of flexure and torsion for prismatic bars. Membrane analogy for torsion. Formulation of the technical theory for beams and plates. Consideration of the variational principles of elasto-mechanics. Discussion of curvilinear coordinates and differential geometry of surfaces. More detailed application considered in 1.584 and 1.588.
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
Introduction to matrix algebra and linear transformations. Rigorous formulation of the governing equations for an ideal truss using matrix notation. Discussion of the displacement and force methods of solution and their corresponding variational principles. Development of flexibility relations for a member element. Formulation of governing equations for a system of member elements using matrix notation and consideration of the various solution procedures. Discussion of finite element methods for plate and shell structures. *Connor*

1.582 *Structural Reliability* (A)
Prereq.: 1.51
Year: G (2) 2–0–4
Statistics and probability theory applied to structural engineering. Resistance and loading functions as random variables. Probability of failure or survival. Reliability of structural systems. Probabilistic approach to structural design based on consequences of failure. Cost versus reliability. Practical applications. *Cornell*

1.584 *Analysis of Shell Structures* (A)
Prereq.: 1.561
Year: G (2) 2–0–4
General derivation of the governing equation for the technical theory of thin shells. Specialization for various types of shells such as spherical, cylindrical, etc. Discussion of the assumptions, limitations, and solution techniques for the membrane theory. Consideration of parametric expansion procedures for the bending theory of shells of revolution with application to cylindrical and spherical shells. Discussion of shallow shell theory with application to various shells such as hyperbolic paraboloids, etc. *Z. M. Elias*

1.586 *Structural Dynamics* (A)
Prereq.: 1.51
Year: G (1) 2–0–4
Analysis and design of structures subjected to dynamic loads. Modal analysis of multi-degree systems. Numerical methods. Inelastic response. Continuous systems. Practical design methods. Applications to earthquake design, blast-resistant structures, machine supports, bridge vibration, etc. *Biggs*

1.588 *Buckling of Structures and Structural Elements* (A)
Prereq.: 1.561
Year: G (2) 2–0–4
Detailed consideration of elastic and plastic buckling behavior of individual column and flexural elements. Buckling of plates considered and applied to local buckling of structural members. Buckling of shells, frames, trusses and arches also discussed. *Connor*

1.60 *Applied Fluid Dynamics*
Prereq.: 1.05
Year: U (2) 3–0–6
Continuation of 1.05. Nonuniform flow and energy dissipation in conduits for compressible and incompressible fluids. Compound conduit systems for fluid transport. Non-uniform, free surface flow. Problems in unsteady flows including mass oscillations and shock wave formation. Drag and lift forces on immersed bodies. Free surface effects and compressibility effects on resistance. Turbulent jets, momentum and mass transfer, turbulent diffusion, and mixing processes. *Eagleson, 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. *McLaughlin, 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 bound-

ary 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*

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.: 1.632 or 1.65
Year: G (2) *Arr.*
Advanced topics selected by students for individual study with staff approval. Choice of subjects from theoretical, experimental, and practical phases of hydromechanics, hydraulic engineering, and water resources. *Ippen*

1.681 *Experimental Hydromechanics* (A)
Prereq.: 1.05
Year: G (1) 2–0–4
Theory of dynamic similarity, dimensional analysis, and correlation of experimental data. Modelling of hydraulic structures, free surface flows, flows over erodible beds, flow through porous media, transport processes, rotating fluid systems, hydraulic machinery, and ships. Use of analogies. Practical methods of establishing dynamic similarity in distorted and undistorted models. Instrumentation and experimental techniques. *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*

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. *Staff*

1.71 *Hydrology* (A)
Prereq.: 1.00, 1.05
Year: G (1) 3–0–6
Study of the problems of long-term basin yield and of short-term streamflow prediction from the viewpoint of the response of linear and nonlinear physical systems to periodic, transient, and random inputs. Presentation of physical hydrology in a manner suitable for problem formulation, with attention given to those statistical techniques needed in forecasting, fitting, and evaluation. *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 physical processes involving resistance and dispersion. Basic media characteristics in relation to transport phenomena. Analysis of steady and unsteady flow problems in confined and free surface aquifers. Multiple phase flow, miscible fluid displacement, and mixing. Applications in the field of groundwater flow including seepage in embankments, extraction and recharge of groundwater, water quality, and saline intrusion. *Harleman*

1.731 *Water-Resource Systems I* (A)
Prereq.: 1.05
Year: G (1) 2–2–4
General principles of the application of system analysis to problems in water-resource engineering. Water-resource projects as systems. Identification of objectives, economic benefits, costs, and decision variables. Application of microeconomics to design. Analysis of performance and production. Techniques for finding optimal development or minimum cost. Computation periods for problems requiring a combination of economic and engineering analysis. *McLaughlin*

1.732 *Water-Resource Systems II* (A)
Prereq.: 1.00, 1.07, 1.71, 1.731
Year: G (2) 2–2–4
Continuation of 1.731. Mathematical models for hydrologic inputs. Design and operation of reservoirs, decision theory, queuing theory, dynamic and linear programming, flood routing. Analysis and optimal design of systems with closed conduits, open channels, or hydraulic machinery. Conjunctive use of surface and subsurface reservoirs. Case studies. Computation periods for problems requiring a combination of several of the topics covered in 1.731 and 1.732. *McLaughlin*

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. Unit processes and operations of water quality control. Mass transport and turbulent diffusion processes. Distribution

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and dispersion of pollutants in rivers and estuaries. Selective withdrawal of liquids in stratified systems, thermal pollution, recirculation, and mixing processes in lakes and reservoirs. Optimal design of systems for water quality control. Computation periods and laboratory experiments. *Harleman, McLaughlin*

1.922J *Building Process*
(Same subject as 4.402J)
Prereq.: ——
Year: U (1) 3–3–6
The building process as influenced by structure, environment, and materials and by social, legal, and industrial constraints. Evolution of building systems in response to functional and expressive needs. Introduction to the total process of design and construction of buildings, with concentration in the laboratory-studio work on a selected aspect or development in building technology.
Dietz, Schiffer

1.951 *Construction Management* (A)
Prereq.: 1.922J
Year: G (1) 3–0–6
Field and office organizations for large construction operations, relationships of various activities necessary to prosecution and completion of constructed facilities. Functions and relationships of engineer, architect, and constructor. Types of contracts and contract documents, their bearing on construction organization. Surety and insurance. Labor organizations and labor relationships in construction. Principles of costs and cost control as applied to construction. Class work supplemented by field surveys of building and heavy construction. Participation by constructors, architects, and engineers. *Dietz*

1.952 *Construction Management Seminar* (A)
Prereq.: 1.143, 1.951
Year: G (2) 3–0–6
Continuation of 1.951. Management models of construction operations. Bar charts and their development; network flow as a basis for analysis of construction operations; critical path scheduling including arrow diagrams, critical path, normal and crash times; linear programming as applied to construction problems; elements of PERT; dynamic models (as time permits). Surveys, library research, seminar reports, term papers. Extensive contributions by students. Participation by invited industry representatives. *Dietz*

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

1.971-1.979 *Research in Civil Engineering* (A)
Prereq.: ——
Year: G (1, 2) *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.: —
Year: U (1) 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. Electrical examples and student projects on case studies of historical significance, as well as problems of current interest. *Paynter*

2.012 *Mechanics of Solids*
Prereq.: 8.02, 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. *Dahl*

2.022 *Introduction to System Dynamics*
Prereq.: 8.01, 18.02
Year: U (2) 3–1–8
Dynamic modeling, by linear and nonlinear 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 architecture. *Richardson*

2.03 *Dynamics*
Prereq.: 2.022, 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. *Crandall*

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 nonlinear vibrations. *Den Hartog*

2.06 *Vibrations*
Prereq.: 2.03
Year: U (2) 3–0–6
Analysis of vibrations in multi-degree-of-freedom systems. Characterization of physical systems by mathematical models using matrices or partial differential equations. Free vibrations and natural mode theory. Response of such systems to steady-state single-frequency excitation, to transient pulses, and to random vibration. Practical applications to vibration measurement and control. *Crandall*

2.061 *Random Vibration* (A)
Prereq.: 2.03, 18.05
Year: G (1) 3–0–9
Introduction to mathematical description of stochastic processes. Fourier transforms, power spectral density and autocorrelation functions. Analysis of response of mechanical systems to random excitation. Properties of narrow band Gaussian distributions. Application to vibration problems in missiles and jet airplanes involving wide-band random excitation. Fatigue damage under random loading. *Crandall*

2.062 *Wave Propagation* (A)
Prereq.: 18.05, 18.06
Year: G (2) 3–0–9
Wave kinematics, phase and group velocities, energy propagation. Examples of elastic, acoustic, electromagnetic, and magnetohydrodynamic waves. Ray theory versus wave theory. Transmission, absorption, refraction, diffraction, and scattering of waves. Method of stationary phase. Selected topics from the following: propagation through periodic structures, propagation through layered media, propagation through inhomogeneous, moving or random media, nonlinear waves. *Crandall*

2.063 *Sound and Structural Vibration* (A)
Prereq.: 2.03, 18.06
Year: G (1) 3–0–9
Review of stress and strain analyses of isotropic solids, elastic constants, dynamical equations. Vibration of thin beams and plates. Equations of fluid motion; stress-strain relations for viscous fluids. Small-amplitude approximations. Acoustic intensity and energy density. Generation of sound. Radiation of sound from vibrating panels, fluid loading effects, critical frequency. The statistical theory of room acoustics. Sound absorption and reverberation time. Direct and reverberent sound fields. 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 1966–67.*) *Lyon*

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*

2.08 *Strength of Materials*
Prereq.: 2.012, 2.03
Year: U (1) 3–0–6
Stress and strain in the elastic as well as the plastic states. Failure theories. Elastic and plastic torsion. Thick cylinders and rotating discs. Energy methods. Beams on elastic foundations. Introduction to plates and shells. Limit design. *Berg*

2.082 *Plasticity* (A)
Prereq.: 2.012
Year: G (2) 3–0–9
Tensor notation for stress, strain, equilibrium and geometrical conditions. Yield criteria and associated flow rule for mono- and polycrystalline material compared to data. Uniqueness. Limit analysis. Plane strain. Applications to deformation, residual stress, and fracture in bars, beams, and tubes. Other current problems. R. Hill, *Mathematical Theory of Plasticity.* *Berg*

2.083 *Advanced Mechanics* (A)
Prereq.: 2.08
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. *Dahl*

2.085 *Continuum Mechanics* (A)
Prereq.: 2.082 or 2.083 or 2.25; 2.092 or 18.15
Year: G(1) 3–0–9
Geometric foundations of continuum mechanics. Description of motion in Cartesian frames. Conservation theorems in Cartesian form. Cartesian tensors and invariants. Curvilinear frames and elements of tensor calculus. Isotropy. Application of laws of mechanics and thermodynamics to continua. Construction of constitutive relations. Irreversible thermodynamic extremal principles. Applications of above to finite elasticity, non-Newtonian flow, plastic wave propagation, viscoelasticity. *Berg*

2.092 *Methods of Engineering Analysis* (A)
Prereq.: 18.06
Year: G (2) 3–0–9
Study of the nature of complex problems in engineering analysis and of the means of obtaining practical solutions. Formulation of mathematical models for complex physical situations and the organization of computational programs for their solution. Examples chosen from mechanics, hydraulics, heat transfer, elasticity, compressible flow, etc. Numerical methods including iteration, relaxation, finite difference, and variational methods. *Crandall*

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2.101 ***Computer Models of Physical and Engineering Systems I***
Prereq.: ——
Year: U (1, 2) 3–3–6
Introduction to the power of direct application of simulative analog and digital computation to a wide variety of elementary but universally applicable systems. Lectures covering elementary philosophy of rational modelling, universal use of linear graphs for systems of relations, nature of modern analog and digital computers, and use of computers as flexible and articulate working models of both simple and sophisticated systems. Student problem work in small teams using available analog and digital machines, together with other experimental facilities of the Engineering Projects Laboratory. (*Limited enrollment.*) *Paynter*

2.13J ***Electromechanical Components and Systems***
(Same subject as 6.48J)
Prereq.: 2.022 or 6.01
Year: U (1, 2) 4–2–6
Elementary treatment of magnetic and dielectric materials and circuits, including energy conversion and force relations, with applications to electromagnetic, electrostatic and electromechanical devices, including instruments, control components, and power machinery. Laboratory work to illustrate practical and theoretical questions. *Paynter, Kingsley*

2.14 ***Control System Principles***
Prereq.: 2.022; 2.201T or 2.211; 18.034
Year: U (1, 2) 3–0–6
Dynamic analysis of interacting systems with emphasis on closed loop systems. Criteria of stability, speed of response considerations, minimization of errors, and discovery of critical transient surges of key variables. The role of feedback in a wide variety of automatic control systems. Extensive use of techniques of linear analysis. Consequences of linearization of nonlinear systems. Transient response, frequency response, and root locus techniques. Application of classical and operational methods for solution of linear differential equations. The role of computers in nonlinear as well as linear analysis. *Sheridan*

2.141 ***System Dynamics and Control*** **(A)**
Prereq: 18.05
Year: G (1) 3–0–9
Introduction to system analysis for graduate students who have not had the sequence 2.022 (or 2.02), 2.03, and 2.14. Modeling of complex linear and nonlinear mechanical, electrical, fluid, and thermal systems with emphasis on subdivision into simple multiported elements and representation with bond graphs. Concentration on lumped models but introduction to field concepts and distributed systems. Energy state functions and variational methods. Analog and digital machine simulation. Operational and transform methods for linear systems including Laplace, Fourier, matrix, and signal-flow-graph techniques and frequency and transient responses. Design of feedback systems using Nyquist, root locus, and other conventional techniques. *Paynter*

2.151 ***Advanced Control Systems*** **(A)**
Prereq.: 2.14 or 6.213T or 16.30
Year: G (2) 3–0–9
Brief survey of principal concepts and methods of analysis for interacting systems with emphasis on closed-loop behavior and design considerations. Selected topics of nonlinear control systems including sampled-data systems, describing function method, graphical analysis, optimum switched system, and basic principles of statistical designs. Discussions on adaptive control systems and time-variable parameter systems are also included. *S. Y. Lee*

2.153 ***Distributed Systems*** **(A)**
Prereq.: 2.062 or 2.14 or 2.161 or 6.07T or 16.30; 18.05
Year: G (1) 3–0–9
Power and signal flow in distributed media, with emphasis on one-dimensional structuring of engineering systems. Coupled and uncoupled elastic, acoustic, fluid, thermal, and electromagnetic energies. Uniform and nonuniform, symmetric and nonsymmetric, linear and nonlinear transmission lines. Lumped and distributed modeling, transmission matrices, matrizants, wave-scattering variables, frequency and transient response, stability, frequency-dependent dispersion and attenuation, channel capacity, and bandwidth. Systems and terminations, junctions, and mixed lumped and distributed elements. Examples such as energy transducers, counterflow heat exchangers, thermal-viscous dispersion in fluid lines and skin effect in electromagnetic lines, acoustic drivers and horns, fluid jet amplifiers, and travelling-wave parametric amplifiers. *F. T. Brown*

2.161 ***Analysis and Design of Engineering Systems I*** **(A)**
Prereq.: 2.03, 2.201T, 2.42
Year: G (1, 2) 3–0–9
Application of general system concepts to wide range of physical and engineering processes. Emphasis on variable flow of matter, energy, entropy, and information, directed toward predicting performance for specified designs. Introduction of central theme of functional reticulation into multiported elements. Systematic study of relations and interactions in terms of logical operations, transformations, matrices, ordinary and partial differential equations, signal flow graphs, block and bond diagrams, analogies, and computing systems. Lectures and problem work cover electrical, mechanical, fluid, thermal, chemical, nuclear, and biological systems. (*Not offered 1966–67.*) *Paynter*

2.162 ***Analysis and Design of Engineering Systems II*** **(A)**
Prereq.: 2.161
Year: G (2) 3–0–9
Continuation of 2.161 with emphasis on the synthesis and design of systems assembled from multiported primitives to accomplish specific tasks and functions. Particular attention given to the use of analog and digital computers as electronic models for studying alternative designs and modes of operation. Lectures and problems dealing with stochastic processes and variables, in both frequency and time domains, and with stationary and nonstationary parameters. Substantial portion of time allotted to original studies on a team basis using available electronic computers. (*Not offered 1966–67.*) *Paynter*

2.171 ***Fluid Power Controls*** **(A)**
Prereq.: 2.14; 2.201T or 2.211
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 nonlinearities with aid of computers. Selected laboratory projects to expose students to real problems encountered with fluid power control components 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.: 2.022 or 6.05
Year: U (1) 2–2–5
Man as a component in a physical system. Fundamental concepts pertaining to the transmission and processing of information through the human organism. Engineering specification of sensory and motor performance. The human operator in closed loop control systems. Design of displays and controls in the physical environment for most efficient matching to the organism. Laboratory experiments and design practice utilizing a variety of problems in which the man interacts with the machine. *Sheridan*

2.181 ***Advanced Topics in Man-Machine Systems*** **(A)**
Prereq.: 2.18 or 6.37T or 9.35
Year: G (2) 2–2–5
Critical study of current models of the human operator in control and communication systems. Evaluation of research objectives and measuring techniques in selected areas of engineering development such as manned space vehicle guidance, remote manipulation, control of ground vehicles, programmed instruction, sensory and prosthetic devices for blind and other physically deprived persons. Computer simulation of man-machine systems with emphasis on engineering application. Several experimental projects or case studies. *Sheridan*

2.191J ***Special Studies in Systems Engineering*** **(A)**
(Same subject as 1.16J, 6.604J, 16.362J)
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 trade-offs 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. (Projects for 1966 were: Group 1 — An integrated urban transportation system; Group 2 — A manned satellite inspection and retrieval system.) *Baumann, Bisbee, Seifert, Li*

2.201 ***Fluid Mechanics***
Prereq.: 2.022, *2.403*, 18.034
Year: U (1, 2, S) 4–0–8
General introduction to dynamics of fluid motion; kinematics; concept of control volume; continuity equation; momentum theorem; theorem of moment of momentum; dynamics of inviscid fluid; Euler and Bernoulli equation; energy equation; dimensional analysis and similitude; potential flow; viscous and turbulent flow; Navier-Stokes equation; lift; drag; boundary layer; head losses; fluid machinery. *Springer*

2.201T ***Fluid Mechanics***
Prereq: 2.012, *2.42*, 18.034
Year: U (1) 4–0–8
Content similar to 2.201. (*Not offered until 1967-68.*)
Heiser, Springer

2.202 ***Gas Dynamics***
Prereq.: 2.201
Year: U (1, 2) 3–0–6
Introduction to gas dynamics. One-dimensional compressible flow, with applications to problems associated with the design of turbojets, ramjets, rockets, combustion chambers, supersonic inlets, supersonic wind tunnels, gas turbines. Unsteady one-dimensional fluid motions. Two-dimensional flows at subsonic and supersonic speeds. Basic concepts of rarefied gas flows. *Springer*

2.202T ***Fluid Mechanics***
Prereq.: 2.201T, 8.03
Year: U (2) 3–0–6
Content similar to 2.202. (*Not offered until 1967-68.*)
Heiser, Springer

2.211 ***Fluid Dynamics***
Prereq.: 2.022, 2.403, *18.05*
Year: U (1) 3–0–6
Broad introduction to fundamental concepts and principles of fluid dynamics. Model and properties of the continuum. Kinematics of fluid motion. Continuity, momentum, moment-of-momentum, and energy equations for the system and the control volume. Statics. Euler and Bernoulli equations. Vorticity. Theorems of Kelvin and Helmholtz. Viscous stress tensor and Navier-Stokes equations. Dimensional analysis and similitude. Potential flow. Lift. Laminar and turbulent flow in pipes. Boundary layer theory and skin drag. Separation and form drag. *Heiser*

2.212 ***Fluid Dynamics***
Prereq.: 2.211, 2.404T, *6.03*
Year: U (2) 3–0–6
Application of fluid dynamics to topics selected from the following areas: compressible gas dynamics; unsteady flows, waves, and shocks; magnetohydrodynamics; propulsion; boundary layer theory; motion of highly rarefied gases. *Heiser*

2.22T ***Fluid Machinery***
Prereq.: 2.202T
Year: U (2) 3–0–9
Unified treatment from a fundamental point of view of different types of liquid and gas-handling machinery: displacement type pumps, compressors, and motors; centrifugal and axial pumps and compressors; radial, axial, and mixed flow turbines; propellors; and jet pumps *Erickson, P. G. Hill*

2.25 ***Advanced Fluid Mechanics*** **(A)**
Prereq.: 2.201T, *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

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theory. Turbulence. Drag. Wave propagation. Applications to fluid machinery, propulsion systems, process industries, and aerodynamics. *Shapiro*

2.261 *Kinetic Theory of Gases and Plasmas* (A)
Prereq.: 2.273, 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. Line, band, and continuum radiation from atoms, molecules, and ions. Theory of line broadening. 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, radiation, and recombination. 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.: 2.201T, 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. *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.: 2.201T, *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. Gasdynamic 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. *Probstein*

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; multi-component MHD fluid models. *Fay*

2.275 *Dynamic Fluid Machines* (A)
Prereq.: 2.202T 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. *P. G. Hill*

2.281 *Reacting Gas Dynamics* (A)
Prereq.: 2.201T or 2.211 or 10.30 or 16.02 or 16.03
Year: G (1) 3–0–9
Fundamental treatment of problems in gas dynamics involving simultaneous occurrence of chemical reaction and transport of energy, mass, and momentum. Chemical thermodynamics. Applied chemical kinetics. Transport coefficients in reacting mixtures. Conservation equations considering chemical reaction and multispecies diffusion. Detonation waves. Propagation of laminar and turbulent flames. Flame stabilization. Diffusion flames. Heterogeneous combustion. Ignition. Reacting boundary layers. High-temperature gas flow in nozzles and in hypersonic boundary layers. Applications to engineering problems. *Toong*

2.282 *Advanced Topics in Combustion* (A)
Prereq.: 2.281 or 10.70 or 16.052
Year: G (2) 3–0–9
Selected subjects of current interest in combustion. Comprehensive treatment of combustion principles. Critical examination of theories of ignition, flame propagation, and flame stabilization. Interactions among burning fuel droplets. Combustion instability. Similitude rules. Mechanism of burning of solid propellants. Supersonic combustion. Electric and magnetic effects. *Toong*

2.29 *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, Shapiro, Toong

2.291 *Research in Combustion* (A)
Prereq.: 2.281 or 10.70 or 16.052
Year: G (1 or 2) *Arr.*
Selected analytical or experimental problems in combustion, such as flame propagation, flame instability and stabilization, ignition, burning of liquid and solid propellants, stabilization of detonation waves, ablation, supersonic combustion, electric and magnetic effects, etc. Work arranged on an individual basis in consultation with instructor. *Toong*

2.30 *Mechanical Behavior of Materials*
Prereq.: 2.012; 3.13T or 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, *An Introduction to the Mechanical Behavior of Materials.* *Argon*

2.303 *Physics of Strength and Plasticity* (A)
Prereq.: 2.30, 3.141
Year: G (1) 3–0–9
Formal stress-strain relationships in elasticity, viscosity, and plasticity. Visco-elasticity and relaxation processes. Physics of elasticity, rubber-elasticity, viscosity, and visco-elasticity. General features of plasticity in crystalline materials. *Orowan*

2.304 *Physics of Strength and Plasticity* (A)
Prereq.: 2.303
Year: G (2) 3–0–9
Dislocation theory of plasticity; yield stress, strain hardening, solution, and age hardening; yield phenomena. Transient and viscous creep. Recrystallization. Structural features and mechanical behavior of polymers. Plastic instability; fracture; brittleness of steels. Fatigue phenomena. *Orowan*

2.332 *Dislocation Theory* (A)
Prereq.: 2.012; 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*

2.34 *Non-Metallic Materials*
Prereq.: 3.141
Year: U (2) 3–0–6
Chemical, structural, physical, and mechanical properties of polymers, including rubbery materials, glasses, ceramics, textiles, and other non-metallic materials. Production, testing, and engineering use of non-metallic materials. *Orowan*

2.398 *Seminar on Fracture* (A)
Prereq: 2.30 or 3.31 or 2.08
Year: G (1) 2–0–4
Cohesive forces in solids. Surface energy. Nucleation of fracture due to twinning and dislocation interactions. Fracture in steels and alloys by both cleavage and growth of holes. Elastic and plastic stress and strain distributions around growing cracks in tension and shear. Elastic and plastic stress distributions around inclusions and holes. Fracture of brittle materials, especially under compression, with effects of friction and penetrating fluids. *Argon, McClintock, Pelloux*

2.399 *Research in Materials* (A)
Prereq.: 2.30
Year: G (1 or 2) *Arr.*
Undergraduate and graduate students carry out experimental or theoretical research work on mechanical properties (strength, plasticity, etc.) of metallic and non-metallic materials. *Orowan*

2.402 *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
Thermodynamic concepts; the laws of thermodynamics; equilibrium; absolute temperature; entropy and availability; the phase rule; perfect systems; mixtures; flow processes; chemical potential; chemical equilibrium. *J. L. Smith*

2.404T *Statistical Mechanics and Kinetic Theory*
Prereq.: 8.02, 18.02
Year: U (2) 4–0–8
Introduction to the laws of thermodynamics through a study of the motion of large numbers of atoms or molecules. Classical and quantum mechanics of molecules. Phase space and ensembles, and the most probable macrostate of a system. Thermodynamic properties and laws. Work and heat. Properties of perfect gases, crystals, and thermal radiation. Heat engines and fluid flow. Transport of heat and mass in a perfect gas. *Fay*

2.41J *Thermodynamics and Statistical Mechanics*
(Same subject as 16.00J)
Prereq.: 8.02, 18.02
Year: U (1, 2) 3–2–7
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. *Gouse, Wachman*

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.: 8.02, 18.034
Year: U (1, 2) 4–0–8
First and second laws applied to nonfluctuating simple systems: reversibility; heat engines; entropy; equilibrium; thermodynamic temperature; chemical reactions, chemical potential; and chemical equilibrium. First and second laws applied to fluctuating systems: quantum states; ensembles; time averages as properties; probability of a state in terms of availability; canonical and grand-canonical distribution functions; Fermi-Dirac and Bose-Einstein statistics; equations of state of idealized gases, radiation, and crystals. *Hatsopoulos, Stickney*

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

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rule; systems of one and two components; idealized gases, mixtures, and solutions; equations of state; thermodynamic potentials; chemical reactions and chemical equilibrium. *Keenan*

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. *Keenan, Rohsenow*

2.454 *Direct Energy Conversion* (A)
Prereq.: 2.404T
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, Carabateas*

2.455J *Physical Electronics and Particle Optics* (A)
(Same subject as 6.639J)
Prereq.: 2.404T or 6.08T or 8.07
Year: G (2) 3–0–9
Interactions among individual charged particles, neutral particles, photons, fields, and solid surfaces, primarily under circumstances of low concentration. Thermodynamics and statistics of thermionic, photo, field, secondary, and Auger emission; adsorption, ionization processes, and related effects. Optics of charged particles: Gaussian optics, Liouville's theorem, diffraction, and paraxial ray equation; mass selecting, energy selecting, and confinement properties of electric and magnetic fields. *Stickney, Crawford*

2.46 *Statistical Mechanics* (A)
Prereq.: 2.403 or 2.404T
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. *Fay*

2.50 *Heat and Mass Transfer*
Prereq.: 2.201T, 2.403
Year: U (1, 2, S) 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 2.211 or 2.25 or 10.30 or 10.52T; 2.50 or 2.55 or 10.31 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, Gouse*

2.60 *Applied Thermodynamics*
Prereq.: 2.42
Year: U (1, 2) 3–0–6
First and second laws applied to steady and unsteady bulk flow: turbines, compressors, heat exchangers. Introduction to kinetic theory of rate processes: Maxwell-Boltzmann distribution function, mean speed, energy, momentum, mean-free path, collisions, effusion, diffusion transport, viscosity, heat conductivity diffusivity. Heat conduction, convection, heat radiation. Cycles: power generation, refrigeration. *Wilson*

2.61 *Power Generation*
Prereq.: 2.201T or 2.211 or 2.50 or 16.02; 2.403 or 2.41J
Year: G (1) 3–0–6
General principles of power generation from primary energy sources (e.g., chemical, nuclear, solar). Thermodynamics of rate processes and energy conversion. Techniques for transforming thermal energy to mechanical and electrical energy. Electrical, mechanical, aerodynamic, and rate process limitations on the performance of specific energy converters. Radiative and convective heat rejection. Rankine and Brayton based cycles for power generation. Influence of component performance on the selection of cycle temperatures, pressures, and working fluids. Survey of current developments in the field of energy conversion. Application to design of a power system of current interest. *Gouse, P. G. Hill*

2.611 *Elementary Internal Combustion Engines*
Prereq.: 2.022, 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.: 2.022 or 2.611; 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*

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 2.62
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*

2.62 *Gas Turbines and Jet Propulsion*
Prereq.: 2.22T
Year: U(2) 3–0–6
Analysis and design of gas turbines, rockets, and ram jets. Limitations on performance imposed by thermodynamics, fluid mechanics, and strength. Group design project of gas turbine or jet engine for a particular application. *E. S. Taylor*

2.621 *Gas Turbines* (A)
Prereq.: 2.202; 2.402 or 2.41J
Year: G (1) 3–0–9
Application of engineering science to the design and development of gas turbines. Thermodynamics and fluid mechanics for flow phenomena in turbines and compressors. Problems of mechanical strength and vibrations encountered in rotating machinery and blading of turbines and compressors. Design of turbines, compressors, heat exchangers and combustion chambers. Operating characteristics of gas turbine power plants. Consideration of special problems encountered in aircraft applications. *E. S. Taylor*

2.622 *Gas Turbines* (A)
Prereq.: 2.621
Year: G (2) 3–0–9
Detailed study of the design of a gas turbine component. Lectures supplemented by group discussions to solve a specific design problem. Preparation of a report on one phase of the problem by each student. *E. S. Taylor*

2.631 *Lubrication and Friction*
Prereq.: 2.201
Year: U (2) 2–0–4
Thick-film lubrication: thrust and journal bearings under steady and unsteady loads, including end-leakage and extent of the film; rolling-contact bearings, involving deformation of the surfaces and the influence of pressure on viscosity. Effects of local thinning of the film due to surface irregularities: lubricant breakdown, deformation of the surfaces, solid-solid contact, and wear. Lubrication under extreme environmental conditions (high temperature, low pressure). *Rightmire*

2.632 *Research in Lubrication* (A)
Prereq.: 2.631
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

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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.: 8.04
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*

2.642 *Food Engineering*
Prereq.: 2.641
Year: U (2) 3–2–4
Continuation of 2.641. Application of thermodynamic principles to problems in heat transfer, fluid flow, refrigeration and air conditioning as related to food processing and preservation. Methods, materials, and equipment. Laboratory work and plant trips to supplement lectures. *Hesselschwerdt*

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. Typical air conditioning equipment and control systems will be considered 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.: 2.201T or 2.50 or 16.02; 2.403 or 2.41J
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, Maulbetsch*

2.648 *Refrigeration and Air Conditioning Laboratory*
Prereq.: 2.643, *2.646*, 2.671
Year: U (2) 0–3–6
Experimental work involving application and research problems in air conditioning and refrigeration; equipment includes standard condensing units, air washer, heating and cooling coils, constant temperature rooms, and equipment of special design. Facilities available for use of more than one refrigerant. *Hesselschwerdt*

2.649 *Low Temperature Refrigeration* (A)
Prereq.: 2.403
Year: G (1 or 2) 3–3–6
Thermodynamic processes for producing low-temperature refrigeration. Problems of heat exchangers, insulation and rectification. Applications of low-level refrigeration to purification of oxygen and nitrogen. Laboratory projects on related topics according to individual interests. *J. L. Smith*

2.65 *Industrial Plant Engineering*
Prereq.: 8.02
Year: U (1) 3–0–6
Principles of safety engineering and fire protection engineering as applied to the industrial plant before, during, and after construction. Materials and mechanical equipment for heating, ventilating, and air conditioning. Presentation by an authority in each field. *Hesselschwerdt*

2.651 *Physical Measurement and Analysis*
Prereq.: 8.02, 18.02
Year: U (1, 2) 2–1–5
Essentially the same material as in 2.654, presented in brief form for upper-class students who have not taken 2.654. *Cook, Rabinowicz*

2.652 *Experimental Stress Analysis*
Prereq.: 2.012
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. Em-

phasis 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

2.67 *Design and Experiment*

Prereq.: 8.02, 18.02

Year: U (2) 2–6–4

Student-defined research tasks relevant to an overall 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.

Gouse, Mann

2.671 *Experimental Engineering*

Prereq: 2.012, *2.022, 2.201,* 2.403

Year: U (1, 2) 2–4–2*

2.671T *Experimental Engineering*

Prereq: 2.012, *2.022, 2.201, 2.42*

Year: U (1, 2) 1–8–3*

Engineering laboratory subject for all Mechanical Engineering juniors, extending over two semesters. Major emphasis on interplay between analytical and experimental methods in the solution of research and development problems. A few formal familiarization exercises followed by project investigations of some depth to develop major emphasis in specific case studies. Small student groups supervised by faculty members; facilities of most of the laboratories in Mechanical Engineering Department to be utilized. Lectures to supplement laboratory experience. *(2.671T not offered until 1967-68.)*

Griffith

** 2.671 carries total credit of 8 units: 1–2–1 units to be spent in first term, 1–2–1 in second term. 2.671T carries total credit of 12 units: 0–3–1 units to be spent in first term, 1–5–2 in second term.*

2.701 *Architectural Geometry I*

Prereq.: ——

Year: U (1, 2) 0–4–2

Systems of representation of objects. Orthographic, axonometric, and perspective pictorials. Brief introduction to dimensioning and standard drafting practices. Modern projective geometry with applications to perspective, generation of curves, ruled and doubly curved surfaces. Elementary introduction to descriptive geometry methods. Emphasis is on both theory and drafting technique. Specially designed for architecture and industrial design students. *Coons*

2.702 *Architectural Geometry II*

Prereq.: 2.701

Year: U (1, 2) 0–4–2

Analysis of three-dimensional space relationships by graphical methods. Geometric characteristics of varied space configurations such as convolutes, doubly curved, and warped surfaces. Topics on graphic statics. Formal treatment of shadows and intersections between irregular surfaces. Frequent class projects to enhance the usefulness of theoretical material and develop spatial visualization and graphical competence. Material specially prepared for architecture and industrial design students.

Lent

2.71 *Geometry of Design*

Prereq.: ——

Year: U (1, 2) 0–6–6

Formation of design concepts and their analysis, applied to scientific and engineering problems. Graphical techniques of display, exploration, and solution; descriptive geometry, projective geometry, graphical calculus, logical information flow diagrams, etc. Projects in complex surface geometries, potential flow fields, mechanisms, space frames, optical and computer systems, etc.

Coons, Lent

2.711 *Engineering Geometry*

Prereq.: ——

Year: 1 (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, heliostat for a solar furnace. *Lent*

2.722 *Descriptive Geometry*

Prereq.: ——

Year: 1 (1, 2) 0–4–2

Representation of three-dimensional space relations by two-dimensional diagrams. Analysis of problems involving points, lines, planes, and surfaces into fundamental components. Development of methods of attack and of capacity to think in space terms. Elementary programming and computer-plotting of views. *D. P. Adams*

2.723 *Elementary Nomography*

Prereq.: ——

Year: 1 (1, 2) 2–0–4

Graphical representation and solution of equations by alignment diagrams based upon plane geometry 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*

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2.731 *Engineering Design*
Prereq.: 2.022, *2.30*, 2.861
Year: U (2) 3–3–6
Instruction and experience in the integrated aspects of creative design and design analysis. In the context of an overall 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. (*Those students wishing to do so and who can arrange mutually satisfactory projects with their respective Faculty Counselors, may undertake a single project to satisfy the requirements both of 2.731 and of the second term of 2.671, Experimental Engineering.*)
Mann

2.732 *Design Concepts*
Prereq.: 2.731
Year: U (1) 2–2–5
The concept-development stage of engineering design, centered around the planning and critical analysis of engineering systems. Case studies, drawn from problems of current and anticipated technological significance, carried out by student groups in cooperation with participating industrial organizations and academic laboratories within the Institute. Such topics as automated production equipment; analog and digital computation techniques in the design and control of engineering systems; data processing and materials handling; and the dynamics, control, and design of transport systems. Objectives: development of ability to plan, organize, and lead engineering projects of broad scope, basing decision on fundamental physical laws, experimental data, experience, and engineering judgment. *Baumann, Richardson*

2.733 *Special Projects in Engineering Design* (A)
Prereq.: 2.731
Year: G (1, 2) *Arr.*
For students desiring to carry on substantial design projects of own choosing. Special lectures and seminars to be arranged when appropriate. Projects arranged on individual basis in consultation with instructor. *Mann*

2.736 *Modern Kinematic Problems*
Prereq.: 2.012, 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 (1, 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 materials test data to process analysis. Application of economic principles to manufacturing. *Lent, Cook*

2.862 *Machine Tool Fundamentals*
Prereq.: 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*

2.864 *Manufacturing Technology*
Prereq.: ——
Year: U (2) 3–0–6
Special topics in machine tool design and performance, including: machine tool requirements, kinematic considerations, power supply and transmission, thermal stability, bearings and other components, controls, vibrations and testing of machine tools, automation, statistics, and quality control. New developments including new machining methods, machining of new materials of construction, use of glass and ceramic materials, new fastening materials. *Cook*

2.865 *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, Reichenbach*

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*

2.903 *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 *Physics of Fibrous Materials* (A)
Prereq.: 18.034
Year: G (1) 3–0–6
Analytical treatment of the interaction between fiber properties and the physical behavior of fabricated fibrous structures. *Fine structure of fibers:* molecular composition and configuration; effect of treatments during manufacture; discussion of X-ray, infrared, and electrical measurements; dependance of mechanical properties on fine structure. *Fibrous structures:* differential geometry of twisted materials, translation of fiber properties into yarn behavior, role of fiber variability, applied mechanics of paper and non-woven systems. *Backer*

2.906 *Physics of Fibrous Materials* (A)
Prereq.: 2.905
Year: G (2) 3–0–6
Fiber rheology: principles of elasticity, viscoelasticity, creep and relaxation time-temperature effects, and static and dynamic testing. *Fibrous structures:* cloth geometry; interaction of yarn and fabric structures; analysis of physical behavior of woven, knitted, and braided materials; laminate and composite systems used in engineering, decorative, and apparel applications. *Backer*

2.911 *Fiber Research Laboratory* (A)
Prereq.: 2.905
Year: G (1) 3–3–2

2.912 *Fiber Research Laboratory* (A)
Prereq.: 2.911
Year: G (2) 3–3–2
Application of the research group method to solution of experimental problems. Exercise in analysis of fiber and structural properties affecting intermediate or end product behavior and in design of apparatus and/or experiments for their measurement. *Backer*

2.913 *Fibers and Polymers Seminar* (A)
Prereq.: 2.30
Year: G (1) 2–0–2

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, Valko*

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*

3.
Metallurgy

3.00T *Thermodynamics of Materials*
Prereq.: 5.01, *8.02*
Year: U (2) 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. *Elliott*

3.01T *Thermodynamics and Statistical Mechanics*
Prereq.: 3.00T, 18.034
Year: U (1) 4–0–8
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. *C. M. Adams, R. M. Rose*

3.02T *Chemistry of Materials*
Prereq.: 3.00T, 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*

3.03T *Chemical Metallurgy*
Prereq.: 3.01T, 3.02T
Year: U (1) 3–0–6
Application of principles of 3.02T 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*

(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.

3.04 ***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.: 5.01, 8.03
Year: U (2) 3–0–6

Description of amorphous and crystalline structure of silicates. Application of this structural knowledge, thermodynamics, and theories of deformation and transport processes to the analysis and understanding of selected ceramic processes, including slip casting, plastic forming, dry pressing, dry and viscous forming.
Kingery, Uhlmann

3.07 ***Physical Ceramics I***
Prereq.: 3.13T or 3.141
Year: U (1) 3–0–6

Characteristics of vitreous and crystalline nonmetals. Relationships of atom arrangements and interactions to thermal, mechanical, and electrical properties. Application of phase equilibria, surface properties, atomic mobility, nucleation, and crystal growth to development of structure during fabrication, shaping, heat treatment, and use. Relationship of structures to thermal, electrical, and mechanical properties. *Kingery, Wuensch*

3.08 ***Principles of Materials Separation***
Prereq.: 3.00T
Year: U (2) 4–3–5

Separation of materials in solid, liquid, or gaseous form according to bulk or surface properties. Movement in fluids, mass transfer, and chemistry of solutions and surfaces. Consideration of physical separations according to size, density, surface characteristics, magnetic, electrical, and kinetic phenomena. Chemical separations including adsorption, solution, precipitation, distillation, segregation, solvent extraction, and electrolysis. Principles applied to representative processes. Laboratory work using real materials and separation techniques.
de Bruyn, Witt

3.09 ***Structure and Properties of Materials***
Prereq.: ——
Year: 1 (1) 3–0–3

Lectures and demonstrations on selected topics of atomic, molecular, crystal, and phase structure of solids. Correlation of the mechanical and chemical properties of solids with composition, processing, and environmental factors. *Wulff*

3.10T ***Structure and Properties of Electronic Materials***
Prereq.: 5.01
Year: U (2) 3–0–3

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. *Wulff*

3.11T ***Mechanics of Materials***
Prereq.: 8.01, 18.02
Year: U (1) 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

3.12T ***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*

3.13T ***Materials Science I***
Prereq.: 3.01T, 3.11T, 3.12T
Year: U (2) 4–3–5

Principles underlying the physical, mechanical, and chemical properties of metallic, ionic, and polymeric materials. Introduction to bonding; equilibrium and nonequilibrium phase relationships in one-, two-, and three-component systems; mechanisms and kinetics of diffusion; elasticity; lattice imperfections; plasticity and fracture; recovery, recrystallization and grain growth; oxidation. Emphasis upon correlation of properties with crystal structure and microstructure, including quantitative metallography. Laboratory experiments on some of the basic techniques used to evaluate the structure and properties of materials. *Cohen, Breedis*

3.14T ***Physical Metallurgy I***
Prereq.: 3.13T 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.: 5.01, *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 nonequilibrium transformations in multi-component 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, Wulff

3.144 *Physical Metallurgy I*
Prereq.: 3.13T or 3.141
Year: U (1) 4–0–4
Same as 3.14T but without laboratory. *Bever, Cohen*

3.15T *Materials Science II*
Prereq.: 3.13T, 8.03, 18.034
Year: U (2) 4–3–5
Discussion of physical properties of materials from the experimental point of view. Treatment within a framework of lectures, experimentation, demonstration, and computer calculations of the basic concepts of such phenomena as electrical and thermal conductivity, heat capacity, optical transmission and emission, dia-, para- and ferromagnetism, thermoelectricity, and superconductivity. Discussion of these properties in terms of quantum mechanical and macroscopic theories. Development of the interrelationships between atomic structure and the measured properties of materials. *Kaplow, Moss*

3.16T *Physical Metallurgy II*
Prereq.: 3.14T 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: 1 (2) 3–0–3
Study of actual processes leading to induction of generalizations and their subsequent application in science and engineering education. 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*

3.18T *Materials Processing*
Prereq.: 3.13T 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.: 3.13T or 3.141
Year: U (1) 4–0–4
Same as 3.18T but without laboratory. *Coble*

3.20T *Thermodynamics in Metallurgy* (A)
Prereq.: 3.01T
Year: G (1) 4–0–6
Advanced treatment of the thermodynamic properties of metallurgical systems. Free energy relations among compounds of metals. Properties of substitutional, interstitial, and liquid metallic solutions. Reactions of metals with metallic compounds, gases, slags, and refractories. *Elliott*

3.21T *Kinetic Problems in Metallurgy* (A)
Prereq.: 3.01T, 3.13T
Year: G (1) 4–0–8
Treatment of the kinetics of some metallurgical and ceramic reactions. Emphasis on the rates of heterogeneous reactions determined by transport processes, such as diffusion in solids, liquids, and gases, or by chemical processes at phase boundaries. *Russell*

3.22 *Defects in Solids* (A)
Prereq.: 3.01T, 3.13T
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 nonmetallic materials. *Russell*

3.30 *Advanced Physical Metallurgy* (A)
Prereq.: 3.01T, 3.12T, 3.14T
Year: G (1) 4–0–8
3.31T *Advanced Physical Metallurgy* (A)
Prereq.: 3.30
Year: G (2) 4–0–8
Advanced treatment of important subjects within the general field of physical metallurgy, including application of generalized thermodynamics to metallic systems, thermodynamic aspects of deformation processes, thermodynamics of solid solutions, atomic arrangements in solid solutions, intermetallic compounds, grain boundary and interface phenomena, diffusion, growth, nucleation, phase transformations, recrystallization and grain growth, crystal elasticity and plasticity, anelastic phenomena, dislocation theory. The more recent publications covering these topics. *Bever, Cahn*

3.32T *Electron Microscopy of Crystalline Materials*
Prereq.: 3.13T, 8.03
Year: G (1) 2–0–4
Application of the electron microscopy technique to studies of metals and other materials. Introduction to the optics of the electron microscope, electron diffraction, contrast mechanisms in replicas and in foils containing lattice defects and second phases, and methods of specimen preparation. Consideration of the reliability of the method in various applications. (*Not offered 1966-67.*) *Breedis*

3.33T *Electron Optics*
Prereq.: 3.13T 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*

3.34T *Advanced X-ray Metallurgy* (A)
Prereq.: 3.12T
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*

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3.35T ***Solidification Processing*** **(A)**
Prereq.: 3.13T 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*

3.36T ***Welding Engineering*** **(A)**
Prereq.: 3.13T 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. *C. M. Adams*

3.37T ***Deformation Processing*** **(A)**
Prereq.: 3.11T; 3.13T or 3.141
Year: G (2) 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*

3.38 ***Behavior of Metals at Elevated Temperatures*** **(A)**
Prereq.: 3.13T 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.: 3.15T or 6.08T; 8.051
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.: 8.03
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 and quantum mechanics, electromagnetic theory, and statistical mechanics. Some specific topics: Fermi-Dirac and Bose-Einstein statistics, free electron theory of metals, the electromagnetic Hamiltonian, Maxwell equations, Schrödinger equations. *R. A. Brown*

3.42T ***Physics of Solids II*** **(A)**
Prereq.: 3.41
Year: G (1) 4–2–6
Two series of lectures and a computer laboratory in the general fields of lattice vibrations and electron states in crystals. *Series A:* Periodic structures, the reciprocal lattice, Brillouin zones, Bloch's theorem; lattice dynamics, frequency spectrum, specific heat, diffraction by crystals, Debye-Waller factor. *Series B:* Free and nearly free electrons, tight-binding, cellular methods, orthogonalized plane waves, Hartree-Fock equations; types of solid from the band and bond pictures, ionic and metallic cohesion, density of states and electronic specific heat. Use of a time-shared computer and remote console in the laboratory to solve problems in these topics. *Averbach, Sellmyer*

3.43T ***Physics of Solids III*** **(A)**
Prereq.: 3.42T
Year: G (2) 4–2–6
Two series of lectures and a computer laboratory in transport properties, magnetism, optical properties, and Fermi surfaces. *Series A:* Dynamics of electrons, Wannier functions, equation of motion, mass tensor; theory of transport properties, electrical and thermal conductivity, Hall effect, thermoelectric power; spin paramagnetism, ferromagnetism, antiferromagnetism. *Series B:* Electron-electron interaction, screening, optical properties of solids, theory of Fermi surface phenomena. Use of a time-shared computer and remote console in the laboratory to solve problems in the above topics. *Averbach*

3.50T ***Thermodynamics in Process Metallurgy*** **(A)**
Prereq.: 3.03T, 3.20T
Year: G (1) 2–0–6
Advanced treatment of the thermodynamic properties of metallurgical systems with emphasis on molten metals, slags, and mattes. Problems in the roasting and reduction of ores. Reactions of molten iron, steel, and other metals with slags and gases, and problems in the refining and solidification of molten metals. *Chipman*

3.51T ***Process Metallurgy*** **(A)**
Prereq.: 3.03T
Year: G (1) 3–0–6
Study of integrated metallurgical processes. Application of the fundamental treatment of 3.03T 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. (*Not offered 1966–67*). *T. B. King*

3.52T ***Dynamic Behavior of Metallurgical Systems*** **(A)**
Prereq.: 3.01T, 18.034
Year: G (1) 3–0–6
Interpretation of the behavior of metallurgical systems by application of the methodology of process analysis and control theory. Modeling of systems and exploration of their characteristics with digital and analog computers. *Eliott*

3.53T ***Electrochemistry*** **(A)**
Prereq.: 3.01T
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*

3.54T ***Corrosion*** **(A)**
Prereq.: 3.01T
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*

3.55T *Mineral Engineering*
Prereq.: 3.08
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
Discussion of effects of composition and structure on properties of crystalline ceramics. Treatment of various subjects concerned with the thermal, mechanical, electrical and magnetic, and optical properties of ceramic products, including recent publications. *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 *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*

3.63T *Ceramic Processes* (A)
Prereq.: 3.06 or 3.07; 3.20T; 3.21T
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*

3.70T *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 (1) 3–1–3

3.702 *Properties of Metals*
Prereq.: 3.701T
Year: G (2) 3–1–3
Properties of metals with reference to materials used in ship construction. Microstructure, processing, heat treatment, joining and corrosion resistance of nonferrous and ferrous metals. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Floe*

3.72 *Radiation Damage in Crystalline Solids*
Prereq.: 3.13T or 3.141 or 22.71T
Year: G (1) 2–0–4
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. *Ziebold*

3.73T *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. I.B.M. 7094 and/or 360 computer used. *Kaplow*

3.74 *Statistical Thermodynamics of Materials* (A)
Prereq.: 3.01T
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. *R. M. Rose*

3.75T *Structure and Properties of Interfaces* (A)
Prereq.: 3.01T
Year: G (1) 3–0–6
Thermodynamics of systems containing extensive surfaces and boundaries. Application to systems with plane and curved interfaces. Surface tensions of solids and liquids. Conditions for three-phase stable contact. The electrochemical double layer at reversible and completely polarizable surfaces. The physical model of the double layer at interfaces; its theory and correlation with thermodynamic surface properties. Electrokinetics, theory, and measurement. Applications to metals and other electronic materials. *de Bruyn*

3.76T *Electronic Materials* (A)
Prereq.: 3.15T
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*

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4.
Architecture

4.011 *Graphics Laboratory I*
Prereq.: ——
Year: 1 (1) 0–3–2
Freehand drawing exercises to develop accurate observation and skill in graphic representation. Linear, light and shadow, detail and perspective renderings of varied subject matter. Control of line, value, color, texture and form using pencil, pen, and brush. *Preusser*

4.012 *Graphics Laboratory II*
Prereq.: ——
Year: 1 (2) 0–3–2
Continuation of practice in representational techniques. Exercises employing graphic devices useful in all types of freehand drawing. Use of charcoal pencil, pen and ink, and water color as effective means to create the graphic equivalent of what is observed or visualized. *Preusser*

4.013 *Graphic Composition*
Prereq.: 4.032T
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 complimentary, exploration of symbolic images. Objective: realization of visual meaning and composition through synthesis of graphic imagery. *Preusser*

4.021T *Visual Design Problems*
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*

4.022T *Visual Design Projects I*
Prereq.: 4.021T or 4.051 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 II*
Prereq.: 4.032T
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*

4.031T *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*

4.032T *Form and Design II*
Prereq.: 4.031T
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*

4.033T *Form and Color I*
Prereq.: 4.031T
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*

4.034T *Form and Color II*
Prereq.: 4.032T
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.: 4.031T
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.: 4.032T
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. Photography utilized 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*

4.051 *Creative Photography I*
Prereq.: ——
Year: U (1, 2) 2–6–0

4.052 *Creative Photography II*
Prereq.: 4.051
Year: U (1, 2) 2–6–0
Development of visual awareness and creative capacity through the practice of photography. Exercises in selective observation and visual organization together with the study of light as a form-giving element. Emphasis on creative seeing and experimental manipulation of the photographic process through studio and darkroom procedures. Demonstrations providing technical information about the medium and seminars concerned with photography as an art form. *Limited enrollment.* *M. White*

4.053 *Evaluating Photography*
Prereq.: 4.031T or 4.051
Year: U (1, 2) 3–0–5
Investigation of the impact of photography as communication and as art form. Public response to photographs and critical standards. Seminar and field studies. *Limited enrollment.* *M. White*

4.054 *Advanced Photography*
Prereq.: 4.032T
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 photo-metaphor for the varied purposes of visual evocation. *Limited enrollment.* *M. White*

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 032T
Year: U (1, 2) 2–4–6
Study of plastic sculptural form based on continuity of surfaces, synthesis of diverse goemetries, 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*

4.131T *Architectural Design*[1]
Prereq.: 4.122
Year: U (1) 0–6–6

4.132T *Architectural Design*[1]
Prereq.: 4.131T
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. *Schiffer*

4.141 *Architectural Design*[1]
Prereq.: 4.132T, 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.: 4.132T, 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 multistory construction, mass circulation movements, and areas requiring specialized space forms or equipment or having multiple uses. Consideration of the thermal problems of buildings, the distribution of daylight and artificial light, and the control of sound in buildings as they influence the design concepts and also in the installations associated with them. *Myer*

[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.

(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.

4.151 ***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 Committee. *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 Committee. *(Not offered 1966–67.)* *Staff*

4.161 ***Architectural Design*** **(A)**
Prereq.: 4.151
Year: G (1) 0–15–15
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. Sections and themes elected 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

4.17 ***Architectural Design, Special Problems***
Prereq.: ——
Year: U (1, 2) *Arr.*
Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff. *Staff*

4.19 ***Special Problems in Architectural Design*** **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Supplementary design work for graduate students. Registration subject to prior arrangement for subject matter and supervision by staff. *Staff*

4.30 ***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. *Staff*

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. *Staff*

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. *Staff*

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. *LeMessurier*

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. *LeMessurier*

4.402J ***Building Process***
(Same subject as 1.922J)
Prereq.: ——
Year: U (1) 3–3–6
The building process as influenced by structure, environment, and materials and by social, legal, and industrial constraints. Evolution of building systems in response to functional and expressive needs. Introduction to the total process of design and construction of buildings, with concentration in the laboratory-studio work on a selected aspect or development in building technology.
Dietz, Schiffer

4.41 ***Materials***
Prereq.: 8.02
Year: U (1) 3–2–3
Emphasis on inorganic materials of construction. Elements of chemistry applicable to materials. Basic properties of cementitious materials, aggregates, and concrete; factors affecting strength and durability of concrete. Ceramic products based on burnt clay. Natural stones. Glass and its properties in building. Principles under-

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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.

lying systems of metallic alloys; phase diagrams and their interpretation; working and heat treatment; alloys based on iron, copper, aluminum, and other principal metals. Corrosion and protection against corrosion. Laboratory exercises and projects. *Dietz*

4.42 *Materials*
Prereq.: 8.0[illegible]
Year: U (2) 3–2–3
Emphasis on organic materials of construction. Micro- and macro-structure of wood. Effect of structure upon hygroscopic and strength properties, appearance. Identification. Wood destroyers and preservatives. Adhesives and adhesively-bonded wood construction: plywood, laminated timber, wood derivatives. Chemistry of plastics and other polymeric materials. Influence of molecular structure upon physical-mechanical properties. Fabricating variables. Foams and films. Reinforcing agents, high-pressure laminates, and reinforced plastics. Composites and sandwiches. Protective and decorative coatings. Fibers, filaments, yarns, fabric structure. Laboratory exercises and projects. *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. *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.
Newman

4.45 *Environmental Control — Light*
Prereq.: 8.03
Year: U (2) 2–0–4
Analysis and integration of light in architecture. Light measurement and control techniques. Psychological and physiological factors examined in relation to design objectives. Quality, direction, and contrast of natural and artificial light in building; color in various light contexts; lighting equipment and control considerations. (*Not offered 1966–67.*) *Staff*

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.
W. V. Andersen

4.602 *Introduction to Modern Art*
Prereq.: ——
Year: U (2) 3–0–5
Painting and sculpture from the late 18th century to the present. An investigation of the thoretical 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, this subject will also deal with problems of interpretation and criticism. *Staff*

4.603 *Painting and Sculpture in the Middle of the Nineteenth Century*
Prereq.: 4.602
Year: U (2) 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 (1) 3–0–5
Cézanne, Gaugin, Van Gogh, and Seurat presented against a background of Impressionism and other 19th 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. Anderson*

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-Painteriy Abstraction styles, Pop Art, and the recent Optical Art Movement, considered both historically and critically. (*Not offered 1966–67.*) *W. V. Andersen*

4.606 *Sculpture in the Twentieth Century*
Prereq.: 4.604 or 4.605
Year: U (2) 3–0–5
Development, against a background of Rodin and late 19th 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 course devoted to American sculpture since 1930.
W. V. Andersen

4.607 *Twentieth Century Art Theories*
Prereq.: 4.605 or 4.606
Year: G (1) 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.: 4.064; 4.605 or 4.606
Year: G (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.*) *W. V. Andersen*

4.61 *Architecture in the Ancient World*
Prereq.: ——
Year: U (1) 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. *Millon*

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4.62 ***Architecture 1400-1750***
Prereq.: ——
Year: U (2) 3–0–5
Same as 4.61, but covering the period from the beginning of the Renaissance to the end of the Rococo. *Staff*

4.621 ***Origins of Contemporary Architecture in the Eighteenth Century*** **(A)**
Prereq.: 4.601, 4.602; or 4.61, 4.62, 4.63, 4.64
Year: G (1) 3–0–5
Seminar surveying the principal works of architecture and major theoretical statements of 18th century architects and writers in order to define, understand, and examine the origins of contemporary theoretical positions. (*Not offered 1966–67.*) *Millon, S. Anderson*

4.63 ***Architecture in the Middle Ages***
Prereq.: ——
Year: U (1) 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. *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. *S. Anderson*

4.641 ***Modern Architecture in Germany from 1895 to the Bauhaus*** **(A)**
Prereq.: 4.601, 4.602; or 4.61, 4.62, 4.63, 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. (*Not offered 1966–67.*) *S. Anderson*

4.65 ***Studies Toward a Theory of Architecture*** **(A)**
Prereq.: 4.61, 4.62, 4.63, 4.64
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.: 4.61, 4.62, 4.63, 4.64
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. (*Not offered 1966-67.*) *Millon, S. Anderson*

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.***

4.95 ***Thesis Research*** **(A)**
Prereq: 4.261
Year: G (1) 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. *Staff*

4.96 ***City Planning Research*** **(A)**
Prereq:
Year: G (2) *Arr.*
Selected topics in city planning. Supervised study, with conferences, readings, and reports. No lectures. *Staff*

4.97 ***Regional Planning Research*** **(A)**
Prereq.: ——
Year: G (2) *Arr.*
Selected topics in regional planning. Supervised study with conferences, readings, and reports. No lectures. *Staff*

5.
Chemistry

GENERAL CHEMISTRY
Undergraduate Subjects

5.01 ***Chemical Principles I***
Prereq.:——
Year: 1 (1, 2) 5–2–5
Basis of atomic theory, an introduction to the structures of atoms and molecules; gases, kinetic theory; solids, crystal structure; liquids and solutions; chemical equilibrium; electrochemistry; introduction to chemical thermodynamics. Laboratory: physico-chemical experiments, integrated with lecture topics. *W. R. Moore*

5.02 ***Chemical Principles II***
Prereq.: 5.01
Year: U (2) 5–2–5
Kinetics, reaction mechanisms; atomic structure, the nucleus; molecular structure and chemical bonding; survey of the properties of selected elements emphasizing correlation of structure and reactivity. Laboratory: physico-chemical experiments related to lecture topics. *W. R. Moore*

INORGANIC CHEMISTRY
Undergraduate Subjects

5.03 ***Principles of Inorganic Chemistry I***
Prereq.: 5.42, 5.63
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 nontransition elements. *Seyferth, 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. *Davison*

INORGANIC CHEMISTRY
Graduate Subjects

5.065 ***Advanced Inorganic Chemistry* (A)**
Prereq.: 5.03
Year: G (1) 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. (*Alternate years.*) *Seyferth*

5.067 ***Topics in Theoretical Inorganic Chemistry* (A)**
Prereq.: 5.04
Year: G (1) 2–0–4
Elements of group theory and its application to problems of molecular structure; treatment of vibrational spectra of inorganic compounds; introduction to ligand field theory and its use in the interpretation of spectral and magnetic properties of compounds of the transition elements; other current problems in theoretical inorganic chemistry, as time permits. (*Alternate years. Not offered 1966–67.*) *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. *Coryell, 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. *Coryell, 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. (*Not offered 1966–67*). *Gordon*

ANALYTICAL CHEMISTRY
Undergraduate Subjects

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. *Hume*

5.15 ***Chemical Applications of Spectroscopy***
Prereq.: 5.41
Year: U (2) 1–4–1
Introduction to the complementary use of infrared, ultraviolet, nuclear magnetic resonance and mass spectrometry as techniques for identifying chemical compounds. Lecture material deals with basic principles and instrumentation. Laboratory work involves obtaining spectra and interpreting them for unknown compounds. (*Alternate years.*) *Hercules*

5.16 ***Instrumental Methods of Analysis***
Prereq.: 5.14, 5.61
Year: U (2) 4–4–4
Theory and application of modern optical and electrical instruments in the solution of chemical problems. Basic electronics. Polarography, potentiometry, and conductometry, ultra-violet, visible and infrared spectrophotometry; colorimetry, light scattering, fluorimetry, flame photometry, gas chromatography, and automatic instruments. Laboratory coordinated with lecture. (*Not offered 1966–67.*) *Hercules, Roe*

ANALYTICAL CHEMISTRY
Graduate Subjects

5.192 ***Electrochemistry* (A)**
Prereq.: 5.14, 5.62
Year: (2) 2–0–4
Development of a quantitative description of electrode processes through diffusion theory and rates of charge transfer theory. Survey of theory of electrode-solution double layer. Application of theory to electrochemical measurement methods, including polarography, chronopotentiometry, a. c. polarography, cyclic voltammetry and transient techniques. (*Alternate years. Not offered 1966–67.*) *Roe*

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 nonaqueous solvents. Separation methods including liquid-liquid partition, ion exchange, volatilization, precipitation and zone refining. Emphasis on multistage partitioning processes and relevant rate theories. (*Alternate years.*) *Hume, Roe*

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. (*Alternate years. Not offered 1966–67.*) *Hume*

5.195 ***Electronic and Mass Spectrometry* (A)**
Prereq.: 5.63
Year: G (1) 3–0–6
Discussion of the theory and practice of mass spectrometry and molecular electronic spectroscopy. Topics in-

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cluded will be interpretation of mass spectra of organic compounds, molecular electronic absorption and emission spectra, energy transfer, photochemistry. (*Alternate years.*) *Biemann, Hercules*

ORGANIC CHEMISTRY
Undergraduate Subjects

5.41 ***Organic Chemistry I***
Prereq.: 5.01
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. *Swain*

5.412 ***Organic Chemistry Laboratory I***
Prereq.: 5.41
Year: U (1) 1–5–0
Application of the techniques of synthetic organic chemistry to the preparation and purification of simple organic compounds. *T. C. French*

5.42 ***Organic Chemistry II***
Prereq.: 5.41, 5.412
Year: U (2) 4–0–8
Study of organic reactions, with emphasis on the relation between structure and reactivity. *F. D. Greene*

5.422 ***Organic Chemistry Laboratory II***
Prereq.: 5.412, *5.42*
Year: U (2) 1–5–0
Introduction to the literature of organic chemistry. Study of advanced preparations involving special techniques. *T. C. French*

5.428 ***Introduction to Organic Research***
Prereq.: 5.53
Year: U (2) 2–9–1
Instruction in the use of current research techniques for the identification, separation, and synthesis of organic compounds. *House*

ORGANIC CHEMISTRY
Graduate Subjects

5.51 ***Advanced Organic Chemistry: Synthesis*** **(A)**
Prereq.: 5.53
Year: G (1) 3–0–6
Organic reactions and the methods by which they are applied to synthetic problems in organic chemistry. *House*

5.53 ***Molecular Structure and Reactivity*** **(A)**
Prereq.: 5.42, 5.422
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. *F. D. Greene*

5.54 ***Physical Organic Chemistry*** **(A)**
Prereq.: 5.53
Year: G (2) 3–0–6
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, Whitesides*

5.55 ***Organic Chemistry: Natural Products*** **(A)**
Prereq.: 5.51
Year: G (2) 3–0–6
The chemistry and physiological action of natural products. Methods of isolation; determination of structures and synthesis. *Büchi*

PHYSICAL CHEMISTRY
Undergraduate Subjects

5.61 ***Physical Chemistry I***
Prereq.: 5.01, 8.02, 18.02
Year: U (1, 2) 4–0–8
First and second laws of thermodynamics; properties of solutions; phase equilibrium; chemical equilibrium and the third law of thermodynamics; ionic equilibria and voltaic cells. *Shoemaker, Kinsey, Garland*

5.613 ***Physical Chemistry Laboratory I***
Prereq.: 5.61
Year: U (1) 0–4–2
Experimental topics in physical chemistry. Priority to Course V students. Limited to 75. *Bowers, Dubrin*

5.62 ***Physical Chemistry II***
Prereq.: 5.61
Year: U (2) 4–0–8
Elementary kinetic theory and statistical mechanics; transport properties of gases and liquids; rates of chemical reactions. *Ross*

5.623 ***Physical Chemistry Laboratory II***
Prereq.: 5.61
Year: U (2) 0–4–2
Continuation of 5.613. Priority to Course V students. Limited to 75. *Dubrin, Steinfeld*

5.63 ***Physical Chemistry III***
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*

PHYSICAL CHEMISTRY
Graduate Subjects

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. (*Alternate years.*) *Amdur*

5.70T ***Introduction to Statistical Thermodynamics*** **(A)**
Prereq.: [illegible]
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. *Garland*

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 ***Chemical Thermodynamics II*** **(A)**
Prereq.: 5.61, 18.05
Year: G (2) 3–0–6
Development of the general thermodynamic theory from the first and second laws. Application of the theory to

homogeneous and heterogeneous systems in which chemical reactions may take place. *(Alternate years. Not offered 1966–67.)* *I. Oppenheim*

5.73 *Introductory Quantum Mechanics I* (A)
Prereq.: 5.63, 8.03
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*

5.74T *Introductory Quantum Mechanics II* (A)
Prereq.: 5.73 or 8.361; 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. *Thorson*

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. *(Alternate years. Not offered 1966–67.)* *Lord*

5.77 *Chemical Crystallography* (A)
Prereq.: 5.73
Year: G (1) 3–0–6
Symmetry groups of molecules and crystals; diffraction physics; X-ray, neutron, electron diffraction; determination of crystal structures; discussion of crystal structure types in relation to chemical bonding *(Alternate years. Not offered 1966–67.)* *D. P. Shoemaker*

5.78 *Statistical Mechanics* (A)
Prereq.: 5.63, 5.70T, 18.03
Year: G (2) 3–0–6
Principles and methods of statistical mechanics. Classical and quantum statistics, grand ensembles, fluctuations, cooperative phenomena, molecular distribution functions, and other selected topics, with applications to gases, liquids and solids. *(Alternate years. Not offered 1966–67.)* *I. Oppenheim*

5.79 *Kinetic Theory* (A)
Prereq.: 5.61, 18.05
Year: G (1) 3–0–6
Fundamental concepts of the kinetic theory of gases. Properties of gases at low densities; transport phenomena in relation to molecular interactions; introduction to fluctuations and Brownian motion. *(Alternate years.)* *Amdur*

5.81 *Magnetic Resonance* (A)
Prereq.: 5.73, 18.06
Year: G (2) 3–0–6
Interaction of nuclear and atomic moments with radiation and with their surroundings; steady-state and transient nuclear magnetic, paramagnetic, and pure quadrupole resonance experiments; theory of spectra and relaxation times. Emphasis on applications to studies of molecules and crystals. *(Alternate years. Not offered 1966–67.)* *J. S. Waugh*

RESEARCH

5.90 *Special Problems in Chemistry* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Directed research and study of special chemical problems. *For graduate students only.* *Garland*

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.
Hume (5.915), Roe (5.916)

5.931 *Seminar in Physical Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.932 *Seminar in Physical Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of topics of current interest in physical chemistry by staff members and students.
Bowers (5.931), Kinsey (5.932)

5.941 *Seminar in Inorganic and Nuclear Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.942 *Seminar in Inorganic and Nuclear Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of current research in inorganic and nuclear chemistry by graduate students and staff.
Seyferth (5.941), Gordon (5.942)

5.951 *Research Conference in Analytical Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.952 *Research Conference in Analytical Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of research problems under investigation by graduate students and staff. *Roe (5.951), Hume (5.952)*

***Research* (A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Research for any of the advanced degrees in inorganic, nuclear, analytical, organic, or physical chemistry. *Staff*

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6.
Electrical Engineering

6.001 ***Elements, Systems, and Computation I***
Prereq.: 8.01, 18.02
Year: U (1) 4–0–8

6.002 ***Elements, Systems, and Computation II***
Prereq.: 6.001
Year: U (2) 4–0–8

Two-term experimental sequence, which may be substituted for 6.01 and 18.034 by students majoring in electrical engineering. Interconnection of basic elements into signal and information processing networks and systems for communication, computation, and control. Modeling of basic building blocks. Network variables, equilibrium relations. State variables. Analytic and algorithmic methods. Existence and uniqueness of solutions. Convergence, stability, and error analysis. Development of necessary mathematics, including topics from set theory, linear algebra, differential and difference equations, and numerical analysis. Interrelation of principles in analysis and synthesis of systems. Use of computers in lecture demonstrations and homework assignments. Students without knowledge of Fortran IV may wish to take 6.47 concurrently. *(Registration limited.)*
S. J. Mason, Dertouzos, Athans

6.01 ***Introductory Circuit Theory I***
Prereq.: 8.03, 18.034
Year: U (1, 2) 4–0–8

6.013 ***Introductory Circuit Theory I***
Prereq.: 8.03, 18.034
Year: U (1) 4–0–8

Kirchhoff's laws, network equilibrium equations, algebraic and graphical solutions for resistive networks. Differential equations for RLC networks with exponential excitations; transient and steady-state behavior. Response of networks to steps and other singularity functions. System functions as functions of applied and natural frequencies and their geometrical interpretation in the complex frequency plane. Loop and node variables, linearity, Tellegen's theorem, reciprocity, and energy relations. *A. V. Oppenheim, Huang*

6.02 ***Introductory Circuit Theory II***
Prereq: 6.01
Year: U (2) 4–0–8

6.023 ***Introductory Circuit Theory II***
Prereq: 6.013
Year: U (2 4–0–8

Modeling of electronic control valves or power modulators, and analysis of nonlinear 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 modes. 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, 8.03, *18.05*
Year: U (1, 2, S) 4–0–8

6.033 ***Electromagnetic Fields and Energy***
Prereq.: 6.023, 8.03, *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*

6.06T ***Fields, Forces, and Motion***
Prereq.: 6.03
Year: U (1, 2, S) 3–0–9

6.063T ***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, Woodson

6.07T ***Energy Transmission and Radiation***
Prereq.: 6.03, 18.05
Year: U (1, 2) 4–0–8

6.073T ***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 nonuniform 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. *Bers*

6.08T ***Thermodynamics and Quantum Statistics***
Prereq.: 8.05 or 8.051
Year: U (1, 2) 4–0–8

6.083T ***Thermodynamics and Quantum Statistics***
Prereq.: 8.05 or 8.051
Year: U (1, 2) 4–0–8

Thermodynamics of materials interacting with electric, magnetic, mechanical and thermal environments. The laws of thermodynamics; state functions and their role in thermodynamic equilibrium; Maxwell relations and energy conversion. Connections to microscopic models of physical systems: particle in a box; harmonic oscillator; multiparticle systems. Statistics of weakly coupled

systems: Fermi, Bose-Einstein, Maxwell-Boltzmann statistics; mixed statistics; the partition function. Derivation of macroscopic material properties from microscopic models: ideal gas, electron gas, phonon and photon gases, magnetic and electric dipole systems. Semiconductor statistics; thermodynamics of masers; negative temperature; entropy and information. *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*

6.13T *Electric and Magnetic Properties of Matter*
Prereq.: 6.03 or 6.033; 8.04 or 8.05 and 8.051 or 8.06
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 ferro-magnetism. Electronic and ionic contributions to the dielectric constant. Some elements of statistical mechanics and thermodynamics. *A. C. Smith*

6.14 *Electronic Networks and Devices*
Prereq: 8.03, 18.034
Year: U (1, 2) 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. *S. J. Mason*

6.17 *Illumination*
Prereq.: 8.03
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. *Moon*

6.20 *Electronic Control and Measurement*
Prereq.: 6.05
Year: U (1, 2) 3–0–6

Analysis and design principles of electronic systems for control and measurement. Input and output conversion transducers; grid-current at negative grids; direct-coupled amplifiers; differentiating and integrating circuits; amplitude, frequency, and phase modulation; frequency-selective amplifiers; phase- and frequency-sensitive detectors. Emphasis on the nonlinear properties of electron tubes and transistors either as limitations or as useful characteristics. *T. S. Gray*

6.202 *Electronic Light Measurements*
Prereq.: 6.02
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 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. (*Not offered in 1966–67. See* 6.711 – 6.719.) *Edgerton*

6.213T *Feedback Control Principles*
Prereq : 6.05, 18.05
Year: U (1, 2) 3–2–7

An elective subject for seniors. Theoretical background for analysis and synthesis of feedback control systems. Representation of physical systems by transfer functions. Stability theory. Frequency response and root-locus methods. Analysis of cascade and feedback compensation techniques to improve performance. Selected topics from the following list: sampled and quantized-data systems, nonlinear systems studied through the use of the describing function method and the phase plane, introduction to Lyapunov stability theory, sensitivity analysis in conventional design, introduction to optimization theory for deterministic and stochastic signals, control of distributed systems, control system components. Laboratory. *L. A. Gould*

6.214 *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*

6.215 *Simulation Methods for Analysis and Control of Complex Systems*
Prereq.: 6.213T or 6.601
Year: U (2) 3–4–5

Introduction to simulation methods for analysis of complex dynamical systems and their controls. A background of elementary control theory assumed. Some knowledge of digital computer programming desirable but not required. Analog, hybrid, and digital methods for simulation treated by means of case studies. Use of one or more special languages useful in digital simulations. Speed and cost of alternative computing procedures considered. Analytical checking methods and pertinent questions of numerical analysis emphasized. Project-type problems using both analog and digital facilities used to illustrate modern simulation methods. *Newton*

6.216 *Dynamics of Electric Machines* (A, except for Course VI)
Prereq.: 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*

6.241 *Engineering Problems*
Prereq.: 6.05, *6.06T*
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

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discuss economic, legal, and other non-technical aspects, as well as technical engineering. Faculty counselors to be consulted about availability, field, and instructor.
O. C. White, Adler

6.243 *Inventions and Patents*
Prereq.: 14.01, 21.02
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.: 18.05
Year: U (1, 2) 3–1–8
An introduction to the use of digital computers as engineering tools for the solution of numerical and non-numerical problems and for on-line laboratory experimental work. The interdependence of machine hardware features and programming. Machine-to-machine interface and assembly language programming. Man-machine interface through problem-oriented languages. Numerical methods. 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.: 6.47, 18.034
Year: U (1, 2) 3–2–7
Basic principles of programming systems. Techniques for translation from problem-oriented languages to machine languages. Computer organization, programming, program planning and organization. Construction of assemblers, interpreters, compilers, monitor systems, time-sharing systems, debugging programs. Creation and use of tables, searching and ordering techniques. Laboratory work in the preparation and testing of programs for the IBM 7094 computer. Note: acceptable ability to program a computer will satisfy 6.47 prerequisite. *Corbato, R. M. Graham*

6.252 *Digital Systems Engineering*
Prereq.: 6.05
Year: U (1, 2) 3–0–6
Introduction to basic concepts in design of digital systems, with emphasis on logical aspects. Brief treatment of computer organization and digital representation of information. Boolean algebra. Methods for logical synthesis of switching networks, both combinational and sequential. Utilization of electronic devices as bivalued elements in digital building blocks. Organization of these blocks into counters, arithmetic and control elements, and memory units. Self-checking and self-correction in digital systems. *Susskind*

6.253T *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*

6.254 *Data Structures for Symbol Manipulation*
Prereq.: 6.25T or 6.251
Year: U (2) 3–0–6
Review of 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*

6.255T *Discrete Systems Analysis*
Prereq.: 6.02, 18.034
Year: U (1) 4–0–8
Study of the basic concepts of modern algebra, with emphasis on finite mathematical systems and their application to problems in the processing and transmission of information. Fundamentals of set theory, Boolean algebra and its application to logical design. Group theory and its application to coding. Fields as generalized arithmetic systems, polynomials over fields, and circuit counterparts. Vector spaces and linear transformations. Linear codes and linear sequential circuits. Semigroups and their application to the study of finite-state machines. *Hennie*

6.256T *Applications of Combinatorial Mathematics*
Prereq.: 6.255T 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 that will be covered are: 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*

6.257T *Elements, Systems, and Computation*
Prereq: 6.01, 18.034
Year: U (2) 3–0–9
Relation of theoretical and algorithmic approaches to static-dynamic, linear-nonlinear, and continuous-discrete systems which are abstracted from the physical world. Topics covered: modeling and approximation of continuous and discrete, linear and nonlinear, electrical and nonelectrical elements; interconnection of elements into networks and other structures; equilibrium relations; theoretical and computational methods for linear-nonlinear algebraic, differential, and difference equations; memoryless and dynamic, linear-nonlinear, continuous-discrete systems, the sequential model and state-space point of view; digital computer simulation; notions of convergence, stability, error propagation, theorem, algorithm existence, and uniqueness. Use of digital computers and associated graphical displays for demonstrations and for homework. (*Not offered 1966–67.*)
Dertouzos

6.28J *Probabilistic Systems Analysis*
(Same subject as 15.09J)
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. Theory of probability presented on an axiomatic basis. Emphasis on sample 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 modelling. Applications presented concurrently with the development of the theory. *Drake*

6.311T *Principles of Communication*
Prereq.: 6.05
Year: U (1, 2) 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.
R. S. Kennedy

6.32 *Principles of Plasma Dynamics*
Prereq.: 6.07T
Year: U (1) 3–0–6
Introductory course on plasma phenomena with emphasis on wave propagation. Motion of particles in electric and magnetic fields. Creation of an ionized gas. The Boltzmann equation. The plasma as a continuum and plasma waves such as electromagnetic waves, longitudinal waves, cyclotron waves, whistler modes, helicon waves. The magnetohydrodynamic limit and Alfvén waves. Energy extraction from moving plasmas. *Briggs*

6.341 *Principles of Transistors I*
Prereq.: 6.02 or 6.14 or 6.44; *8.051*
Year: U (1) 3–3–6
First half of a two-term sequence (6.341 and 6.342) covering the theory, characteristics, and applications of transistors from semiconductor physics through transistor circuit design. Introduction to semiconductor physics required for an understanding of transistor internal electronics; internal mechanisms of the transistor and development of electrical terminal characteristics, including appropriate d-c, small-signal, and switching models; the transistor as a circuit component, including considerations of operating point selection, dependence of parameters on temperature and operating point, stability, gain, impedance matching, and coupling. Related laboratory work. *Wedlock, Searle*

6.342 *Principles of Transistors II*
Prereq.: 6.341
Year: U (2) 3–3–6
Second half of sequence 6.341, 6.342. Investigation of the limits on transistor circuit performance imposed by temperature, gain, power, and speed limitations; application of feedback to transistor circuit design; representative circuit applications with emphasis on features which characterize good design, using examples which illustrate the limitations of transistor circuit performance. Digital circuit design. Physics and circuit operation of other semiconductor devices, including field-effect transistors and PNPN switches. Related laboratory work. *Searle, Wedlock*

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. *Bose*

6.36J *Speech Communication*
(Same subject as 23.764J)
Prereq.: ——
Year: U (2) 3–0–6
For well-qualified students with a serious interest in speech communication. Survey of structural properties of natural languages with special emphasis on the sound pattern. Survey of physiology of speech production, articulatory phonetics. Accoustical theory of speech production: the vocal tract as a generator of acoustical signals; acoustical correlates of vocal-tract configurations, both stationary and dynamic. Perception of speech: the auditory capabilities of man; the role of set in perception; analysis by synthesis. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. *Stevens, Halle*

6.37T *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, S. J. Mason*

6.372T *Introduction to Neuroelectric Potentials*
Prereq.: 8.04, 18.034
Year: U (2) 3–3–6
Introduction to basic phenomena of signal generation and transmission in the nervous system. Discussion of impulse initiation and transmission in nerve fibers. Synaptic transmission and sensory 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*

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 develop-

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ments, 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*

6.43 ***Introduction to Electrical Science***
Prereq.: 8.03
Year: U (1, S) 4–2–6

6.44 ***Introduction to Electrical Science***
Prereq.: 6.43
Year: U (2) 4–0–8

Two-term sequence for students not majoring in electrical engineering or electrical science. Introduction to the communications aspects of electrical science. Linear and nonlinear operations upon electrical signals. Synthesis of basic operations by means of electric and electronic circuits. Emphasis on transistor circuits. General properties of linear circuits and systems. The correlation concept. Analysis of signals and their spectra, some examples of random signals and noise. Modulation and detection processes. *S. J. Mason*

6.47 ***Introduction to Automatic Computation***
Prereq.: ——
Year: U (1, 2) 2–2–2

Principles of describing computation processes and programming digital computers to do them. Programming and running of suitable elementary problems in an algebraic language. *Kehl, Corbató*

6.48J ***Electromechanical Components and Systems***
(Same subject as 2.13J)
Prereq.: 2.022 or 6.01
Year: U (1, 2) 4–2–6

Elementary treatment of magnetic and dielectric materials and circuits, including energy conversion and force relations, with applications to electromagnetic, electrostatic, and electromechanical devices, including instruments, control components, and power machinery. Laboratory work to illustrate 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. *T. S. Gray*

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*

6.521 ***Electrical Energy Conversion*** **(A)**
Prereq.: 2.403 or 6.08T or 8.07; 18.05
Year: G (2) 3–0–9

Introduction to theory and design of processes for direct electrical energy conversion. Typical processes: thermoelectric conversion, thermionic conversion, fuel cells, and photovoltaic conversion. From first principles to a discussion of such topics as electronic transport in solids using Boltzmann transport theory, quantum statistics, energy band theory of solids, electronic and thermal conduction processes, and thermionic emission. Introduction to irreversible thermodynamics and their use to describe device operations. Detailed treatment where possible of device characteristics including efficiency, power density, and terminal properties. *D. C. White*

6.526 ***Magnetohydrodynamic Energy Conversion*** **(A)**
Prereq.: 2.274 or 6.06T or 8.461 or 18.63
Year: G (2) 3–0–9

Application of the interactions between electromagnetic fields and conducting fluids to achieve electromechanical energy conversion. Fundamental properties of alternative coupling schemes for a-c and d-c systems on a one-dimensional, idealized basis. Degrading effects of viscosity, heat conduction, end effects, etc. Physical conditions for application of MHD energy conversion systems for power generation and propulsion. Analysis of existing and proposed systems. *Woodson*

6.527 ***Continuum Electromechanics*** **(A)**
Prereq.: 2.211 or 6.06T; 6.03
Year: G (1) 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 nonlinear 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*

6.536J ***Systems Engineering and Operations Research*** **(A)**
(Same subject as 15.594J)
Prereq.: 6.28J or 18.10 or 18.18; 18.05
Year: G (2) 3–0–9

Analysis of linear probabilistic systems. Application of linear system theory to the study of finite- and infinite-state, discrete- and continuous-time, stationary and nonstationary, Markov 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*

6.537T *Computational Models* (A)
Prereq.: 6.252
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*

6.538T *Computational Models* (A)
Prereq.: 6.537T
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 content-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. (*Not offered 1966–67. See 18.163*) *Minsky*

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*

6.561 *Network Analysis and Synthesis* (A)
Prereq.: 6.05, 18.05
Year: G (1, 2) 3–0–9
Advanced treatment of linear passive network theory with primary emphasis on synthesis aspects. Thorough discussion of the conditions that network functions must satisfy to be physically realizable; application to the design of networks for prescribed driving-point and transfer characteristics. Specific topics include: natural frequencies; Tellegen's theorem; properties of LC, RC, RL and RLC networks; the synthesis procedures according to Foster, Cauer, Darlington and Bott-Duffin; design of low pass, band pass, high pass, and notch filters; and precorrection for parasitic effects. *H. B. Lee*

6.563 *Electronic Circuit Theory: Linear and Time-Invariant* (A)
Prereq.: 6.20 or 6.342 or 6.60
Year: G (1) 3–0–9
Principles of analysis and synthesis of linear active circuits. Emphasis on general principles including conservation theorems, imbedding, invariants, realizability limitations, and perturbation analysis. Illustrative applications related to RLC circuits, amplifiers, feedback systems and active filters. Some problem assignments involving the use of analog and digital computers. *H. B. Lee, Thornton*

6.564 *Electronic Circuit Theory: Nonlinear and Time-Varying* (A)
Prereq.: 6.20 or 6.342 or 6.60
Year: G (2) 3–0–9
Principles of analysis and synthesis of nonlinear circuits. Emphasis on general principles, including piecewise-linear methods, state-space analysis, frequency-power formulas, and conservation laws. Illustrative applications related to oscillators, feedback amplifiers, diode circuit synthesis, parametric and quasi-linear amplifiers, frequency converters, and switching circuits. Some problem assignments will involve the use of analog and digital computers. *H. B. Lee, Thornton*

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*

6.57 *Random Signals and Linear Systems* (A)
Prereq.: 6.02, 18.05
Year: G (1) 3–0–9
Combination of a review of methods for the representation and analysis of linear systems with an elementary introduction to probability theory and the problems of characterizing random signals and noise. Specifically intended for first-year graduate students entering from other schools and planning to pursue further studies in the area of statistical communication theory. Topics in the area of random signals including: fundamentals of probability theory, random variables, distributions, averages, characteristic functions, transformation of variables, limit theorems, ensembles and random processes, correlation functions and spectra, elementary detection and decision problems. Topics in the area of linear systems including: convolution and superposition integral, complex frequency and system func-

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tions, Fourier-Laplace integral representations for signals. Examples selected to illustrate important concepts and problems in modern communication. *Siebert*

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 (1, 2) 3–0–9
Operators and functionals. Volterra functional power series representation for nonlinear systems. Techniques for the study of nonlinear systems under functional representation when the input is a transient, a sinusoid, or a random process. Emphasis given to nonlinear systems with random inputs. Representation of nonlinear systems by Wiener's orthogonal functionals. Measurement of the kernels of a nonlinear system by crosscorrelation. Model of a nonlinear system in the form of a Laguerre-Hermite expansion. Synthesis of nonlinear systems. The optimum nonlinear filter, predictor, and general operator. Use of Bose's gate functions in nonlinear problems. Determination of functional representation for a nonlinear system from nonlinear differential equation representation. Application of functional techniques to modulation problems. *Y. W. Lee*

6.573 *Introduction to Random Processes* (A)
Prereq.: 6.05 and 6.28J; or 6.57
Year: G (1, 2) 3–0–9
Review of probability theory: random variables, density and distribution functions, statistical independence, functions of random variables, expectations and characteristic functions. Random processes: partial and complete characterization, stationarity and ergodicity. Functions of random processes. Time correlation functions. Input-output relations in linear systems. Representation of processes; sampling theorem, orthogonal series. Poisson processes. Gaussian processes. Emphasis placed on developing an ability to formulate and solve probabilistic problems *Van Trees*

6.574 *Transmission of Information* (A)
Prereq.: 6.28J or 6.311 or 6.57 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. Topic for 1966–67: the algebraic theory of error-correcting codes. *Massey*

6.576 *Statistical Theory of Detection, Estimation and Modulation* (A)
Prereq.: 6.57 and *6.573;* or 6.573
Year: G (2) 3–0–9
Application of statistical techniques to the areas of detection, estimation, and modulation theory. Detection theory topics including: decision theory formulation, relationship between various criteria, sequential testing and singular tests. Applications of detection theory in radar and digital communication systems. Estimation theory for signals described by finite parameter sets, measurement errors, generalized Cramer-Rao bounds. Application of finite estimation theory to radar, radio astronomy, and communication problems. Properties of signal ambiguity functions and channel scattering functions and their role in the above areas. Estimation theory for continuous message processes. Structure and performance of efficient demodulators for continuous modulation systems. Threshold problems in nonlinear modulation systems. Relationship to optimum linear filtering and information-theoretic results. *Van Trees*

6.577 *Modulation Theory and Systems* (A)
Prereq.: 6.311; or 6.57 and *6.573;* or 6.573
Year: G (2) 3–0–9
Detailed study of the joint application of coding, modulation, and detection theory to the design, instrumentation, and evaluation of communication systems. Channel capacity and performance limitations due to noise. Effects of input and output quantization. Coder and decoder implementation and characteristics. Channels with filters and fading. Time, frequency, and coding diversity. Performance of continuous modulation systems; noise suppression, threshold, and constraints due to channel capacity. Quantitative comparison of discrete and continuous signaling. *Staff*

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 applications to communications, detection, and control systems. Probability as a model for empirical averages. Random variables and probability distribution functions. Statistical averages, correlation, and characteristic functions. Elements of sampling theory and estimation. Derivation of statistical properties of such physical phenomena as Brownian motion and shot noise. Basic properties of Wiener, Poisson, Markov, and Gaussian random processes. Passage of random processes through linear systems, definition of spectra, and an introduction to the theory of optimum linear systems. Elements of statistical detection theory. Various additional applications at the discretion of the instructor. (*Restricted to Practicing Engineers in The Center For Advanced Engineering Study.*) *Davenport*

6.583 *Advanced Topics in Continuum Electrodynamics* (A)
Prereq.: 6.07 or 8.72 or 8.721
Year: G (1) 3–0–9
Precise material to be covered and prerequisites change from year to year according to interest of the instructor in charge. Typical subjects: electromagnetism of moving media, electromechanical dynamics, waves in dispersive media, force in moving media, and source-excited electromagnetic fields. In 1966–67: electromagnetic fields supported by open structures in the presence of a source, with detailed consideration given to approximating integrals involved. Relationship between modes of the system and singularities of the integrands. Saddle-point asymptotic techniques, complex waves and relationship to radiation fields. The dielectric slab,

plasma layer, surface waves, leaky waves, and space waves. The Zenneck wave-Sommerfeld pole controversy, modified saddle-point technique, complex numerical distance. Stratified media, lateral wave, and relationship to leaky wave. *Bernard*

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. *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*

6.592 *Analytical Models for Human Processing of Sensory Inputs* (A)
Prereq.: 6.37 or 6.372T
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 1966–67.*) *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. *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 will vary from term to term and year to year. Topics for 1966–67: pattern recognition for 6.595 and electro-optical image processing for 6.596. *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 nonlinear 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. *Athans, Brockett*

6.601 *Control System Theory* (A)
Prereq.: 6.05; *6.57* 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 nonlinear 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 nonlinear 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 nonlinear systems. Study of time-varying and nonlinear 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 nonlinear theory, optimal control,

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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, 16.362J)
Prereq.: 6.311T or 6.536J 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 trade-offs 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. (Projects for 1966 were: Group 1 — integrated urban transportation system. Group 2 — manned satellite inspection and retrieval system.) *Seifert, Bisbee, Baumann, Li*

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.: 6.601 or 10.35; 18.05
Year: G (2) 3–0–9
Control of industrial processes with emphasis on applications in the chemical industries. Development of lumped and distributed dynamic models of chemical processing units. Partial differential equations of linear convective processes and methods of solution. Perturbation theory for typical nonlinearities. Conventional regulation problems. Control of multi-variable 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*

6.61 *Production and Control of Charged Particle Beams* (A)
Prereq.: 6.03, 18.05
Year: G (2) 3–0–6
Introduction to the dynamics of directed charged particle beams, discussed from several viewpoints: by analogy with geometrical optics, as single-particle trajectories in electromagnetic fields, and as interacting many-particle flows. Brief review of the variational principles of mechanics, relevant to the subject, with application to the problem of particle beams. Presentation and discussion of several approaches to the problem of electric and magnetic interactions in intense beams. Description of certain representative particle beam devices with brief surveys of selected topics from the technology of particle accelerators, viz., ion sources, technique of high vacuum, high energy acceleration, insulation of high voltages. *Philp*

6.621 *Microwave Circuits* (A)
Prereq.: 6.07T
Year: G (1) 3–2–7
Analysis of electromagnetic wave propagation in uniform cylindrical waveguides; reduction of waveguide and discontinuity problems to equivalent transmission line and network problems; obstacles as matching elements. Cavity resonators; perturbation theory. Multiple waveguide junctions; matrix algebra techniques. Laboratory experiments. *Bers*

6.622 *Antennas* (A)
Prereq.: 6.07T
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.: 6.07T or 8.72
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, angular, 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. *Staelin*

6.625 *Fundamentals of Radio Astronomy* (A)
Prereq.: 6.624 or 8.05 or 8.051
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 6.625.*) *Barrett*

6.632 *Electronic Instrumentation and Control* (A)
Prereq.: 6.05
Year: G (1, 2) 3–0–9
Transistors, other solid-state devices, and electron tubes in electronic instrumentation for control and measurement. Electronic conversion transducers; direct-coupled, pulse, and signal-processing amplifiers; modulators and demodulators; monostable and bistable switching circuits; gates; coincidence circuits; random-event counting

and count-rate circuits. Illustrations from such applications as time-interval and frequency measurements, high-speed counting and recording instruments, computer components, strain gages, tachometers, and nuclear-reactor control. *T. S. Gray*

6.634J *Plasma Laboratory* (A)
(Same subject as 22.65J)
Prereq.: 2.274 or *8.231* 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. *D. J. Rose*

6.635T *Semiconductor Electronics* (A)
Prereq.: 6.08T, 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; brief introduction to p-n junction lasers; avalanche processes in p-n junctions and transistors; four-layer diodes and controlled rectifiers; field-effect transistors. *Adler*

6.636T *Microelectronics* (A)
Prereq.: 6.341; 6.342 or 6.635T
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. *Navon*

6.637 *Beam-Type Microwave Tube* (A)
Prereq.: 6.07T, 6.621
Year: G (2) 3–0–9
Interactions between electron beams and stationary or traveling electromagnetic fields; space charge waves, cyclotron waves; coupling of modes in propagating systems; kinetic power theorem; propagation in plasma waveguides. *Smullin*

6.638 *Seminar on Solid-State Plasma Effects* (A)
Prereq.: 6.07T or 8.72; 6.08T or 8.07
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 semi-metals. *McWhorter, Bers*

6.639J *Physical Electronics and Particle Optics* (A)
(Same subject as 2.455J)
Prereq.: 2.404T or 6.08T or 8.07
Year: G (2) 3–0–9
Interactions among individual charged particles, neutral particles, photons, fields, and solid surfaces, primarily under circumstances of low concentration. Thermodynamics and statistics of thermionic, photo, field, secondary, and Auger emission; adsorption, ionization processes and related effects. Optics of charged particles: Gaussian optics, Liouville's theorem, diffraction, the paraxial ray equation; mass selecting, energy selecting, and confinement properties of electric and magnetic fields. (*Not offered 1966–67.*) *Crawford, Stickney*

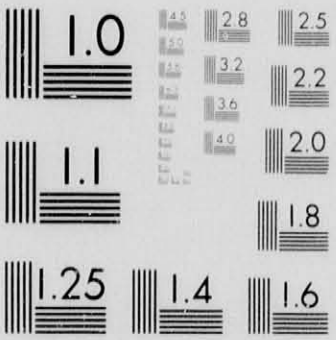
6.641J *Laboratory in Physics of Solids* (A)
(Same subject as 3.40J)
Prereq.: 3.15T or 6.08T; 8.04 or 8.051
Year: G (1, 2) 0–8–4
Experimental investigations on the physical properties of materials closely related to current research; brief lectures on the basic theories and experimental methods. Experiments 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.: ——
Year: G (1) 3–0–9

6.643 *Special Topics in the Solid State and Its Application* (A)
Prereq.: ——
Year: G (2) 3–0–9
Primarily for those interested in research on solid-state materials and devices for electrical or electronic applications. Topic and staff to be announced each term. These two subjects given independently or sequentially, as circumstances require. (*Consent of instructor required.*) *Adler*

6.644 *Microwave Magnetics* (A)
Prereq.: 6.07T, 8.051
Year: G (2) 3–0–9
Fundamentals and engineering applications of microwave resonance in magnetically ordered insulators. First part devoted to the linear response of gyromagnetic media to electromagnetic fields, including: derivations of Polder susceptibility tensor, Kittel resonance frequency, Faraday and Cotton-Mouton effects; propagation in ferrite-filled waveguides, reciprocal and non-reciprocal microwave circuit elements such as rotators isolators, circulators, and gyrators; magnetostatic modes, and spin-waves; resonance loss mechanisms. Elastic waves in continuous and discrete media, magnon-phonon interactions and magnetoelastic waves. Second part devoted to nonlinear effects associated with ferromagnetic resonance, including: nonlinear resonances, harmonic generation and frequency mixing; parametrically excited magnon-phonon instabilities, saturation of the main resonance, subsidiary absorption. Nonlinear magnon-phonon spectroscopy. *Morgenthaler*

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6.646 *Conduction Processes in Solids* (A)
Prereq.: 6.08T or 8.07; 6.635T or 8.35 or 8.361 or 8.731
Year: G (2) 3–0–9
Topics in transport theory, including crystal symmetry, Onsager relations, brief discussion of electronic energy bands in solids, Boltzmann transport theory, electronic scattering mechanisms; detailed application to semiconductors for which the problems are of intermediate difficulty. Discussion of quantum effects and non-equilibrium thermodynamical methods, as time permits. *A. C. Smith*

6.647 *Seminar in Fundamental Properties of Materials* (A)
Prereq.: 8.35 or 8.361
Year: G (1) 2–0–7

6.648 *Seminar in Fundamental Properties of Materials* (A)
Prereq.: 6.647
Year: G (2) 2–0–7
Electronic properties of semiconductors studied in relation to their energy band structure. Discussion of measurements of conductivity, magneto-resistance, Hall effect, magnetic susceptibility, cyclotron resonance, optical and magneto-optical properties, and transport properties. Interpretation of experiments in terms of energy bands, effective mass theory, role of spin orbit coupling, non-parabolic effects, and the Bloch electron in a magnetic field. Consideration of deformation potential theory and the properties of semiconductors under pressure. Aimed at relating a formal background in solid state to the planning and interpretation of experiments in materials research. Guest specialists to speak on their current research. *(Not offered 1966–67.)* *Pratt*

6.65 *Quantum Theory of Magnetism* (A)
Prereq.: 8.361
Year: G (2) 3–0–9
Magnetic properties of isolated atoms and ions. Crystal field theory. The spin Hamiltonian. Optical properties of paramagnetic crystals. Spin paramagnetism of metals. Diamagnetism of solids. The de Haas-van Alphen effect. Cyclotron resonance and magneto-optic effects in semiconductors. Ferromagnetic exchange interactions. The Weiss and Heisenberg theories of ferromagnetism. The Bethe-Peierls-Weiss theory. Energy band theory of ferromagnetism. Superexchange coupling in antiferromagnetism. Ferrimagnetism. *Pratt*

6.66 *Engineering Applications of Tensors* (A)
Prereq.: 8.04
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. *Moon*

6.671J *Flight Transportation* (A)
(Same subject as 1.221J, 15.483J, 16.751J)
Prereq.: 6.05 or 6.07T or 6.213T
Year: G (1) 3–0–6
Integrated discussion covering the 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. *Reintjes, Bone, Farrar, R. H. Miller*

6.672J *Flight Transportation Seminar*
(Same subject as 1.222J, 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. *Reintjes, Bone, Farrar, Browne*

6.681-6.689 *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 requirements by the student and staff members interested, subject to approval of the professor in charge. *Davenport*

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 *Experimental Electronics*
Prereq.: 6.02 or *6.023* or *6.14*
Year: U (2) 1–4–1
Laboratory work concerned with electrical measurements, electronic components and instruments, and circuits. Experiments to introduce important experimental techniques with an opportunity to use these techniques on individual projects. *Wedlock*

6.71 *Electronic Circuits and Signals Laboratory*
Prereq.: 6.70
Year: U (1, 2) 1–4–1
Required laboratory for electrical engineering students. Experiments on electric and electronic circuits and systems. *Troxel*

6.711-6.719 *Project Laboratory in Electrical Engineering*
Prereq. 6.70
Year: U (1, 2) 2–8–2
Laboratory subjects in such fields as digital circuits, bio-electronics, speech communication, electronic light measurement, etc. Information on current topics available from faculty counsellors or the Department of Electrical Engineering. *(Limited enrollment because of limited facilities.)* *Troxel, Wedlock*

6.72 *Electromagnetic Laboratory*
Prereq.: 6.03 or 6.033
Year: U (1, 2, S) 1–4–1
Required laboratory for electrical engineering students. Experiments and projects on measurements of electromagnetic fields and waves. *Smullin*

6.73 *Advanced Electrical Engineering Laboratory*
Prereq: 6.06T or *6.063T* or *6.07T* or *6.073T* or *6.08T 6.083T; 6.72*
Year: U (1, 2) 1–4–1
Required laboratory for electrical engineering students. Experiments and projects on advanced level, including U.H.F. and microwave techniques, or full term project in Institute research laboratories. *Kyhl*

6.74 ***Advanced Electrical Energy Conversion Laboratory*** **(A)**
Prereq.: 6.06T
Year: G (1 or 2) *Arr.*
Graduate subject planned for the individual student; special problems on electrical energy converters and modulators. *D. C. White*

6.80 ***Electrical Circuits Laboratory***
Prereq.: ——
Year: U (1 or 2) *Arr.*
Experimental work at the sophomore level on electric circuits, meters, basic measurements, etc. *Troxel, Wedlock*

6.81 ***Electrical Engineering Laboratory***
Prereq.: 6.02
Year: U (1 or 2) *Arr.*
Experimental work at the junior and senior levels.
Troxel, Wedlock

6.831-6.839 ***Teaching Electrical Engineering*** **(A)**
Prereq.: ——
Year: G (1, 2) 0–12–0
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. *T. S. Gray*

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, Mass., 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 aero-physics, 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*

6.885T ***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*

6.895T ***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*

6.90T ***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 Johnson City, Pittsfield, Schenectady, Syracuse or Utica. Work in electronic circuitry, solid-state physics, control and guidance systems, and computer applications as applied to research and development of commercial and government communication and control systems and ordnance equipment. *Reintjes*

6.905-6.907 ***Industrial Practice at the International Business Machines Corporation***
Year: U (1, 2, S) 0–9–0
6.908 ***Industrial Practice at the International Business Machines Corporation***
Year: G (S) 0–9–0
Work at an IBM plant in Endicott, Kingston, Ossining, Owego, or Poughkeepsie. Student participation in computer development, design, and application. Work in advanced circuit theory, solid-state physics, game theory. *Reintjes*

6.909T ***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, 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. 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

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6.919T ***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 ferro-magnetics; acoustics, and microwave electronics. *Reintjes*

6.939T ***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 or Whippany (N. J.), or New York City]. Work in all areas of circuit development pertaining to communication systems. Solid-state physics, microwave propagation, transistor logic circuitry, digital comparators, ferroelectrics, switching systems, electronic instrumentation, push-button dial systems, and pulse transmission systems all available as projects in the development and application stages. *Reintjes*

6.949T ***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*

6.959T ***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 (Canton, Fort Wayne, New York City, or Roanoke). Work associated with the operation and planning of a large multi-state power generation and distribution system. Challenging assignments in computer solutions (analog and digital) of power flow, stability, regulation, and economy loading in a large network. Microwave communication systems, electronic relaying, research in corona and extra-high voltages. Opportunities for outside experience during earlier terms. *Reintjes*

6.979T ***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 Naval duty following graduation. Acceptance optional. *Reintjes*

6.989T ***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 knowl-

edge required for design of electronic equipment in terrestrial, aeronautical, and astronautical environments); communications systems and techniques (in terrestrial and extraterrestrial environments). *Reintjes*

6.999T *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: 1 (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 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.: 5.01, 8.02
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. *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*

7.03 *Genetics*
Prereq.: 7.05, 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. *Fox*

7.031 *Genetics and Microbiology Laboratory*
Prereq.: 7.21
Year: U (2) 1–6–2
A project-type laboratory subject designed 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 *Developmental Biology Laboratory*
Prereq.: 7.02, 7.05
Year: U (1) 1–6–2
Introduction to some classical and modern experimental methods for the analysis of development. Individual projects. *Staff*

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 (1) 0–8–0
Laboratory exercises to illustrate principles discussed in 7.05. *B. S. Gould, G. M. Brown*

7.06 *General Physiology*
Prereq.: 5.61, 7.01, 7.05
Year: U (1) 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. *Dowben, D. F. Waugh*

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7.061 ***General Physiology Laboratory***
Prereq.: 7.06
Year: U (2) 0–6–0
Laboratory investigation of physiological processes.
Staff

7.08 ***Introduction to Biophysics***
Prereq.: 7.00 or 7.01; 8.03
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. *Penman*

7.21 ***General Microbiology***
Prereq.: 7.01, 7.05
Year: U (1) 3–0–6
Properties of unicellular organisms, especially bacteria: composition, metabolic activities, and structural organization. Microorganisms as model systems for the study of cellular growth and its physiological basis. Variation, heredity, and the organization of the genetic system in bacteria. Comparative discussion of cellular organization in bacteria, in other microbes, and in multicellular organisms. *Luria*

7.23T ***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*

7.31 ***Biology Seminar*** **(A)**
Prereq: 7.05
Year: G (1) 2–0–4

7.32 ***Biology Seminar*** **(A)**
Prereq.: 7.05
Year: G (2) 2–0–4
Designed to give graduate students experience in critical evaluation of research and in public speaking by presenting oral reports before staff and students. *Staff*

7.36 ***Advanced Neurophysiology*** **(A)**
Prereq.: 7.06
Year: G (1) 2–0–4
A series of lectures, with student participation, on some aspects of the nervous system. Foundation for work on the structure and function of the nervous system. *Wall*

7.50 ***Physical Chemistry of Macromolecules*** **(A)**
Prereq.: 5.61, 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*

7.51 ***Organ and System Physiology*** **(A)**
Prereq.: 7.01, 7.06
Year: G (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 will be arranged if sufficient students interested in quantitative system analysis register. *Wall*

7.68 ***Intermediary Metabolism*** **(A)**
Prereq.: 7.05
Year: G (2) 3–0–6
Survey of chemical pathways of metabolism with emphasis on recent literature in biochemistry. Biosynthesis of important tissue constituents such as amino acids, proteins, lipids, nucleic acids, vitamins, and porphyrins. Mechanisms of biochemical reactions. *Buchanan, Robbins*

7.69 ***Seminar in Biochemistry*** **(A)**
Prereq.: 7.05
Year: G (2) 2–0–4
Reading and reporting of reviews and recent publications in biochemistry. Designed to be taken simultaneously with 7.68. *(Permission of instructors required.)*
Robbins, Buchanan

7.70 ***Seminar in Protein and Nucleic Acid Structure*** **(A)**
Prereq.: 7.05
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*

7.81 ***Enzymology*** **(A)**
Prereq.: 7.05
Year: G (1) 2–0–4
Quantitative study of enzymes emphasizing their general properties; kinetics of reactions catalyzed by them; conditions which control their activity. *Sizer*

7.811 ***Enzymology Laboratory*** **(A)**
Prereq.: 7.81
Year: G (1) 0–4–2
Methods of purification of enzymes; determination of their catalytic activity and chemical properties; effects of environmental factors on enzymes. *Robbins*

7.85 ***Optical Methods in Biophysics*** **(A)**
Prereq.: 7.06, 8.03
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
Recent experimental and theoretical developments in molecular genetics will be reviewed. Emphasis on the genetic, isotopic, and radiation experiments which yield information on the replication of nucleic acid, the mechanism of genetic recombination, and the translation of genetic information into molecular structure.
Levinthal, Fox

7.90 ***Seminar in Enzymology*** **(A)**
Prereq.: 7.81
Year: G (2) 2–0–4
Discussion of recent advances in the field of enzymology, with emphasis on enzymes concerned with respiration, phosphorylation, and intermediary metabolism. *Sizer*

7.911 ***Instrumentation and Research Methods*** **(A)**
Prereq.: 8.03
Year: G (1) 2–0–4
Introduction in 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.: 8.03
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.: 7.05
Year: G (1 or 2) *Arr.*
Class work in various fields of biology not covered by the regular subjects of instruction. *Staff*

7.941 *Research Problems* (A)
Prereq.: ——
Year: G (1) *Arr.*

7.942 *Research Problems* (A)
Prereq.: ——
Year: G (2) *Arr.*
Directed research in a field of biological science, but not contributory to graduate thesis. *Staff*

7.95 *Electron Microscopy* (A)
Prereq.: 7.85 or 8.03
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.: 7.06
Year: G (1) 2–0–4
The properties conferred on biochemical substances by assumption of specific physical configurations. Optical methods (emphasizing X-ray diffraction) for determining configuration in macromolecular systems. Selected examples of the relationship between molecular order and function in tissues. *Rich*

8.
Physics

8.001 *Introduction to Physical Ideas*
Prereq.: ——
Year: 1 (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: 1 (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 fields; orbits and scattering. *French*

8.02 *Physics II*
Prereq.: 8.01
Year: 1 (1, 2) 5–0–7
Relativity: deviations from Newtonian dynamics; Lorentz-Einstein transformations; relativistic dynamics. Oscillations and waves: resonant systems; coupled oscillators and normal modes; wave kinematics and dynamics. *French*

8.03 *Electricity and Magnetism*
Prereq.: 8.02, 18.02
Year: U (1, 2) 4–0–8
Elements of electricity and magnetism with emphasis on the invariance of charge; Gauss' law; dielectric and magnetic materials; properties of electric and magnetic fields of moving charges and their interrelationships as brought out by applications of the theory of relativity. *Staff*

8.04 *Modern Physics*
Prereq.: 8.03
Year: U (2) 4–0–8
Topics in atomic and nuclear physics chosen with the objective of illustrating the principles of quantum mechanics. *Staff*

8.05 *Physics of Atoms and Molecules I*
Prereq.: 8.04
Year: U (1) 4–0–8
Survey of the experimental foundation of quantum physics with examples largely from atomic phenomena: optical, X-ray radiofrequency, and infrared spectra; scattering of particles and radiation. Limitations of classical physics; photons, matter waves. Internal structure of atoms, and quantization; vector model, Pauli exclusion principle, and the periodic table of elements. *Clark*

8.051 *Introduction to Quantum Physics*
Prereq.: 8.04
Year: U (1, S) 4–0–8
Study of the experimental foundations of quantum physics and the quantum theoretical interpretation of atomic phenomena. *Enge*

8.053 *Introduction to Nuclear Physics*
Prereq.: 8.051 or *8.06*
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. *Enge*

8.06 *Physics of Atoms and Molecules II*
Prereq.: 8.05
Year: U (2) 4–0–8
Continuation of 8.05. Introduction to quantum mechanics. Application of quantum mechanics to atomic and molecular phenomena. *Clark*

(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.

8.07 ***Statistical Mechanics and Thermodynamics***
Prereq.: 8.05 or 8.051
Year: U (2) 4–0–8
Elementary kinetic theory and statistical mechanics, foundations of quantum statistics. Application to transport phenomena, heat capacities, black body radiation, electric and magnetic susceptibilities. Laws of thermodynamics with specific applications to the properties of matter. *Staff*

8.08 ***Electronics***
Prereq.: 8.04
Year: U (1) 4–0–8
Electron ballistics, mass spectroscopy; special relativity, principles of high-energy accelerators; space charge theory; Fermi-Dirac statistics, thermionic emission, Schottky effect, high field and secondary emission, photoelectric effect in metals; conductors, insulators, and semiconductors. *Harvey*

8.09 ***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.) *A. G. Hill*

8.10 ***Experimental Atomic Physics II***
Prereq.: 8.09
Year: U (2) 0–6–6
Continuation of 8.09 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. *A. G. Hill*

8.11 ***Experimental Physics***
Prereq.: 8.10
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. *Bernstein*

8.12 ***Special Problems in Undergraduate Physics***
Prereq.: ——
Year: U (1, 2) *Arr.*
Opportunity for undergraduates to engage in experimental or theoretical research under the supervision of a staff member. *Staff*

8.13 ***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. *Buechner*

8.14 ***Physics Laboratory***
Prereq.: ——
Year: U (1, 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. *J. G. King*

8.18 ***Special Problems in Optics*** **(A)**
Prereq.: 8.04
Year: G (1 or 2) *Arr.*
Experimental work in optics with assigned reading and consultation. *Staff*

8.20 ***Electromagnetic Theory of Light: Geometrical and Physical Optics***
Prereq.: 8.05, 18.05
Year: G (2) 3–0–9
Propagation of electromagnetic radiation in vacuum and in optically isotropic media; geometrical optics; interference and diffraction of light; light sources and detectors; optical and infrared spectroscopy and the structure of atoms, molecules, and solids; propagation of polarized light in anisotropic or non-linear media. (*Not offered 1966–67.*) *Benedek*

8.231 ***Electrical Discharges in Gases*** **(A)**
Prereq.: 8.05, 8.07
Year: G (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. *S. C. Brown*

8.25, 8.251 ***Special Problems in Electronics*** **(A)**
Prereq.: 8.08 or 8.44
Year: G (1 or 2) *Arr.*
Advanced problems in electronics, with assigned reading and consultation. *Staff*

8.27 ***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*

8.28 ***X-ray Diffraction*** **(A)**
Prereq.: 8.27
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*

8.30 *Special Problems in Crystal Physics* (A)
Prereq.: 8.27
Year: G (1 or 2) *Arr.*
Advanced problems in X-ray diffraction or crystal physics with assigned reading and consultation. *Staff*

8.311 *Introduction to Optical, Microwave, and Radiofrequency Physics* (A)
Prereq.: 8.361 or 8.731
Year: G (1) 3–0–9
Theory of optical, microwave, and radio frequency methods for determining properties of nuclei and atoms in gases and in the solid state. Topics include motion of spins in d-c and oscillating magnetic fields, electron-nuclear interactions, molecular beam methods, emission and absorption of light, optical double resonance experiments, nuclear magnetic resonance in solids, paramagnetic resonance, antiferromagnetic resonance, and ferromagnetic resonance. *Staff*

8.312 *Physics of Quantum Electronics* (A)
Prereq.: 8.731
Year: G (1) 3–0–9
Classical and quantum mechanical details of interaction of coherent electromagnetic fields with matter. Problems related to stimulated emission of radiation and nonlinear optics. *Javan*

8.321 *Advanced Atomic Physics* (A)
Prereq.: 8.361 or 8.731
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. *(Not offered 1966–67.)* *Feld*

8.34, 8.341 *Special Problems in Electromagnetic Wave Phenomena* (A)
Prereq.: 8.311
Year: G (1 or 2) *Arr.*
Advanced problems in optical, microwave, and radio frequency physics with assigned reading and consultation. *Staff*

8.35 *Solid-State Physics* (A)
Prereq.: 3.15T or 8.44; 8.051 or 8.06; 18.05
Year: G (2) 4–0–8
Introduction to wave mechanics of crystalline solids including wave motion of electrons and lattice in perfect crystals; crystal momentum, phonons; imperfections, point defects, dislocations; scattering and dissipative effects, interaction of electrons and photons. Electrical, magnetic, and thermal properties of metals, insulators, and semi-conductors, including specific heat, lattice vibrations, optical absorption, excitons, etc. *R. A. Smith*

8.361 *Quantum Theory and Atomic Structure* (A)
Prereq.: 18.05
Year: G (1) 4–0–8
Principles of quantum mechanics with application to atomic structure. Schrödinger's equation, matrix methods, interaction of atoms and radiation. The hydrogen atom, the electron spin, angular momentum vectors and their interaction. The self-consistent field for atoms and the Hartree-Fock equation. Atomic multiplet theory. *Staff*

8.363 *Theory of Solids* (A)
Prereq.: 8.361 or 8.731
Year: G (2) 3–0–9
Theory of lattice vibrations with application to X-ray, neutron diffraction, and equation of state. Energy band theory and the statistics of electrons in metals. Transport theory with application to electrical and thermal conductivity. *Staff*

8.364 *Selected Topics in the Theory of Solids* (A)
Prereq.: 8.363
Year: G (1, 2) 3–0–9
Topics in solid-state theory varying from year to year. *Staff*

8.37 *Neutron Diffraction* (A)
Prereq.: 3.12T or 8.27
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*

8.38 *Special Problems in Neutron Diffraction* (A)
Prereq.: 8.37
Year: G (1 or 2) *Arr.*
Experimentation in solid-state or neutron physics utilizing neutron scattering techniques. *Staff*

8.40, 8.401 *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*

8.411 *Statistical Thermodynamics I* (A)
Prereq.: 8.731
Year: G (1) 3–0–9
Principles of thermodynamics. Conditions of equilibrium and stability. The thermodynamic potentials. Derivation of the thermodynamic formulae. Phase transitions of the first and second kind. Nernst's law. Statistical foundations. Ensembles. Canonical and microcanonical distributions. Fluctuations. Elementary quantum statistics, Boltzmann gas, Debye theory of specific heat, entropy constants. *(Alternate years. Not offered 1966–67.)* *Tisza*

8.412 *Statistical Thermodynamics II* (A)
Prereq.: 8.411
Year: G (2) 3–0–9
Fermi-Dirac and Bose-Einstein statistics. The adiabatic method, molecules. Periodic structures, lattice vibrations, electrons in periodic fields. Electric and magnetic properties of matter. Density matrix. Radial distribution function. Irreversible thermodynamics, microscopic reversibility, distribution of fluctuation paths. Transport and relaxation effects. Superfluids. *(Alternate years. Not offered 1966–67.)* *Tisza*

(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.

8.421 *Statistical Mechanics I* (A)
Prereq.: 8.731
Year: G (1) 4–0–8
Review of thermodynamics: First and Second Law. Thermodynamic potentials. Conditions for equilibrium. Phase transitions and other applications. Third Law. Classical kinetic theory of gases: method of 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. (*Alternate years.*) *K. Huang*

8.422 *Statistical Mechanics II* (A)
Prereq.: 8.421
Year: G (2) 4–0–8
Quantum statistical mechanics: ensembles and density matrix. Darwin-Fowler method. Classical limit. Ideal gases and selected elementary applications in diamagnetism, paramagnetism, astrophysics. Bose-Einstein condensation. Imperfect gases. Virial expansion. Theory of equation of state and phase transitions. Special topics of application selected from theory of cooperative phenomena, quantum mechanical many body problems. (*Alternate years.*) *K. Huang*

8.44 *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*

8.45 *Special Problems in Solid-State Physics* (A)
Prereq.: 8.412
Year: G (1 or 2) *Arr.*
Advanced problems in the physics of the solid state, with assigned reading and consultation. *Staff*

8.461 *Introduction to Physics of Fluids and Plasmas* (A)
Prereq.: 8.07; 8.711; 8.72 or 8.721
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. (*Not offered 1966–67.*) *Ingard*

8.462 *Non-linear Phenomena in Fluids and Plasmas* (A)
Prereq.: 8.461
Year: G (2) 3–0–9
Survey of non-linear phenomena. Selected topics in the theory of large amplitude waves and oscillations in plasmas. (*Alternate years. Not offered 1966–67.*) *Staff*

8.47 *Wave Propagation in Plasmas* (A)
Prereq: 8.20 or 8.72; 8.231 or 8.461
Year: G (2) 3–0–9
Classical treatment of plane waves in cold homogeneous plasma; Appleton-Hartree and magnetohydrodynamic limits. Beam plasma interactions. Hot plasma and the Vlasov equation. Plasma-electron and ion-acoustic waves; Landau damping; cyclotron resonances. Inhomogeneous plasmas; shock waves in plasmas. (*Alternate years.*) *Allis*

8.48 *Charged Particles in Space* (A)
Prereq.: 8.711, 8.72
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. Alfvén Waves. Elements of shock theory for dilute plasmas. *Rossi*

8.481 *Physics of the Stars* (A)
Prereq.: 8.06, 8.07
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. A final reexamination of the observations in the light of processes discussed. *Iben*

8.482 *Stellar Evolution and Nucleosynthesis* (A)
Prereq.: 8.481
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. Not offered 1966–67.*) *Iben*

8.483 *Selected Topics in Astrophysics I* (A)
Prereq.: 8.50
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, A-rays, and extensive air showers. *Burke*

8.484 *Selected Topics in Astrophysics II* (A)
Prereq.: 8.48
Year: G (2) 3–0–9
Physics of the interplanetary medium. A description of: the outer corona; the interplanetary electron distribution; 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*

8.49, 8.491 *Special Problems in Fluid and Plasma Physics* (A)
Prereq.: 8.461
Year: G (1 or 2) *Arr.*
Advanced problems in fluid or plasma physics with assigned reading and consultation. *Staff*

8.50 *Physics of the Galaxy* (A)
Prereq.: 8.48 or 8.481
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. *Morrison*

8.511 *Nuclear Physics I* (A)
Prereq.: 8.06, *8.711*
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. *Bertozzi*

8.512 *Nuclear Physics II* (A)
Prereq.: 8.511
Year: G (2) 3–0–9
Continuation of 8.511. Ionization, scattering, and radiative losses for swift-charged particles. Properties of neutrons. Origin of gamma rays and their interaction with matter. Transmutation; fission; reactions induced by charged particles, gamma rays, and neutrons; excitation functions. Artificial radioactivity, nuclear spectroscopy. *Bertozzi*

8.531 *Nuclear Physics for Engineers I* (A)
Prereq.: 8.051 or 8.06
Year: G (1) 3–0–9
Nuclear phenomena, for advanced students not majoring in physics. Stationary states of nuclei: nuclear charge, radius, mass, moments, parity, and statistics. Barrier transmission; radioactive transitions; alpha, beta, and gamma decay. Binding energy, nuclear forces, and nuclear models. *Kolenkow*

8.532 *Nuclear Physics for Engineers II* (A)
Prereq.: 8.531
Year: G(2) 3–0–9
Continuation of 8.531. Nuclear dynamics: energetics and cross sections for nuclear reactions, scattering, and fission. Passage of charged particles through matter: ionization, scattering, and radiative losses. Interaction of neutrons and gamma rays with matter. *Kolenkow*

8.541 *Particle Physics* (A)
Prereq.: 8.06, *8.731*
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. *Rosenson*

8.542 *Meson Physics* (A)
Prereq.: 8.731
Year: G (2) 3–0–9
Scattering formalism for particles and photons with application to the analysis of decay interactions, polarization measurements, and resonance scattering. Study of meson-nucleon resonances and of electron-nucleon scattering. An unsophisticated approach to field theory to acquaint the student with "pology" and dispersion relations as guides to experiments and data analysis. (*Alternate years.*) *Staff*

8.543 *Selected Topics in Particle Physics* (A)
Prereq.: 8.732
Year: G (1, 2) 3–0–9
Topics in particle physics, varying from year to year. (*Alternate years.*) *Staff*

8.551 *Theory of Nuclear Structure I* (A)
Prereq.: 8.732
Year: G (1) 3–0–9
Review of the current theories of the structure of atomic nuclei. Nature of internuclear forces as determined by two-body phenomena. Discussion of three- and four-body problems. Nuclear spectroscopy. (*Alternate years.*) *Feshbach*

8.552 *Theory of Nuclear Structure II* (A)
Prereq.: 8.551
Year: G (2) 3–0–9
Continuation of 8.551. Interaction of nuclei with light; beta decay; shell structure; theory of nuclear reactions; alpha decay. (*Alternate years.*) *Feshbach*

8.59 *Statistical Fluctuations in Physical Processes* (A)
Prereq.: 8.06
Year: G (2) 2–0–4
Application of statistical theory of fluctuations and errors to experimental physics. Theoretical frequency distributions: binomial, normal, Poisson, interval, and composite distributions. Statistical characterization of data, and tests of significance. Applications of Poisson statistics to the response of nuclear detection instruments, including scaling circuits and counting rate meters. Appraisal of random processes by inefficient statistics using nonparametric tests. Students not having credit in 8.06 should consult instructor. (*Not offered 1966–67.*) *R. D. Evans*

8.60, 8.601 *Special Problems in Nuclear Physics* (A)
Prereq.: 8.511 or 8.531
Year: G (1 or 2) *Arr.*
Experimental work on radioactivity, nuclear bombardment, and general nuclear research, with assigned reading and consultation. *Staff*

8.61 *Special Problems in Elementary Particle Physics* (A)
Prereq.: 8.06, 8.09
Year: G (1 or 2) *Arr.*
Experimental work on production, interaction, and decays of elementary particles, using a wide variety of electronic and visual techniques. Preparation and analysis of experiments carried out at the Cambridge Electron Accelerator, at Brookhaven accelerators, at Cosmic Ray stations, and in space probes. *Staff*

8.711 *Mechanics I* (A, except Courses V, VIII, XII)
Prereq.: 8.04, 18.05
Year: U, G (1) 4–0–8
Mechanics of particles, planetary motion, scattering, rigid bodies, small vibrations, strings, membranes, acoustical and elastic waves. Lagrange's equations and generalized coordinates. *K. A. Johnson*

(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.

8.712 *Mechanics II* (A)
Prereq.: 8.711
Year: G (2) 4–0–8
Hamilton's equations, variational principles, transformation theory, Hamilton-Jacobi equation. Poisson and Lagrange brackets, invariants, conservation theorems, and symmetry. Lagrangian and Hamiltonian formulations for fields. Relativistic mechanics.
K. A. Johnson

8.72 *Electromagnetic Radiation* (A, except Courses V, VIII, XII)
Prereq.: 8.04, 18.05
Year: U, G (2) 4–0–8
Electrostatics and magnetostatics. Maxwell's equations, the potentials, Poynting's theorem. Plane waves in empty space, reflection and refraction. Wave guides and resonant cavities. Spherical waves, field of oscillating dipole. Radiation from antennas and antenna arrays and from atoms and molecules. Interference, diffraction, scattering. Electron theory of dielectric constant, permeability, and polarization. *Shakin*

8.721 *Electromagnetic Theory I* (A)
Prereq.: 8.04, 18.05
Year: G (1) 4–0–8

8.722 *Electromagnetic Theory II* (A)
Prereq.: 8.721
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. *Bronzan*

8.731 *Quantum Theory I* (A)
Prereq.: 8.06, 8.711, 8.72
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. Nonstationary states; equations of motion. Heisenberg and Schroedinger picture; transitions; the classical limit. Central field problems; angular momentum; elementary scattering theory. *Staff*

8.732 *Quantum Theory II* (A)
Prereq.: 8.731
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*

8.733 *Quantum Theory III* (A)
Prereq.: 8.732
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. *Low*

8.74 *Applications of Group Theory to Theoretical Physics* (A)
Prereq.: 8.361 or 8.731
Year: G (1) 3–0–9
Theory of groups and their matrix representations. Application to physical problems drawn from quantum and classical mechanics. Permutation groups and the Dirac Vector Model. Rotation and double groups. Space groups. (*Alternate years.*) *Koster*

8.75 *Operations Research, Principles and Applications* (A)
Prereq.: ——
Year: G (1) 3–3–6
Selected topics dealing with the application of experimental and theoretical techniques to the analysis of operational systems. Collection of operational data, use of machine simulation, determination of operating rules, and control criteria, illustrated by examples presented in the lectures and also by laboratory exercises.
Morse

8.78 *Relativity* (A)
Prereq.: 8.722
Year: G (2) 3–0–6
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. Not offered 1966–67.*) *Staff*

8.791 *Methods of Theoretical Physics I* (A)
Prereq.: 8.711, 8.721
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 1966–67.*) *Feshbach*

8.792 *Methods of Theoretical Physics II* (A)
Prereq.: 8.791
Year: G (2) 4–0–8
Continuation of 8.791. 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 1966–67.*) *Feshbach*

8.86 ***Topics in Relativistic Quantum Theory* (A)**
Prereq.: 8.733
Year: G (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*

8.90, 8.901 ***Special Problems in Theoretical Physics* (A)**
Prereq.: 8.791
Year: G (1 or 2) *Arr.*
Reading, consultation, and original investigation on a problem in theoretical physics. *Staff*

8.99 ***Special Problems in Physics* (A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
For Graduate Assistants in the Physics Department where assigned research or teaching duties are approved for academic credit by the Department. *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 (1) 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. 9.002 not offered 1966–67.*) *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 1966–67.*) *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.*) *Staff*

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 overall 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) 2–4–3
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*

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. (*Not offered 1966–67.*) *Teuber*

9.03 ***Neural Mechanisms of Learning and Motivation***
Prereq.: 9.001 or 9.002; 9.01
Year: U (1) 3–0–5
Consideration of the evidence for physiological mechanisms of learning and of motivated behavior (e.g. eating,

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drinking, sleep, maternal and reproductive behavior) derived from neuropsychological, neurophysiological and neurochemical experiments. Reports, lectures and discussion. *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. *Hein*

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.: 9001 or 9.002 or 9.35
Year: G (1) 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.: 6.37T 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 1966–67.*) *Richards*

9.361T *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. *Bizzi, Schiller*

9.40 *Learning*
Prereq.: 9.00
Year: U (2) 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 nonverbal 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. One or more of the following themes emphasized in a particular semester: 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. *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 1966–67.*) *Staff*

9.50 *Research in Psychology*
Prereq.: 9.00 and one other subject in psychology
Year: U (2) *Arr.*
Laboratory research in the areas of perception, learning and memory. Each student will 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. One or more of the following themes will be emphasized in a particular semester: 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. *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 nonexperimental 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. *Saltzstein*

9.70 *Social Psychology*
Prereq.: 9.00
Year: U (2) 3–0–5
The basic processes by which people interact, perceive and make judgments of others, influence each other, and develop social beliefs and values, examined in the context of small and large groups and societies. *Saltzstein*

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 1966–67.*) *Saltzstein*

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 1966–67.*) *Hein, Saltzstein*

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 1966–67.*) *Held, 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 *Chemical Engineering*
Prereq.: 5.01
Year: U (1) 3–0–5
Development of methods of analysis of systems and processes relevant to modern chemical engineering, based on the laws of conservation of mass and energy, and the second law of thermodynamics; supplemented by a broad presentation of the concepts and range of disciplines that constitute present chemical engineering, and some consideration of the directions of its future development. *Merrill, Deibert*

10.13 *Chemical Engineering Thermodynamics*
Prereq.: 10.12, *18.034*
Year: U (2) 4–0–6
Second law of thermodynamics and its applications to compressors, pumps, refrigeration equipment, and to separation and other chemical engineering processes. Free energy and applications to chemical and phase equilibria. *Sherwood*

10.15 *Thesis Reports*
Prereq.: ——
Year: U (1, 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.: 5.61, 10.31
Year: U (2) 3–0–6
Industrial chemical processes studied from the point of view of both the chemical reactions forming the basis of the process and the plant necessary for carrying on these reactions. Development of interrelationships of the different industries as to raw materials, sources of energy, and types of apparatus. Extensive problem work to be included. *Meissner*

10.21 *Structure and Properties of Non-Metallic Substances*
Prereq.: 5.42, 5.62
Year: U (1) 3–0–6
Effect of intermolecular forces and molecular structure on physical properties of non-metallic substances. Subject matter similar in content to 10.211 but presented at a level commensurate with background of seniors majoring in chemical engineering. Emphasis on developing an approach based upon examination of phenomena, for solving problems in chemical processing. *Baddour*

10.211 *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. *Baddour*

10.24 *Chemical Engineering Instrumentation Laboratory*
Prereq.: 5.61, 8.04
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,

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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.: 10.12
Year: U (1) 0–10–0
Laboratory practice in modern chemical technology, emphasizing the special features of *applied* chemical research, the application of engineering concepts, effective oral and written presentation of the research program, and safety practices. *Vivian*

10.27 *Chemical Engineering Laboratory*
Prereq.: 10.31
Year: U (1) 0–10–0
Experimental studies of unit operations, with emphasis on momentum, heat, and mass transfer. Laboratory work on fluid flow, mixing, heat transfer, absorption, distillation, drying, filtration, and other unit operations, with particular attention to the dynamic response of such operations and proper instrumentation. *Vivian*

10.30 *Fluid Mechanics*
Prereq.: 10.13, 18.034
Year: U (1) 4–0–6
Introduction to fluid mechanics. Dynamics of fluids in motion; laminar and turbulent flow; applications of continuity; Bernoulli and energy equations; friction in conduits; introduction to boundary layer theory and Navier-Stokes equations. *L. B. Evans, Mohr*

10.31 *Chemical Engineering*
Prereq.: 10.30
Year: U (2) 4–0–6
Quantitative study of basic principles of the unit operations of the chemical industry emphasizing material and energy balances. Basic consideration given to convective, conductive, and radiative heat transfer. Applications considered include simple heat exchange, condensation and evaporation. Discussion of analogies between heat, mass and momentum transfer. *Mohr*

10.32 *Chemical Engineering*
Prereq.: 10.30
Year: U (1) 4–0–6
Unit operations involving mass transfer and general diffusional theory as illustrated by absorption, adsorption, extraction, distillation, air conditioning, and drying; followed by comprehensive process design problems integrating all unit operations. *Sarofim*

10.33 *Analytical Treatment of Chemical Engineering Processes* (A)
Prereq.: 5.62, 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 I.B.M. 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 I.B.M. 7094. (*Limited to ten students. Permission of instructor required.*) *Brian*

10.35 *Dynamics and Control of Chemical Engineering Processes*
Prereq.: 10.31, 18.06
Year: U (2) 3–0–6
Description of the dynamic behavior of processes and equipment by ordinary and partial differential equations. Use of linearized approximations. Introduction to feedback control concepts. Solution of systems of equations by classical methods and by use of Laplace transforms. Use of approximation methods and analog computer solutions. Analysis of the stability of systems. Control system analysis and design. *Brian, L. B. Evans*

10.361 *Process Design*
Prereq.: 10.31
Year: U (1) 3–0–6
Presentation and discussion of real process design problems, with case studies in chemical processing and petrochemicals. Emphasis on conception and invention of processes, as well as analysis and economic balances, to specify optimum design and operating conditions. Discussion of a variety of cases throughout the term. *G. C. Williams*

10.362 *Process Design*
Prereq.: 10.31
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*

ENGINEERING OPERATIONS

10.40 *Chemical Engineering Thermodynamics* (A)
Prereq.: 5.62, 10.13
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.: 10.13, 10.32
Year: G (1 or 2) 3–0–6
Basic principles of distillation as applied to binary and multi-component 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; multi-component

distillation. Distillation of systems of limited miscibility; azeotropic and extractive distillation. Batch distillation; vacuum distillation. Multi-column 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.: 10.31
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. *K. A. Smith*

10.52T *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.: 10.31
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, 10.32
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*

10.58 *Seminar on Properties of Gases, Liquids, and Solids* (A)
Prereq.: 5.62
Year: G (1) 2–0–4
Important concepts in quantum mechanics, kinetic theory, classical and statistical mechanics and their use in interpretation of macroscopically measurable properties. *Reid*

10.59 *Transport Properties of Matter* (A)
Prereq.: 10.40 or 10.58
Year: G (2) 2–0–4
Application of the concepts covered in 10.58 to the interpretation and prediction of the macroscopic properties of matter. *Reid*

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. *Satterfield*

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. *Satterfield*

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 treatment, Langmuir, B.E.T., Harkins-Jura, potential theory adsorption isotherms. Surface-active agents, contact angles, spreading, and wetting phenomena. Properties of colloidal electrolytes, micelles, solubilization phenomena, monolayers. Electrical phenomena at interfaces: origins of surface potential, structure of the diffuse double layer. 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. Stability criteria are derived and discussed. Entropy production and Onsager's reciprocal relations are introduced and applied to simple irreversible thermodynamic problems. *Reid*

10.63 *Colloidal Chemistry*
Prereq.: 5.62
Year: G (1) 3–0–6
Colloids, small size, large interfacial area. Adsorption, surface tension, Gibbs' adsorption equation, ion-

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exchange, chromatography, spreading of monolayers. Lyophobic and lyophilic colloids. Preparation and flocculation of lyophobic colloids. Electric double layer, electrocapillary curve, Van der Waals forces. Rule of Schulze and Hardy, lyotropic effects. Kinetics of flocculation. Mutual flocculation, protective action sensitization. Electro kinetics. Dialysis, ultrafiltration, Donnan equilibrium. Macromolecules, natural and synthetic, preparation. Statistics of coiled chains. Osmotic pressure, viscosity, rubber elasticity. Molecular weight, distribution, methods. Optics, light scattering, birefringence. Hydrophylic colloids, polyelectrolytes. Electroviscous effect, solubility, titration, coacervation, proteins, gels, thixotropy, dilatancy. Emulsions, soaps, soap films. *Overbeek*

10.64 *Structure and Properties of Polymers* (A)
Prereq.: 5.42, 5.61
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

10.65 *Applied Chemical Kinetics* (A)
Prereq.: 5.62, *10.31*
Year: G (2) 3–0–6
Application of kinetics to development and improvement of industrial chemical processes. Basic concepts of homogeneous and heterogeneous reactions and of chain reactions. 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 *Physics and Chemistry of Membranes, Gels, and Networks* (A)
Prereq.: 5.61
Year: G (1) 3–0–6
Exploration in depth of the physicochemical principles which underlie the frontier applications of barrier diffusion: formation and molecular architecture of membranes, gels, and networks; gas permeation and relation to membrane structure. Liquid transport; thermodynamics of swelling of network polymers. Osmosis and reverse osmosis: water and ion diffusion mechanisms. Dialysis and ultrafiltration, including consideration of the artificial kidney; electrodialysis. Introduction to mechanisms of transport in biological membranes. *Vieth*

10.67 *Physicochemical Kinetics and Hydrodynamics* (A)
Prereq.: 5.61
Year: G(2) 3–0–6
Interactions of surface effects with kinetic phenomena and/or hydrodynamic flows. Review of static-free surfaces, especially liquid-air. Electrical double layer theory; electrokinetic theory, including streaming potential. Coagulation and flocculation; nucleation and crystallization, including effects of agitation. Rheology of suspensions and sedimentation; flow in porous media. Mass transfer to rising bubbles, falling drops; dispersed particles, polymers; interaction with turbulent flows.
Vieth

10.68 *Physical Chemistry of Polymers* (A)
Prereq.: 5.42, 5.62
Year: G (1) 3–0–6
Conformation of polymers in solution and in bulk states. Effective "volumes" of random coiling polymers as determined from virial coefficient measurements and from random flight statistics. Thermodynamics of polymer solutions and application to molecular weight determination, phase equilibria and fractionation, and depression of crystalline melting point. The glass transition — thermodynamic and rate interpretations. Determination of molecular weights and distributions by classical methods such as "resinography" and non-Newtonian flow parameters. Brief survey of differences between biologically important polymers and synthetic polymers. *Merrill*

10.69 *Synthetic Chemistry of Polymers* (A)
Prereq.: 5.42, 5.62
Year: G (2) 3–0–6
Study of laboratory and large-scale methods for synthesis of polymers, with emphasis on interrelationships of the reaction kinetics, fluid mechanics, and mass transport. Condensation polymerization, classical free radical synthesis, with considerable emphasis on emulsion polymerization; more recent advances in free radical synthesis; homogeneous anionic and cationic polymerization; and stereo regular polymer synthesis via heterogeneous catalysis. *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.: 10.31
Year: G (2) 3–0–6
Heat transmission in high-temperature operations. Radiation geometry; matrix algebra in application to radiative transfer in enclosures; zoning method as alternative to integral equation; use of machine computation. Thermal radiating characteristics of surfaces, gases, and particle clouds. Radiation methods of temperature measurement. Synthesis of analytical and empirical approach to produce approximations of engineering utility. Quantitative design of several furnaces and high-temperature systems. Interaction of radiative and other transport mechanisms. *Hottel*

SCHOOL OF CHEMICAL ENGINEERING PRACTICE

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. *Vieth*

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. *Vieth*

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. *Vieth*

10.83T ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
Prereq.: 10.82
Year: G (1 or 2) 0–12–0
Continuation of 10.82. *Vieth*

10.84T ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
Prereq.: 10.83T
Year: G (1 or 2) 0–12–0
Continuation of 10.83T. *Vieth*

10.85T ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
Prereq.: 10.84T
Year: G (1 or 8) 0–12–0
Continuation of 10.84T. *Vieth*

10.86T ***School of Chdmical 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.* *Vieth*

10.87T ***School of Chemical Engineering Practice - Oak Ridge Station*** **(A)**
Prereq.: 10.86T
Year: G (1 or 2) 0–12–0
Continuation of 10.86T. *Vieth*

10.88T ***School of Chemical Engineering Practice - Oak Ridge Station*** **(A)**
Prereq: 10.87T
Year: G (1 or 2) 0–12–0
Continuation of 10.87T. *Vieth*

10.89 ***School of Chemical Engineering Practice - Oak Ridge Station*** **(A)**
Prereq: 10.88T
Year: G (1 or 2) 0–12–0
Continuation of 10.88T. *Vieth*

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.: 5.01
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.: 10.32
Year: G (1) 2–0–4

10.992 ***Seminar in Chemical Engineering*** **(A)**
Prereq.: 10.32
Year: G (2) 2–0–4
For students working on doctoral theses. *Gilliland*

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*

11.01 ***Community Planning Design***
Prereq.: 11.001, 11.11
Year: U (1) 0–8–12
Problems in planning of the physical environment. The functional, social, aesthetic, and economic consequences of physical arrangement at the city scale, in the light of fundamental human objectives. Workshop problems in real situations, but under generous limits of time-scale and capability. *Lynch*

11.02 ***City and Regional Planning*** **(A)**
Prereq : 11.01
Year: G (2) 0–8–12
Practical application of city and regional planning theory to towns, cities, and regions, including problems of replanning, redevelopment, and urban renewal in existing communities. Individual problems, supplemented by group projects worked out in collaboration. Work in field, library, and studio leading to written, oral, and graphic presentations. *Staff*

11.03 ***Problems in City Planning*** **(A)**
Prereq.: 11.02
Year: G (1) 0–8–12
Advanced problems in city planning, including pioneering studies and studies in specialized areas. *Staff*

11.05 ***Collaborative Design*** **(A)**
Prereq : 11.02
Year: G (1) 0–12–12
Project work on design problems which will benefit from collaboration between architects and city planners or between these groups and other disciplines. *Appleyard*

(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.

11.06 *Problems in Urban Design* (A)
Prereq : 11.02, 11.05
Year: G (2) 0–12–12
Advanced problems in planning for the visual form of the environment at the scale of cities or regions. *Lynch*

11.08 *Problems in Regional Planning* (A)
Prereq : 11.41, 11.45, 11.83
Year: G (1) 0–8–12
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 1966-67.*) *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. (*Not offered 1966-67.*) *F. J. Adams*

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. *Appleyard, Hornbeck*

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. (*Not offered 1966–67.*) *Rodwin*

11.31 *Urban Landscape* (A)
Prereq.: 4.121 or 11.11
Year: G (1) 2–0–4
The city and its components as aesthetic elements. Role of plan organization, spatial relations, symbol, silhouette, scale, view, movement, light, color, sound, detail, etc. Presentation through field observation, group projects, and seminar discussion. *Lynch*

11.32 *City Design* (A)
Prereq.: 11.31
Year: G (2) 2–0–6
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. (*Seminar, limited registration.*) *Lynch*

11.35 *Psychological Functions of Environmental Form* (A)
Prereq.: 4.121 or 11.11
Year: G (1) 2–0–6
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. Readings mainly from recent literature in experimental psychology, emphasizing theoretical approaches and opportunities for original research. *Carr*

11.41 *Resource Problems and Policies*
Prereq.: 11.60
Year: G (1) 2–0–6
Comprehensive survey of the role of natural, human, and institutional resources in urban and regional development, including the theory of resource use; resources and economic growth in a spatial setting; metropolitan, frontier, and depressed regions; and methods of resource analysis. Critical review of recent major resource policy statements in the U. S. and abroad. (*Not offered 1966–67.*)

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*

11.50 *Urban Social Structure and Process*
Prereq.: ——
Year: U (1) 2–0–6
Social characteristics of urban and suburban communities; population and sociological problems arising in cities in connection with establishment of residential patterns, land use controls, housing, and basic environmental facilities. *Beshers*

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. *Beshers*

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 1966–67.*) *Beshers*

11.53 *Mathematical Sociology* (A)
Prereq.: 11.90
Year: G (1, 2) *Arr.*
Review and critique of recent mathematical models in sociology. Intended for students with previous training in mathematics and in social sciences. *Beshers*

11.55 *Urban Planning and Social Policy* (A)
Prereq.: 11.01, 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*

11.57 *Planning and Poverty* (A)
Prereq.: 11.50
Year: G (2) 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*

11.60 *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 inter-regional characteristics; an evaluation of the issues posed by national policy for urban and regional development. *Lowry*

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 infra-structure 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. *Ganz*

11.65 *Real Estate Economics*
Prereq.: 14.01
Year: G (1) 2–0–4
Social, political, industrial and economic factors affecting the location, construction, financing and marketing 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*

11.70 *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. *Weinstein*

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. *Oppermann*

11.80 *Theory of the Planning Process* (A)
Prereq.: 11.12
Year: G (2) *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
Analysis of the functioning, effects, and implications of the general form of the urban physical environment. Effect of this form on basic human objectives. (*Seminar; limited registration.*) *Carr*

11.83 *Programming for Urban and Regional Development* (A)
Prereq.: 11.12, 11.60, 11.90
Year: G (2) *Arr.*
Ways in which an optimal time sequence of investment projects can be arranged within a spatial setting. The nature of the programming process; design of regional accounts; elements of project formulation and evaluation; long-term projections; programming strategy; determination of priorities; allocation instruments: capital budgets and development maps. ——

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 nonlinear analyses of activities in the city; urban models and simulations.
Fleisher

(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.

11.92 *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. *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*

12.201 *Earth Science*
Prereq.: ——
Year: 1 (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 *Elementary Astronomy*
Prereq.: ——
Year: 1 (2) 2–0–4
Fundamentals of solar system, stellar, and galactic astronomy, with special attention to theories of origin and evolution. Telescopic observations and trips to Harvard College Observatory. *Pinson*

12.211T *Topics in Planetary Science*
Prereq.: 5.01, 8.01, 18.02
Year: U (1) 2–0–4
Selected topics in planetary science. Transformations of celestial coordinate systems; theoretical basis for celestial navigation; 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*

12.221T *Laboratory in Minerals and Rocks*
Prereq.: 12.223
Year: U (1) 1–6–0
Intensive laboratory study of minerals and rocks with emphasis on determinative methods. Use, occurrence, association, and classification of minerals and rocks. Individual projects. Dennen, *Principles of Mineralogy.* *Dennen*

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 Laue, powder, rotating-crystal, Weissenberg, and precision methods. Modern methods of determining the arrangements of atoms in the cell. Buerger, *Elementary Crystallography;* Buerger, *Introduction to Crystals.* *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. *Buerger*

12.231 *Physical Geology*
Prereq.: ——
Year: U (1) 3–4–5
Objective study of the earth including geological agents and processes. Structural relations of rock masses. Laboratory and field exercises. *Dennen*

12.232T *Historical Geology*
Prereq.: 12.231
Year: U (2) 4–4–4
Development of the surface features of the earth from the time of its origin to the present, including the nature and distribution of lands and seas during the past. Evolution of plants and animals. Principles and methods used in interpreting the geologic record of the past. *Mencher, Shrock*

12.241 *Petrology I*
Prereq.: 12.221T
Year: U (1) 2–4–2
Principles and practice of optical crystallography by means of the immersion method of mineral identification. Introduction to the phase equilibria of silicate melts. Larsen and Berman, *Microscopic Determination of the Non-opaque Minerals* (U.S.G.S. Bull. 848); Bloss, *Introduction to Optical Crystallography;* Turner and Verhoogen, *Igneous and Metamorphic Petrology.* *Fairbairn*

12.242 *Petrology II*
Prereq.: 12.241
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*

12.261T *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.* *Shrock*

12.271 *Structural Geology*
Prereq.: 12.231
Year: U (1) 3–3–6
Elementary survey of rock structures and mechanics of rock deformation. Development of elementary concepts of plastic flow and fracture of geologic materials. Within this framework, discussion of observed strains in all classes of rocks in relation to mineral deposits, intrusion, and metamorphism. Laboratory work in map and hand specimen interpretation. At least five Saturdays of field work mapping 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*

12.32 *Crystallographic Research* (A)
Prereq.: 12.223
Year: G (1 or 2) *Arr.*
Supervised research on a crystallographic problem. *Buerger*

12.321 *Mineralogical Seminar* (A)
Prereq.: 12.224
Year: G (1 or 2) 2–0–4
Presentation and discussion of literature bearing on certain phases of theoretical mineralogy. *Buerger*

12.33 *Spectrochemical Research* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in spectrochemical analysis or instrumentation. *Dennen*

12.34T *Special Topics in Petrology* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised studies in the field of petrology. *Fairbairn*

12.345 *Mineral Deposits and Petrology Seminar* (A)
Prereq.: 12.242
Year: G (1) 2–0–4

12.346 *Mineral Deposits and Petrology Seminar* (A)
Prereq.: 12.345
Year: G (2) 2–0–4
Discussion of igneous and metamorphic rocks, mineral deposits, and problems bearing on their genesis. (*Alternate years.*) *Fairbairn, Hurley (12.345); Hurley, Fairbairn (12.346)*

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.: 5.61, 18.034
Year: G (2) 3–0–6
Applications of thermodynamics to geological problems — melt and aqueous equilibria, phase transitions, geochemical differentiation of the earth. 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, Stratigraphy, or Marine Geology* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in sedimentology, stratigraphy, or marine geology. *Mencher*

12.361 *Marine Geology and Sedimentology* (A)
Prereq.: ——
Year: G (1) 3–4–5
Nature and possible origin and history of continental margins, oceanic basins and submarine bottom features, based on an integration of geological and geophysical data. Composition, distribution, sources, modes of transportation, and factors leading to deposition of marine sediments. Comparison of recent and ancient marine sedimentary assemblage. (*Alternate years.*) *Mencher*

12.363 *Advanced Sedimentology* (A)
Prereq.: 12.361
Year: G (1 or 2) *Arr.*
Discussion of latest literature on the origin, deposition, classification and significance of sediments and sedimentary rocks. Laboratory and microscopic study of the important primary and secondary physical, chemical and structural characteristics of sedimentary rocks using hand specimens, polished sections and thin sections. Work arranged to suit the preparation and requirements of individual students. *Mencher*

12.37 *Structural Research* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a structural problem. *Brace*

12.372 *Mechanics of Rock Deformation* (A)
Prereq.: 12.271
Year: G (2) 3–0–9
Topics in elasticity, fracture, and flow important in the analysis of rocks deformed under geologic conditions. Survey of experimental rock deformation, crystal plasticity. Subject matter may vary from year to year. Jaeger, *Elasticity, Fracture and Flow.* *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*

(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.

12.38 *Special Topics in Experimental Petrology* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised studies in experimental petrology or geochemistry. *Luth*

12.381 *Experimental Petrology*
Prereq.: 5.61, 12.224, 12.242
Year: G (1) 3–0–6
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. *Luth*

12.382 *Experimental Petrology Laboratory*
Prereq.: 12.381
Year: G (2) 0–4–0
Measurement of P, V, T; apparatus used in experimental petrology: experimental study of reactions using sealed silica tubes (constant volume); experimental study of selected reactions using Tuttle-type pressure vessels and the simple squeezer. Last half of the laboratory to be devoted to individual projects selected by the student on the basis of his interests and the methods developed in the first portion of the laboratory. *Luth*

12.51 *Geochemical Research* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in geochemistry. *Staff*

12.511 *Geochemistry I* (A)
Prereq.: 5.61
Year: G (1) 3–0–9
Intensive review of thermodynamics and solution physical chemistry with application to phenomena in the earth sciences. *Staff*

12.512 *Geochemistry II* (A)
Prereq.: 5.62
Year: G (2) 3–0–9
Selected topics in chemistry applied to current geochemical research. (*Alternate years.*) *Staff*

12.611 *Potential Theory in Geophysics*
Prereq.: 8.04, 18.05
Year: U (1) 3–0–9
Application of potential theory to problems in gravity, magnetism, steady current flow, and elementary electromagnetism. Examples drawn from fundamental and applied geophysics: spherical earth, half space, layered earth, and finite geometry bodies; acquisition of data, instrumentation used, resolution, and quantities measured; noise problems, filtering. Brief mention of magnetic and electrical properties of earth materials. *Strangway*

12.612 *Earth and Solar System*
Prereq.: 5.01, 8.03, 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. *Toksöz*

12.70 *Geophysics Seminar* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Problems of current geophysical interest; subject matter varying from term to term. (*Background in geophysics required.*) *Staff*

12.701 *Physics of the Earth* (A)
Prereq.: 8.03, 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.* (*Admission by permission of instructor only.*) *Staff*

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*

12.721 *Wave Propagation in Fluids* (A)
Prereq.: ——
Year: G (1) 3–0–9
Advanced topics in the acoustics of fluids with emphasis on geophysical applications. Sources of sound in stationary and moving media. Energy and momentum transport. Propagation in layered media. Long-range propagation in the ocean and atmosphere. (*Admission by permission of instructor only.*) *Dean*

12.723 *Introduction to Theoretical Seismology* (A)
Prereq.: 18.05
Year: G (1) 3–0–9
Derivation of equations of motion of theoretical seismology. Analysis of stress, strain, and stress-strain relationships. Boundary conditions, uniqueness theorems, reciprocity and modelling relationships. Mathematical techniques useful in treating various problems which are idealizations of complex earth geometries. *Gangi*

12.731 *Geomagnetism* (A)
Prereq.: 8.03
Year: G (1) 3–0–9
Description and analysis of geomagnetic field and secular variation. Hydrodynamics of rotating fluids; thermal convection; simple magnetohydrodynamic flows, including Alfvèn waves, Hartmann flow, homogeneous dynamos. Internal constitution of earth. Theories of geomagnetism. Magnetic fields of other astronomical bodies. (*Not offered 1966–67.*) *Hide*

12.732 *Geoelectricity* (A)
Prereq.: 12.731
Year: G (2) 3–0–6
Electric and electromagnetic phenomena in the earth's interior, ionosphere, and exosphere. Review of elec-

tromagnetic theory. Electrical conductivity and cross-coupling properties of earth materials. Studies of the earth's interior by means of electric and electromagnetic fields. Electrical properties of the ionosphere and electromagnetic waves in plasmas. Naturally occurring electromagnetic wave phenomena in the earth-ionosphere-exosphere system and their use in studying the space environment. *(Alternate years.)* *Madden*

12.735 *Rock Magnetism* (A)
Prereq.: 8.05, 18.05
Year: G (1) 3–0–6
Fundamentals of magnetism and applications to the earth. Intensive investigation of the physics of dia-, para-, ferro-, ferri-, and antiferro-magnetism with particular attention to the properties of natural materials. Topics will include instrumentation for rock magnetism studies, applications of magnetic data to a study of the history of the earth's magnetic field, geothermometry, geologic correlation, polar wandering, and continental drift. *Strangway*

12.742 *Fields and Waves in the Upper Atmosphere* (A)
Prereq.: ——
Year: G (2) 3–0–9
Review of the theories of propagation and scattering of electromagnetic waves; application to experimental results of current interest in the ionosphere and magnetosphere of the earth and in interplanetary space; description of modern experimental techniques at radio, microwave, and optical wavelengths. The four modes of wave propagation in a homogeneous magnetized plasma. The ionosphere and magnetosphere in quiet and disturbed conditions. Meteoric phenomena. Scattering of e.m. waves by plasmas. Scattering of light by small particles. Zodiacal light. Dust. Radiation pressure. *Fiocco*

12.744 *Advanced Topics on Electromagnetic Phenomena in the Solar System* (A)
Prereq: ——
Year: G (2) 2–0–4
Varying contents, mainly related to current research, typically in the following areas: non-thermal emissions from plasmas; meteors, comets, dust; atmospheric optics and transmission of coherent radiation; electromagnetic properties of planetary surfaces; modern instrumentation. *(Admission by permission of instructor only.)* *(Alternate years.)* *Fiocco*

12.781-12.784 *Planetary Physics Seminar* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Problems of current interest in planetary physics relating to geophysics. Subject matter varying from term to term. *Staff*

12.791-12.796 *Special Problems in Geophysics* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For graduate students desiring to perform special investigations, special laboratory work, or special field work in geophysical subjects. *Staff*

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.)* *von Arx*

12.90 *Special Problems in Oceanography* (A)
Prereq.: ——
Year: G (1, 2, S) *Arr.*
For graduate students conducting or participating in scientific activities at sea. *Staff*

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 *Oceanographic Methods and Measurements* (A)
Prereq.: 5.02; 8.04; 12.811 or 19.83
Year: G (1 or 2) 3–0–6
Critical inquiry into present physical oceanographic practices, their classical origins, and possible future development in the light of modern technology and applied physics. *von Arx*

12.92 *Research in Chemical Oceanography* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in chemical oceanography. *Carritt*

12.921 *Chemical Oceanography I* (A)
Prereq.: 5.02, 8.04
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. *(Restricted to graduate students in Geology and Geophysics; others admitted only by permission of instructor.)* *Carritt*

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. *Carritt*

12.99 *Oceanography* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Topics in submarine geology and geophysics and marine biology. Lectures varying from term to term and given by staff members from both M.I.T. and the Woods Hole Oceanographic Institution. *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.

13.

Naval Architecture and Marine Engineering

13.00 ***Principles of Naval Architecture***
Preq.: 1.05 or 1.612 or 2.201T
Year: U (1, 2) 4–1–7
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. *Abkowitz, Mandel*

13.01 ***Applied Hydrostatics*** **(R)**
Prereq.: ——
Year: G (S) 1–7–2
Indoctrination lectures on elementary principles of naval ship design and statics of naval architecture. Work in the 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. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Stark*

13.02 ***Propulsion Hydrodynamics*** **(A)**
Prereq.: 1.05 or 2.201T; *13.00*
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.: 13.00
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 (2) 2–0–4
Linear and nonlinear 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 13.30; 13.00 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; wake harmonic analysis. Instrumentation for dynamic measurements. Emphasis on forming computational models. Lectures augmented by water tunnel and towing tank demonstrations. *N. A. Brown*

13.10 ***Ship Structural Analysis and Design***
Prereq.: 2.012
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*

13.12 ***Ship Structural Theory*** **(A)**
Prereq.: 2.012, 2.022
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 ***Naval Structural Theory*** **(RA)**
Prereq.: 13.12
Year: G (2) 3–0–6
Selected topics of advanced structural analysis including sidesway in continuous frames, optimization of structural sections, web discontinuities, stiffened plates under lateral load, stiffened cylindrical shells, and ship oscillation loadings. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *J. H. Evans*

13.14 ***Ship Structural Design I*** **(A)**
Prereq.: 13.12
Year: G (2) 0–5–0
Determination of load distribution on the hull of naval vessel types and development of optimized primary longitudinal structure. *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 *Advanced Structural Theory* (A)
Prereq.: 13.10 or 13.12
Year: G (2) 3–0–6
Subject matter same as 13.13 except for substitution for certain classified material. Most lectures in common with 13.13. *J. H. Evans*

13.20 *Energy Conversion Systems and Components*
Prereq.: 2.012, *2.201T*, 2.403
Year: U (2) 4–0–8
Energy conversion devices and systems of types applicable to ships, involving thermal, mechanical, hydraulic, and electrical machinery; interaction of coupled devices under steady state and transient conditions; optimization principles. *Powell*

13.21 *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 13.22T. *Powell*

13.22T *Naval Ship Propulsion* (RA)
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. (*Restricted to selected officers of the U.S. Navy and Coast Guard.*) *Reed, Powell*

13.23 *Propulsion System Reliability and Control* (A)
Prereq.: 6.28J or 13.96 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*

13.24 *Naval Electrical Engineering* (RA)
Prereq.: 18.07
Year: G (2) 3–0–4
Review of basic electrical engineering. Lumped-constant mechanical, electrical, and fluid systems and system response by transform methods and by analogs. Application to transient analysis of shipboard power and control systems. Design criteria of shipboard electrical machinery and electrical distribution systems. (*Restricted to selected officers of the U.S. Navy and Coast Guard.*) (*Not offered 1966–67.*) ——

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.*) *Kingsley*

13.30 *Mechanical Vibration*
Prereq.: 2.012, 2.022
Year: U (1) 3–0–5
Dynamic problems of marine engineering. Elementary vibration theory, the balance of rotating and reciprocating machinery. Torsional vibration of reciprocating machinery, the vibration of turbines, and the vibration of ships. (*Not offered 1966–67.*) ——

13.31 *Mechanical Vibration* (A)
Prereq.: 2.012, 2.022
Year: G (1) 3–0–6
Free and forced vibration of systems of a single degree of freedom; complex variable and vector representation; Fourier series; harmonic analysis by tabular and mechanical methods; systems of several degrees of freedom; torsional systems; balance of rotating machinery and reciprocating engines; elements of torsional vibration problems in reciprocating engines. *Den Hartog*

13.40 *Introductory Ship Design*
Prereq.: 13.00, 13.10
Year: U (2) 1–8–3
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.: 13.00; 13.10 or 13.12
Year: G (1) 2–4–5
Fundamental distinction among water-borne vehicles; engineering, economic, and military principles involved in the selection of dimensions and coefficients of displacement type commercial ships and warships; influence on dimension selection of rough water as well as smooth water considerations; design of hull form; internal arrangement design with emphasis on subdivision for survival after damage. Design exercises in application of principles. (*Not recommended for students who have taken 13.40.*) *Mandel*

13.42 *Preliminary Design of Ships* (A)
Prereq.: 13.41
Year: G (1, 2) *Arr.*
Preparation of the preliminary design of a water-borne vehicle selected by the student; emphasis on hydrodynamic, structural, or power plant aspects to suit interests of student. Fulfills department requirement of a comprehensive design problem for the Engineer degree. *Mandel, Powell*

13.43 *Naval Ship General Arrangements I* (R)
Prereq.: 13.01
Year: G (2) 3–0–5
Principles involved in the general arrangements of naval ships and in the design and installation of hull systems, fittings, and auxiliary machinery. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Stark*

(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.

13.44 ***Naval Ship General Arrangements II*** **(R)**
Prereq.: 13.00, 13.43
Year: G (1) 0–5–0
Analyses of general arrangement problems; preparation of general arrangement plans. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Stark*

13.45 ***Principles of Naval Ship Design*** **(RA)**
Prereq.: 13.44
Year: G (1) 3–0–6
Fundamental considerations in selecting and providing the military features of naval ships. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Stark*

13.46 ***Preliminary Design of Naval Ships*** **(RA)**
Prereq.: 13.41, 13.45
Year: G (2) 0–9–3
Project-type studies, including the preparation of the necessary plans and calculations for the preliminary design of a naval ship. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Stark*

13.90 ***Special Problems in Naval Architecture and Marine Engineering***
Prereq.: ——
Year: U (1, 2) *Arr.*
Special reading, study, design, and/or investigation under supervision of a specially qualified member of the faculty. Topics in naval architecture or marine engineering individually arranged to suit the interests of the student. (*Only for students with background in the field of naval architecture and marine engineering.*) *Powell*

13.91 ***Special Problems in Naval Architecture and Marine Engineering*** **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Special reading, study, design, and/or investigation under supervision of a specially qualified member of the faculty. Topics in naval architecture or marine engineering individually arranged to suit the interests of the student. (*Only for students with background in the field of naval architecture and marine engineering.*) *Powell*

13.92 ***Shipping Economics*** **(A)**
Prereq.: 13.00, 13.20, *13.40*
Year: G (2) 3–0–6
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*

13.93 ***Decision Processes in Ship Operation and Construction*** **(A)**
Prereq.: 6.28J or 13.96 or 18.10; 13.00; 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*

13.94 ***History of Naval Ships*** **(R)**
Prereq.: ——
Year: G (1) 3–0–4
A seminar-type subject in which students prepare and present papers. Selection of subjects designed to review development of characteristics of warships as well as interrelationship of such characteristics with international policies of the several powers. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) (*Not offered 1966–67.*) *Stark*

13.95 ***Hydroacoustics*** **(A)**
Prereq.: 2.03 or 8.712 or 13.30 or 13.31; 18.06
Year: G (1) 3–0–6
Topics in underwater acoustics important to modern naval architecture and marine engineering. Physics of water; mechanism of cavitation; cavitation noise. 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*

13.96 ***Application of Operational Methods***
Prereq.: 18.034
Year: U (2) 4–0–8
Elementary probability theory and statistics. Linear, nonlinear, 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*

14.
Economics

GENERAL ECONOMICS AND THEORY

14.01 ***Economic Principles I***
Prereq.: ——
Year: U (1, 2, S) 3–0–5
Introduction to fundamental economic concepts, such as production, money, banking, business organization, government fiscal policy, international trade, with emphasis upon the level and fluctuations in income, employment, and prices. Current economic problems. *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 of the equilibrium of the firm and the industry under conditions of competition, monopoly, and monopolistic competition; the consumption equilibrium of the household; factor markets and income distribution; introduction to concept of general equilibrium. *Rothenberg*

14.04 ***Industrial Organization and Public Policy***
Prereq.: 14.02
Year: U (2) 3–0–5
Case studies of the economic organization of particular American industries, with evaluations of their efficiency and technological progressiveness; anti-trust laws and other regulations of business. *Crandall*

14.05 *Economic Fluctuations and Growth*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
Analytical study of determinants of national income level, employment, and prices; study of their fluctuations and long-run trends. Consideration of historical and current behavior of the economic system, and role of stabilization policies. *Sidrauski*

14.06 *Structure of the American Economy*
Prereq.: 14.03
Year: U (1) 3–0–5
Study of magnitudes and quantitative relationships in the American economy having special relevance to an evaluation of the performance of the economy (its efficiency, growth, etc.), and to the design of public policy. Two or three special topics selected for detailed exploration; e.g., government expenditure, capital formation, industrial concentration, war-potential, labor force, income distribution, productivity, foreign trade. (*Not offered 1966–67.*) ——

14.07 *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. *Bardhan*

14.08 *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. (14.07 is desirable preparation but not a prerequisite.) ——

14.09 *Economic Problems Seminar*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
A seminar designed to complete a three-term humanities combination in economics and taking up selected problems of business and public policy, chosen because of their current interest or continuing significance for engineers and scientists. Development and application of the analytical techniques of 14.01 and 14.02. (*Sections limited to fifteen students.*) ——

14.10 *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. *Eckaus*

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. *Shell*

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. *Samuelson*

14.11 *Linear and Nonlinear Programming*
Prereq.: 14.03; 18.15 or 18.20
Year: U (1) 3–0–5
Origin of linear programming problems. Properties of solutions. Simplex and other methods of computation. Duality and interpretation of the dual problem. Applications to firm, industry, and aggregate planning. Nonlinear programming. Discrete programming. Relations to general economic theory. *Shell*

14.114 *Economics and Finance: Principles and Policies I*
Prereq.: ——
Year: G (S) 4–0–9
Introductory discussion of the determination of national income and its fluctuations; the composition and pricing of output; financial institutions and the functioning of money and capital markets; fiscal and other stabilization policies; industrial economics, price policy and the relations of government and business; and international economics. (*Restricted to Sloan Fellows.*) *E. C. Brown*

14.115 *Economics and Finance: Principles and Policies II*
Prereq.: 14.114
Year: G (1) 3–0–6
Continuation of 14.114. (*Restricted to Sloan Fellows.*) *Millikan*

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*

14.121T *Economic Analysis* (A)
Prereq.: 14.03
Year: G (1) 4–0–8

14.122T *Economic Analysis* (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 (2) 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, nonnegative 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. *Shell*

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14.124 *Advanced Economic Theory II* (A)
Prereq.: 14.122
Year: G (1) 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. *Arrow*

14.132 *Schools of Economic Thought* (A)
Prereq.: 14.121
Year: G (2) 3–0–6
Economic ideas developed by different groups of economists in recent times. *Rosenstein-Rodan*

14.151 *Mathematical Approach to Economics* (A)
Prereq.: 14.122
Year: G (1) 3–0–6
The use of mathematical methods in all the fields of economics. *Samuelson*

14.161 *American Economic History* (A)
Prereq.: 14.121
Year: G (1) 3–0–6
Quantitative approach to the growth of the economy of the United States. Topics included: magnitude of long-term changes in population and income; impact of resources, technology, and institutions on growth; possible existence of patterns and cycles in the aggregate data. Emphasis on events during the nineteenth century. *Temin*

14.162 *American Economic History* (A)
Prereq.: 14.121
Year: G (2) 3–0–6
Study of the growth of American economy. Emphasis on effects of colonial status on American economic development, role of public policy, impact of law and legal institutions, consequences of the nation's factor endowment, and relative rates of growth of various sectors. Deals primarily with the period 1620 to 1865. *Letwin*

14.163 *European Economic History* (A)
Prereq.: 14.121
Year: G (1) 3–0–6
Selected topics in recent European economic history with special attention to problems associated with technical progress and productivity changes. *Postan*

14.164 *European Economic History* (A)
Prereq.: 14.121
Year: G (2) 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. *Travis*

14.171 *Theory of Economic Growth* (A)
Prereq.: 14.122, 14.451
Year: G (1) 3–0–6
The interaction of economic variables in the long-run growth process. Theoretical models of the relationships among population and resource patterns, capital formation, monetization of the economy and growth of markets, technological change, sectoral patterns of investment, foreign trade, and the like. *Rosenstein-Rodan*

14.172 *Research Seminar in Economic Development* (A)
Prereq.: 14.171
Year: G (2) 3–0–6
Conceptual and empirical problems of conducting both library and field research on economic development. Discussion of formulation of relevant research topics, problems of quantification and measurement, interpretation of results, etc. Case materials from literature and from research in progress. *Millikan*

14.182 *Capitalism, Socialism and Growth* (A)
Prereq.: 14.121, 14.451
Year: G (2) 3–0–6
A comparative study of capitalist and socialist economies mainly from the point of view of development and growth, and with major emphasis on the economy of the Soviet Union. (*Not offered 1966–67.*)

14.191 *Economics Seminar* (A)
Prereq.: 14.121
Year: G (1) 3–0–6
14.192 *Economics Seminar* (A)
Prereq.: 14.121
Year: G (2) 3–0–6
Special economic problems. (*Open to graduate students only.*) *Bruno (14.191), Shell (14.192)*

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.: 14.121, 14.451
Year: G (2) 3–0–6
Topics in economics of current intest.
Arrow (14.193), Walters (14.194)

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

14.22 *Economics of Particular Industries*
Prereq.: 14.03
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. *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. An energy program for an underdeveloped country. Intended for students of either economics or engineering. *Rosenstein-Rodan*

14.231 *Seminar in the Economics of Eastern Hemisphere Petroleum* (A)
Prereq.: 14.03
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. *Adelman*

14.271 ***Problems in Industrial Economics*** **(A)**
Prereq.: 14.03
Year: G (1) 3–0–6
Small and large enterprises in the American economy; market structures; degrees of monopoly and competition; requisites of public policy. *Adelman*

14.272 ***Government Regulation of Industry*** **(A)**
Prereq.: 14.271
Year: G (2) 3–0–6
Follows 14.271. Development of anti-trust policy, generally and in specific cases. "Public utility" price fixing, government ownership as alternative. *Adelman*

14.282 ***Economics of Technology and Innovation*** **(A)**
Prereq.: 14.03
Year: G (2) 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 overall 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

14.371 ***Statistical Theory***
Prereq.: 18.034
Year: U (1) 3–0–6
Elementary but mathematical viewpoint. Axiomatic probability, random variables, mathematical expectation, generating functions, probability distributions, convolution, correlation, and regression. *H. A. Freeman*

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.
H. A. Freeman

14.373 ***Time-Dependent Probability*** **(A)**
Prereq.: 14.371 or 18.10
Year: G (1) 3–0–6
An elementary course in time-dependent processes. Markov chains, Markov processes, the ergodic theorem, general stochastic processes, martingale theory.
H. A. Freeman

14.374 ***Design and Analysis of Scientific Experiments*** **(A)**
Prereq.: 14.371 or 18.10
Year: G (2) 3–0–6
Linear hypotheses and the associated analysis of variance. Discussion ranging from simple comparative experiments to experiments involving many factors and many variables. *H. A. Freeman*

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. *Foley*

14.383T ***Econometrics*** **(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 recent estimation procedures. Term project applying econometric techniques to economic phenomena required for each student. *Kuh*

14.384 ***Advanced Topics in Econometrics*** **(A)**
Prereq.: 14.383T
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. *Kuh*

14.39 ***Economic Research Seminar***
Prereq.: 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. *Staff*

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.: 14.02
Year: U (1, 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, Sparks*

14.43 ***Public Finance***
Prereq.: 14.02
Year: U (1) 3–0–5
Effects of government revenue and expenditure programs on the level and distribution of economic activity; intergovernmental fiscal problems; relationship of fiscal to other economic policies. *Diamond*

14.451T ***Theory of Income and Employment*** **(A)**
Prereq.: 14.05
Year: G (1) 4–0–8
Examination of principal determinants of aggregate levels of income and employment. *Eckaus*

(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.

14.452T *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. *Solow*

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.
Williamson, Sparks

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. *Samuelson*

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. *E. C. Brown, Diamond* (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, Diamond*

INTERNATIONAL ECONOMICS

14.54 *International Trade*
Prereq.: 14.02
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.
J. H. Williamson

14.581T *International Economics* (A)
Prereq.: 14.03, 14.05
Year: G (1) 4–0–8

14.582T *International Economics* (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. *Kindleberger*

14.584 *Seminar in International Economic Theory* (A)
Prereq.: 14.582
Year: G (1) 2–0–7
Joint seminar meeting alternate weeks at Harvard and M.I.T., limited to second-year graduate students and beyond, including especially students preparing theses in international economics. Emphasis on theory, rather than empirical questions or policy issues, and on student contribution. *Kindleberger*

14.585 *Elements of Economic Growth*
Prereq.: 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*

14.586 *Interregional Economics* (A)
Prereq.: 14.03
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. *J. R. Harris*

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. *Alfred*

14.671 *Labor Economics* (A)
Prereq.: 14.64
Year: G (1) 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. *Myers*

14.672 *Public Policy on Labor Relations* (A)
Prereq.: 14.64
Year: G (1 or 2) 3–0–6
Major trends in labor legislation, the legality of union activities, protection of the right to organize and bargain collectively, regulation of wages and hours, governmental machinery for the adjustment of labor disputes, and social insurance. The broad economic and social questions raised by these trends. (*Not offered 1966–67.*)

14.673 *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.*) *Myers, Siegel*

14.674 *The Labor Movement: Theories and Histories* (A)
Prereq.: 14.64
Year: G (2) 3–0–6
Comparative analysis of labor organization in different contexts. (1) A review of traditional theories of the labor movement. (2) Examination of key labor problems common to industrialized or industrializing countries. (3) Historical analysis of labor organization in selected countries. *Siegel*

14.69 *Labor Problems Seminar*
Prereq.: 14.64
Year: U (1 or 2) 3–0–5
Supplements the humanities combination in labor relations and labor economics. Selected labor problems chosen for their current interest or continuing significance. Development and application of problems and techniques of 14.63 and 14.64. (*Section limited to fifteen students.*) *Alfred*

14.691 *Research Seminar in Industrial Relations* (A)
Prereq.: 14.671 or 14.672
Year: G (1) 3–0–6
Discussion of important areas for research in industrial relations, frameworks for research, research techniques, and methodological problems. Centered mainly on the thesis research of advanced graduate students. *Myers*

14.692 *Research Seminar in Industrial Relations* (A)
Prereq.: 14.691
Year: G (2) 3–0–6
Continuation of 14.691. *Myers*

15.
Management

15.00 *Introduction to Managerial Accounting*
Prereq.: ——
Year: 1 (1, 2) 3–0–3
Introduction to the profit logic of business enterprise, the structure of information system of business enterprises in terms of managerial needs for data as a basis for planning and controlling enterprise operations, and the use of accounting data in the social sciences. Design and operation of an accounting system adequate to the needs of a small business, an extracurricular or community enterprise, or a person or family. Construction and use of budgets. *Goetz*

15.01 *Economics for Management*
Prereq.: 14.01
Year: U (2) 3–0–6
Economics of the firm and of the industry. How the price-profit system works through operation of supply and demand. Market structures and market behavior in specific industries. *MacAvoy*

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.*) *Alexander*

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.*) *Alexander*

15.02T *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.: 15.02T 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 sub-sampling; multi-stage sampling; combinations of cluster sampling and stratified sampling; disproportionate stratified sampling; two-phased and sequential sampling. *Durand*

15.04T *Psychology and Human Organization*
Prereq.: ——
Year: U (1, 2) 4–0–8
Organization theory and behavior. Introduction to psychological theory and research relevant to the behavior of people in groups and organizations.
Marquis, T. J. Allen

15.09J *Probabilistic Systems Analysis*
(Same subject as 6.28J)
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. Theory of probability presented on axiomatic basis. Emphasis on sample space concept. Discussion of algebra of events, operations on random

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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 modelling. Applications presented concurrently with the development of the theory. *Drake*

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*

15.092 *Mathematics for Management*
Prereq.: 15.091
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. (*Restricted to Sloan School of Management graduate students.*) *L. S. White*

15.095 *Statistical Decision Theory* (A)
Prereq.: 15.09J
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*

15.11 *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.*) *Gruber*

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.*) *T. M. Hill, Poensgen*

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.*) *Pounds*

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
Study of fundamental legal principles as an element of the environment within which management of industrial enterprises is carried out. (*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 overall systems description and improvement. Introduction of such techniques as mathematical and heuristic programming as aids to individual decision-making within complex systems. Discussion of philosophy, techniques, and managerial applications of high-speed information processing systems as aids to information flow and policy design. (*Restricted to Sloan Fellows.*) *Bowman, Forrester*

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.*) *Amstutz*

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.*) *Letwin, Travis, Temin*

15.221 *International Business Management I* (A)
Prereq.: 15.014
Year: G (1) 3–0–6
Theory and institutions of international business. Western enterprise as a force for economic and political development; conflict of interest in international trade and investment; specialized legal, informational, financial, and commercial institutions serving international business, including the law on property rights, rights of aliens, taxation, antitrust, expropriation, arbitration, guarantees; operating under foreign exchange controls; hedging against inflation and devaluation; international banking operations; sources of finance; trade finance;

trade agreements; trade areas; importing and shipping. Term project: an analysis of a foreign market for a specified product. *Robinson*

15.222 *International Business Management II* (A)
Prereq.: 15.221
Year: G (2) 3–0–6
Organizational and operational problems arising from the international nature of business, including the development of an international business structure; forms of international business relationships; and characteristic problems relating to communication, personnel relations, procurement, production, marketing, finance, control, management selection, and public policy. Term project: design of the legal, administrative, and control structure for an international company. *Robinson*

15.231 *Management of Economic Development* (A)
Prereq.: 15.014, 15.201
Year: G (1) 3–0–6
Management problems implicit in the development efforts of emerging nations, with special reference to tropical Africa. Examination of two or three problems drawn from the following: internal financing or development, external financial and technical assistance, development banking and other institutions, regional (intra-African) and multilateral (O.E.C.D.) arrangements for development and co-operation in Africa; role of scientific and technical development, manpower needs. Integration and application of basic management tools. Lectures by outside participants, and returned M.I.T. Fellows in Africa. *Wilson*

15.232 *Development Finance* (A)
Prereq.: 15.231
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*

15.30 *Personnel Administration*
Prereq.: 14.01
Year: U (2) 3–0–6
Effective development and utilization of manpower. Personnel administration treated as staff function but line responsibility. Case method to help students develop a constructive personnel point of view. Organizational planning and executive development; recruitment, selection, placement and follow-up of employees; basic problem of worker's attitude toward authority; progressive discipline, industry as an economic and social system; management-union relationships, establishment and maintenance of satisfactory working conditions; job analysis and grading; wage and salary administration; interviewing and psychological tests as tools of management; employee participation in problems having to do with production. (*Not offered 1966–67.*) ——

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

15.322 *Problems in Labor Relations and Personnel Administration* (A)
Prereq.: 15.312
Year: G (2) 3–0–6
The function of personnel administration and the role of the personnel administrator in the individual firm. Assumptions, objectives, and methodologies of the personnel function in several major problem and program areas. Field studies to examine company personnel programs. *Myers*

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 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 *Influence, Persuasion, and Attitude Change* (A)
Prereq.: 15.331
Year: G (2) 3–0–6
Seminar presenting some theoretical models of attitude change and examining their relevance for the influence of an organization on its members. Emphasis on gathering data and working up own projects. (*Enrollment limited to 15 students; admission by permission of instructor.*) *Schein*

15.334 *Interpersonal Behavior* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Study of interpersonal behavior and the nature of human relationships. Relevant theoretical writings and clinical data, various approaches to changing interpersonal behavior. (*Enrollment limited to 15 students; admission by permission of instructors.*) *Kolb*

15.335 *Personality Theory and Assessment* (A)
Prereq.: 15.334
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 10 students; admission by permission of instructor.*) *Kolb*

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

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specialists; professionalization of management; relations of industry to community and society. Field studies, secondary analysis of survey data, and library research on selected problems. *Evan*

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. *Evan*

15.372 *Organizational Psychology* (A)
Prereq.: 15.184
Year: G (1) 3–0–6
Analysis — through lectures, discussions, and class exercises — of management of human resources in industry. Emphasis on internal relations of management. (*Restricted to Sloan Fellows.*) *Schein, Beckhard, Haire*

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). (*Enrollment limited to 15 students; admission by permission of instructor.*) *Beckhard, Bennis*

15.374 *Organization* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Study of organization theory and formal descriptions of organizational behavior. Development of concepts and a theoretical framework for explaining organizational process and structure, drawing on findings from a number of social science disciplines. Discussion of selected organization research studies. (*Enrollment limited to 15 students; admission only by permission of instructor.*) *Soelberg*

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. (*Primarily for doctoral candidates; others admitted by permission of instructor.*) *Soelberg*

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.*) *Evan*

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.*) *Soelberg*

15.381 *Administrative Theory and Practice* (A)
Prereq.: 15.312, 15.412T, 15.712, 15.812T
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. *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.: 15.014, 15.331
Year: G (2) 2–0–7
Lecture-discussions by different faculty members on organization and management of laboratories and groups engaged in research and development, with attention to economic and behavioral factors in decisions on planning, performing and controlling research and development. (*Restricted to second-year graduate students.*) *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*

15.391 *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.*) *Staff*

15.41 *Financial Management*
Prereq.: 15.50T
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*

15.412T *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*

15.42 *Investments*
Prereq.: 15.02T, 15.41
Year: U (1) 3–0–6

Restatements of investment objectives and nature of alternative means for attaining these objectives; nature of investment risks and development of institutions for specialized risk taking: comparative advantage in investment and the returns for risk taking; the management of institutional portfolios; industry and security analysis; security and commodity markets; emphasis on use of anaytical and techniques. *Cootner*

15.432 *Capital Markets and Financial Institutions* (A)
Prereq.: 15.412T
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 re-allocation 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.: 15.412T
Year: G (1) 3–0–6

Influence of the tax structure on the decisions of management and the conduct of business enterprise. Situations where taxes directly impinge on the firm or where personal and business tax considerations are related to action pursued by the business firm. The relation between corporate and personal income taxes; effect of capital gains taxation on the price of stock and the flow of capital to business; appropriate basis for and timing of depreciation charge; depletion allowances; deferred and contingent compensation (pension plans, stock options, etc.); other related topics. Sufficiently broad interpretation of the role and interests of management to include an examination of the effect of taxation on the level of investment and how it is financed.
D. M. Holland

15.46 *Financial Administration of Industry* (A)
Prereq.: 15.412T
Year: G (2) 3–0–6

Analysis of specific problems confronting business managers in internal financial management. Emphasis on financial planning; analysis of models for capital expenditure decisions in the context of the firm's environment. Stress on problems of forecasting fund flows and alternative methods of financing. *Kuh*

15.472 *Risk and Uncertainty in Financial Decision-Making* (A)
Prereq.: 15.092 or 15.59; 15.412T
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, 6.671J, 16.751J)
Prereq.: 15.412T; 15.59 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.
Farrar, Bone, Reintjes, R. H. Miller

15.484J *Flight Transportation Seminar*
(Same subject as 1.222J, 6.672J, 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.
Farrar, Bone, Reintjes, Browne

15.50T *Management Information and Control*
Prereq.: ——
Year: U (1, 2) 4–0–8

Introduction to basic concepts and techniques of collecting, processing, and reporting information generated by business activities. Theory and methods of measurement of income and wealth. Justification and utility

(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.

of controls as tools of applied economics with emphasis on their employment by management for decision-making. Introduction to the nature and uses of standard costs. Investigations into the nature, generation, organization, analysis, and interpretations of data needed in evaluating and controlling the performance of the many activities of the individual business enterprise. *Staff*

15.501 ***Management Information and Control***
Prereq.: ——
Year: G (1) 3–0–6
Similar to 15.50T with portions of subject matter covered by means of programmed self-instruction. *(Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.)* *Hekimian*

15.503 ***Management Information and Control* (A)**
Prereq.: ——
Year: G (1, 2) 3–0–6
More intensive coverage of subject matter embraced by 15.53. *(Designed for non-Course XV graduate students not planning to take 15.412.)* *Staff*

15.51 ***Cost for Control and Decision Making***
Prereq.: 15.01; 15.50T or 15.53
Year: U (2) 3–0–6
Similar to 15.511 but with more emphasis on techniques of cost control and their implementation through the accounting system. *Hekimian, Poensgen*

15.511T ***Costs for Managerial Decisions* (A)**
Prereq.: 15.501 or 15.503
Year: G (1, 2) 3–0–6
The planning and control system as an effective management tool. Study of these systems as a means of communicating necessary information, evaluating performance, motivating efficiency, and undertaking remedial action in the firm. Critical evaluation of actual and standard cost systems and flexible budgeting. Problems of measuring costs and profits of segmented activities of the total firm (product lines or divisional activities). Use of cost data in evaluating activities and decision making involving alternative courses of action, such as pricing and bidding decisions, make or buy decisions. Case material from a variety of industrial situations to supplement readings. *Hekimian, Poensgen*

15.512 ***Advanced Concepts in Managerial Information for Planning and Control* (A)**
Prereq.: 15.012, 15.511T
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 semi-decentralized operations. Problems encountered in the design of information and control systems. Concepts of integrated information systems, functional systems and associative-adaptive systems for overall managerial planning and control. *Zannetos*

15.522 ***Financial Accounting Problems* (A)**
Prereq.: 15.412T
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.
T. M. Hill

15.53 ***Management Information and Control***
Prereq.: ——
Year: U (1, 2) 3–0–6
Similar to 15.50T but with less attention to theory and methods of measurement of income and wealth and with extended coverage of financial analysis for decision-making. Problems of investment evaluation and determination of the cost of capital which are also covered in 15.41. *(Designed for non-Course XV students not planning to take 15.41.)* *Staff*

15.542 ***Management Information Systems* (A)**
Prereq.: 15.50T or 15.501 or 15.53
Year: G (1, 2) 3–0–6
Introduction to digital computers, and data processing techniques. Emphasis on use of large-scale digital computers in integrated information and decision-making systems, and the technology required to implement them. Topics covered include computer architecture, programming languages, operating systems, data collection, transmission and display, data storage and retrieval, sequential versus random access processing, heuristic techniques, simulation, systems design, analysis and evaluation, cost and value of information, on-line systems, integrated systems and their implementation, military information systems, and the role of information systems in an organization. Lectures, library research, programming project, and other exercises. *Carroll*

15.555 ***Advanced Computer Systems* (A)**
Prereq.: 6.251 or 15.542
Year: G (1, 2) 2–0–7
Seminar in the management use and organization of future computer systems. Varying topics to include economic and operational consideration of man-machine communication, time sharing, real-time systems, multiprocessing and multiprogramming, information storage and retrieval, heuristic programming, computer simulation, data collection and transmission, role of computers in organizational planning and control, computer-aided design, symbolic computation, and computer languages. Laboratory use of M.I.T. time-sharing equipment. Paper required on research topic or field study of student's choice. *(Enrollment limited.)* *Carroll, Greenberger*

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 ide as 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 overall 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. *E. B. Roberts*

15.582 *Industrial Dynamics II* (A)
Prereq.: 15.58 or 15.581
Year: G (2) 3–0–6
Application of industrial dynamics to actual company and government problem situations. Discussion of objectives of industrial dynamics, steps in a study. Analysis of an actual organization from a dynamic systems point of view. Stress on the relationship of management policy and organizational structure to overall performance. Identification of a systems problem, development of a verbal and mathematical model. Simulation and validation of the model. Interpretation of simulation results and revision of objectives and model. Redesign and improvement of the business system. Initiation of implementation of study recommendations. *E. B. Roberts*

15.59 *Mathematical Programming I*
Prereq.: 18.034
Year: G (1, 2) 3–0–6
Linear algebra and linear programming. Algebraic topics include: vectors, matrices, and determinants, linear transformations, convex sets and n-dimensional geometry, eigenvalue problems, and quadratic forms. Treatment is rigorous but not abstract. Linear programming coverage includes: the theory and computational procedures of the simplex method, the revised simplex method, duality theory and its ramifications, and special topics. *Staff*

15.591 *Case Studies in Quantitative Analysis* (A)
Prereq.: 15.09J; 15.092 or 15.59
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. *Kaufman*

15.592 *Mathematical Programming II* (A)
Prereq.: 15.092 or 15.59
Year: G (2) 3–0–6
Nonlinear 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. *Little*

15.593 *Stochastic Systems* (A)
Prereq.: 15.09J; 15.092 or 15.59
Year: G (1) 3–0–6
Birth and death processes, recurrent events, single server queues, many server queues, and other stochastic systems. Applications in inventory, maintenance, and customer service operations. *Little*

15.594J *Systems Engineering and Operations Research* (A)
(Same subject as 6.536J)
Prereq.: 15.09J; 15.092 or 15.59
Year: G (2) 3–0–9
Analysis of linear probabilistic systems. Application of linear system theory to the study of finite- and infinite-state, discrete- and continuous-time, stationary and nonstationary, Markov 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*

15.596 *Simulation of Micro-Economic Behavior* (A)
Prereq.: 14.121 or 15.012
Year: G (1) 3–0–6
Critical examination of traditional economic theories of individual decision-making behavior. Emphasis on developing and testing detailed computer simulation models. Seminar discussion of selected models and student research projects. *Clarkson*

15.599 *Research Seminar in Quantitative Analysis* (A)
Prereq.: ——
Year: G (1, 2) 2–0–7
A special topic in quantitative management forming the basis for student research. Review of technical literature, guest lectures, and general discussion. Topics included in the past: the structure of decision process, dynamic modeling and on-line simulation, the organization and manipulation of data bases. Discussion and use of the OPS system and other on-line interactive computer facilities. (*Enrollment limited.*) *Greenberger*

15.61 *Business Law*
Prereq.: 14.01
Year: U (1, 2) 3–0–6
Fundamental legal principles and the nature of the judicial process through study of cases and text material. Selected court decisions presenting typical business situations and illustrating basic problems in the law of contracts, agency, negotiable instruments, and corporations with special emphasis upon the changes in the law brought about by the Uniform Commercial Code. Requirements for formation of a contract, offer and acceptance, necessity for consideration, capacity to contract, the parole evidence rule, public policy concepts, impossibility of performance, quasi contracts, measure of damages for breach of contract, liquidated damages, specific performance, and other equitable remedies; the principal-agent relationship, duties of agent to principal and principal to agent, apparent authority, liability for acts of agent in contract and tort, undisclosed principal; organization of corporations, limited liability, corporations and taxation, powers of a corporation, stockholders' rights, directors' fiduciary duties, and responsibility of management; rights and duties of parties in various banking transactions. *Macmillan*

15.65 *Labor Law*
Prereq.: ——
Year: U (1) 3–0–6
The legal structure of labor-management relations. Review of evolution of labor relations law in the 20th 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*

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15.661 ***American Legal System*** **(A)**
Prereq.: 15.201
Year: G (1, 2) 3–0–6
Survey of the fundamental principles of American laws. Development of insights into capabilities and limitation of legal system, considered as an element of the environment within which management of industrial enterprises is carried out. The way in which the system works and changes, the underlying ethical and political ideas which give it direction, and the major policy issues exemplified in it. Seminar discussion of legal cases and selected essays. *(Admission limited to Sloan School of Management graduate students; others admitted only by permission of instructor.)* *Jacks, Nyhart*

15.71 ***Production Management***
Prereq.: 15.02T
Year: U (2) 3–0–6
Quantitative approach to decision-making in production management. Incremental analysis, linear programming, stochastic models, waiting-line theory, and design of experiments applied to problems of economic quantities, production programming, statistical control, equipment purchase. *Carroll*

15.712 ***Operations Management*** **(A)**
Prereq.: 15.012, 15.092, 15.331
Year: G (1, 2) 3–0–6
Processes of decision making concerning the economic problems of operations management, including operations scheduling, facilities configuration and operation, and performance control. Examination of a wide variety of institutional settings, including factories, airlines, and electric utilities. Applied theory from prerequisite subjects including operations analysis techniques such as mathematical programming and Monte Carlo simulation. *Bowman, Pounds*

15.73 ***Management Laboratory***
Prereq.: 14.01 or 15.71
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*

15.75 ***Manufacturing Analysis***
Prereq.: 15.71
Year: U (1) 3–0–6
Field applications of methods of analysis developed in 15.71. Development of actual data required for operational use of decision-making models. *Goetz*

15.751 ***Manufacturing Analysis*** **(A)**
Prereq.: 15.712
Year: G (1) 3–0–6
Subject matter of 15.75 at advanced level. *Goetz*

15.78 ***Studies in Manufacturing Analysis***
Prereq.: 15.71
Year: U (1) 3–0–6
Examination of studies from current literature devoted to formal methods for analyzing production management problems. Applications of linear programming, other programming applications, waiting-line applications, applications of incremental analysis, and total cost and value models presented from the empirical literatures of management science, operations research, economics, and statistics. Student seminar responsibilities. ——

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. *Goetz*

15.791 ***Operational Models of the Firm*** **(A)**
Prereq.: 15.012, 15.501, 15.712, 18.034
Year: G (1) 3–0–6
Intensive analyses of selected kinds of management decision problems that involve interrelationships among functional areas. Study and solution of decision problems of rather broad scope by use of mathematical and statistical methods such as differential and difference equations, transform theory, calculus of variations, signal flow analysis, and Markov processes. Relation of theory and practice. Design of efficient operating techniques based upon theoretical findings. Student participation in field studies and special projects. ——

15.792 ***Manufacturing Decisions Seminar*** **(A)**
Prereq.: 15.712
Year: G (2) 3–0–6
Seminar based on literature of decision-making and one manufacturing problem area, such as inventory, scheduling, quality, or equipment, combined with field study in a local firm to observe, describe, and predict the decision-making behavior of individuals concerning that manufacturing problem. ——

15.81 ***Marketing***
Prereq.: 15.01
Year: U (1, 2) 3–0–6
Introduction to managerial problems in marketing operations, emphasizing possibilities of gaining insight into the underlying determinants and dynamics of consumer and industrial demand behavior through the medium of social and economic research. Basic policy considerations through which marketing management may adapt operations of firm to changing market environment: selection and control of channels of distribution, product line, pricing, and sales promotion policy. Theoretical concepts and quantitative techniques applied in study of marketing phenomena. *Staff*

15.812T ***Marketing***
Prereq.: 15.091
Year: G (1, 2) 3–0–6
Development of a quantitative, simulation-based approach to marketing policy and strategy formulation, research, and decision-making. Discussion of representative articles from the current literature. Pricing, advertising and promotion, distribution, selling, market research, the impact of competitor strategies and govern-

ment on marketing policy formulation, and the nature of consumer purchase decisions. Models of marketing environment developed and analyzed as guides to marketing planning and decision-making. (*Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.*) *Amstutz*

15.82 *Marketing Management*
Prereq.: 15.81
Year: U (2) 3–0–6
An advanced subject rounding out and building upon material studied in 15.81. Focus on the decision-making process in marketing management. Intensive attention given to opportunities for, and means of, sales development through advertising, sales force, and other promotional means. Product development, pricing, and distribution also considered as integral parts of a marketing strategy. Text and case materials to provide background for team participation and individual exercises based upon a complex computerized marketing game. *Little*

15.821 *Marketing Policy and Administration* (A)
Prereq.: 15.812T
Year: G (1) 3–0–6
Graduate level treatment of subject area of 15.82. Text and case discussions to provide background for team participation in a complex computerized marketing game. Seminar, with student presentation of oral reports. *Little*

15.83 *Marketing Research*
Prereq.: 15.81
Year: U (1) 3–0–6
Research methods and techniques in the solution of marketing problems. Sampling; design of experiments; measuring market potentials, customer motivation and buying habits; sales forecasting; studies of competition; and measuring advertising and sales-force effectiveness. Limited-scale class project to provide experience in formulating a problem and conducting an exploratory investigation, determining types of data needed and methods of collecting them, gathering data, analyzing results, and reporting problem solution. *Montgomery*

15.832 *Marketing Research* (A)
Prereq.: 15.812T
Year: G (2) 3–0–6
Application of quantitative methods to marketing research problems, with special emphasis on measurement of consumer demand. Usage of statistical tools of multiple regression, design of experiments, and sampling methods. Ways of securing valid information from market respondents, including relevant psychometric techniques. Computer programs used for data processing where appropriate. Class project to provide experience in planning and executing a research investigation with cooperating companies. *Montgomery*

15.86 *Product Planning and Development* (A)
Prereq.: 15.812T
Year: G (1) 3–0–6
The product mix as a major element in a marketing strategy. Diversification policy. Sources of ideas for new or improved products and methods for screening such ideas in light of potential market demand, costs, prices, and suitability to company's production and marketing facilities; organizational relationships and methods used to insure coordination between production, research, marketing, financial and other company departments affected by product planning and development. Problems of transferring new products from development stage to regular production, package design, testing market acceptability, and planning introductory sales campaigns. *Casselman*

15.891 *Research Seminar in Marketing* (A)
Prereq.: 15.812T
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 10 students per class, admission only by permission of the systems curriculum committee of the Sloan School of Management.*) *Forrester, Fey*

15.91 *Business Practice and Policy Determination*
Prereq.: 15.41, 15.71, 15.81
Year: U (2) 3–0–6
A terminal subject dealing with the approach to general management problems affecting all facets of the enterprise. Discussions and readings tracing objectives, policy determinations, and practices of business units at all stages of growth from foundation to corporate maturity. Attempt to develop the integrative ability of students to use knowledge gained in core subjects and to prepare them for launching their careers in industrial management with a balanced understanding of their business as an entity. ——

15.921 *New Enterprises* (A)
Prereq.: 15.412T, 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, 15.412T, 15.712, 15.812T
Year: G (2) 3–0–6
Subject matter of 15.91 at advanced level. *Hekimian*

15.942 *Organization Theory* (A)
Prereq.: 15.181
Year: G (1) 3–0–6
Investigation of the principles of top management policy-making. Derivation of authority, the corporate objective, influences on the decider, activation and appraisals of policy decisions. Case studies of selected companies illustrating the principles discussed. (*Restricted to Sloan Fellows.*) ——

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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 relating to the emerging nations, the Western Alliance, arms control, and planning for overseas operations. (*Restricted to Sloan Fellows.*) ——

15.95 *Senior Seminar in Management*
Prereq.: ——
Year: U (2) 2–0–7
Studies and investigations of problems and situations in management. A project, field survey, or research investigation in some phase of management, chosen by the student and carried out individually or in a group under staff supervision. Readings, conferences, reports. (*Restricted to seniors in the Sloan School of Management.*)
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

16.00J *Thermodynamics and Statistical Mechanics*
(Same subject as 2.41J)
Prereq.: 8.02, 18.02
Year: U (1, 2) 3–2–7
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, Gouse*

16.01 *Dynamics*
Prereq.: 8.02, *18.034*
Year: U (1, S) 4–2–6
Dynamics, with applications to aeronautical and astronautical problems. Kinematics and dynamics of particles and of groups of particles. Relative motion as seen by accelerating and rotating observers. Particles of variable mass. Mass properties of rigid bodies, the inertia tensor, geometric and mass symmetries. Kinematics and dynamics of a rigid body in general motion. Euler's dynamical equations, gyroscope equations. *Potter*

16.02 *Aerodynamics*
Prereq.: 16.00J
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. *Ashley*

16.03 *Gasdynamics*
Prereq.: 16.00J, 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, Oates*

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
Conservation relations, rotational and irrotational flows for a compressible medium. Subsonic, transonic, supersonic, and hypersonic inviscid flows in two and three dimensions. Similarity concepts. Small disturbances, method of characteristics, blast waves, blunt bodies. *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 a reacting medium. Non-equilibrium flow and relaxation phenomena. Similarity, dispersion, characteristics, shocks. Radiation coupled flow, application to hypersonic test facilities, blunt bodies, boundary layer, wakes.
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. Application to magnetohydrodynamics. *Trilling*

16.067 ***Gas-Surface Interactions*** **(A)**
Prereq.: 8.05 or 8.051
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, nonplanar lifting surfaces, flows with free vortices, transonic motion, unsteady flows, and other special topics selected in the light of currently important aeronautical problems. *Landahl, Ashley*

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, 16.11T
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*

16.11T ***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 nonlinear 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.: 16.11T
Year: G (1) 3–0–6

Analytic solutions for nonlinear 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*

16.20T ***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.* *Mar, Bisplinghoff*

16.201 ***Solid Mechanics II***
Prereq.: 16.20T
Year: U (1, 2, S) 4–0–6

Fundamentals of solid mechanics applied to analysis of flight vehicle structures. Flight design loads; introduction to plasticity, bending, shear, and torsion of beams

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and rods including thin wall beams. Introduction to energy principles in solid mechanics. Plane stress, plane strain, and thermal elastic problems. Introduction to plate theory. Theories and modes of structural failures. *Witmer, Pian*

16.21 ***Matrix and Numerical Methods of Structural Mechanics*** **(A)**
Prereq.: 16.201
Year: G (1) 3–0–6
Approximate solutions of solid continua and complex flight vehicle structures by finite-element idealizations and matrix structural methods. Influence coefficients by energy and other methods. Finite difference methods. Included are small-deflection elastic behavior, nonlinear large-deflection behavior, plasticity, creep, thermal stresses, and buckling. *(Not offered 1966–67.)* *Witmer*

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. *Mar*

16.24 ***Variational Principles of Structural Mechanics*** **(A)**
Prereq.: 16.201
Year: G (2) 3–0–6
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 principle, and generalizations. Castigliano's theorems. Emphasis on obtaining approximate solutions. Inclusion of initial stresses, initial strains, nonuniform temperatures, small deflections, large deflections, elastic buckling, creep, creep buckling, plasticity, and viscoelasticity. *Witmer*

16.25 ***Advanced Topics in Solid Mechanics*** **(A)**
Prereq.: 16.201
Year: G (1) 3–0–9
Problems associated with viscoelastic and creep behaviors 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. Nonlinear creep laws. Structural analyses in presence of creep. Creep buckling. Mechanical problems associated with solid propellants. Damping by means of viscoelastic materials. *Pian*

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*

16.30 ***Principles of Automatic Control***
Prereq.: 6.43, 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*

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, Vander Velde*

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 nonlinear 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. *Li, Meiry*

16.34 ***Automatic Control of Flight Vehicles*** **(A)**
Prereq.: 16.31
Year: G (2) 3–0–6
Application of design techniques and principles to advanced automatic control systems for air and space vehicles. Synthesis of control systems from standpoint of meeting mission specifications. Analysis of adaptive control systems; their use in meeting performance requirements over widely changing environments encountered by high-speed aircraft and manned spacecraft. Typical engineering problems associated with design of control equipment, considering limitations and uncertainties of components, random input effects, mass cross-coupling effects, etc. (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 measure-

ment 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*

16.362J *Special Studies in Systems Engineering* (A)
(Same subject as 1.16J, 2.191J, 6.604J)
Prereq.: 16.30
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 trade-offs 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. (Projects for 1966 were: Group 1 — An integrated urban transportation system. Group 2 — A manned satellite inspection and retrieval system.) *Li, Bisbee, Baumann, Seifert*

16.37 *Statistical Problems in Automatic Control* (A)
Prereq.: 16.30, 18.05
Year: G (1) 3–0–9
Statistical problems of importance to control engineers. Review of probability theory with application to such problems as evaluation of probability of kill. Introduction to sample theory with application to determination of the CPE for missile systems. Extensive treatment of random processes in linear feedback systems including optimum design of such systems; brief treatment of nonlinear systems in presence of random noise. *Vander Velde*

16.38 *Physical Components of Control Systems* (A)
Prereq.: 6.44
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*

16.39T *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.: 6.43, 16.01
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. *McKay*

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

16.42T *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*

16.45J *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*

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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 6.252 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*** **(RA)**
Prereq.: 16.41
Year: G (1 or 2) *Arr.*
Problems of interest to qualified students in consultation with the instructor. *(Restricted to selected officers of the U. S. Air Force, Army, and Navy.)* *Wrigley*

16.50 ***Vertical Take-Off Aircraft*** **(A)**
Prereq.: 16.11T
Year: G (1) 3–0–6
Analysis of inherent performance stability and control characteristics of vertical takeoff and landing aircraft, including helicopters and ducted fan, tilt wing, jet vectored-lift, and jet vertical-lift aircraft. *Ham*

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.: 2.201T or 16.02 or 16.03; 16.00J
Year: U (2, S) 3–0–6
Study of mechanics and thermodynamics of rocket propulsion devices, compressible flow in nozzles, combustion and heat transfer, turbomachinery, performance of chemical and nuclear-heated rockets, and vehicle performance. Survey of current developments in electrical propulsion including the arcjet, electrostatic and magnetohydrodynamic accelerators. *E. S. Taylor*

16.54 ***Aircraft Engines***
Prereq.: 2.201T or 16.02 or 16.03; 16.00J
Year: U (1) 3–0–6
Applications of solid and fluid mechanics and thermodynamics to determine the performance of airbreathing engines. Special attention is given to factors which limit size, weight, and efficiency. Engine components — inlet diffusors, combustors, compressors, and turbines. The ramjet. The turbojet and its derivatives. Engine-airframe performance characteristics. *E. S. Taylor*

16.561 ***Astronautical Propulsion*** **(A)**
Prereq.: 16.53, 18.05
Year: G (1) 3–0–9
Application of fundamental principles of fluid mechanics and thermodynamics to the analysis of selected special problems found in the research and development of liquid propellant engines and nuclear, ion, arc, and magnetohydrodynamic engines. Discussion of possible and most suitable application of the various engines.
M. A. Hoffman, Oates

16.562 ***Astronautical Propulsion*** **(A)**
Prereq.: 16.561
Year: G (2) 3–0–9
Continuation of the application of kinetic theory of ionized gases and plasma physics to magnetohydrodynamic accelerators and generators, and thermionic energy converters. Analysis of the interrelationships and performance optimization of complete space power supplies suitable for electric propulsion including nuclear-MHD, nuclear-thermionic and nuclear-turbo-electric systems. *Oates, M. A. Hoffman*

16.58J ***Advanced Topics in Plasma Kinetic Theory*** **(A)**
(Same subject as 22.66J)
Prereq.: 22.64
Year: G (2) 3–0–9
Varying content including topics of current interest. Typical subjects: theories of nonlinear 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; nonlinear 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

16.60 ***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*

16.61 ***Projects Laboratory***
Prereq.: 8.01
Year: U (1) 1–4–1
Introduction to experimentation through the accomplishment of individual projects. Lectures on experimental methods, instruments, errors, data reduction, report writing, and oral presentation. *Bicknell*

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***
Prereq.: 16.02 or 16.03
Year: U (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. *Covert*

16.70 ***Aircraft and Spacecraft Design***
Prereq.: ——
Year: 1 (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.: 16.11T, 16.201
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. *Ham*

16.73T ***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, guidance and control requirements, structural design, thermal protection, weight estimation, environmental control and component layout. *R. H. Miller*

16.74 ***Advanced Space Systems Engineering*** **(A)**
Prereq.: 16.201 or 16.53 or 16.73T
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, 6.671J, 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, Reintjes, Farrar

16.752J ***Flight Transportation Seminar***
(Same subject as 1.222J, 6.672J, 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, Reintjes, Farrar

16.761 ***Orbital and Ballistic Flight*** **(A)**
Prereq.: 16.01; 16.02 or 16.03
Year: G (1) 3–0–6
Performance of orbital and ballistic missiles and spacecraft. Atmosphere and space environment of vehicles; orbit mechanics; ballistic trajectories; performance parameters of rocket engines; powered flight trajectories; vehicle system preliminary design considerations. *(Not offered 1966–67.)* *M. A. Hoffman*

16.78 ***Control and Guidance in Flight Transportation*** **(A)**
Prereq.: 16.11T, 16.30
Year: G (1) 3–0–6
Study of the functional and technical aspects of the overall air transportation problems associated with enroute navigation, landing and take-off, and traffic control. Consideration of the interrelationships between the characteristics of the airplane as a whole and the facilities, equipment, and environment, with the view of evolving a comprehensive solution to the air navigation and control problem that meets the desired system performance. Study of existing navigation, traffic control, and automatic control systems. *Whitaker*

16.81 ***Flight Vehicles***
Prereq.: 8.01
Year: 1 (1) 3–0–3
The role of science and engineering in the development of aircraft and space craft. Examination of the fundamental problems and solutions of these problems in the light of current technology. *Koppen*

16.85 ***Industrial Practice***
Prereq.: ——
Year: U (1) 40 h.p.w.
Five months of practical work carried out by the cooperative students in manufacturing, engineering, research, and developments at the plants of organizations participating in the cooperative program. *R. H. Miller*

16.91 ***Continuum Vibrations*** **(A)**
Prereq.: 16.02 or 16.03; 16.201
Year: G (1) 3–0–6
Dynamics of elastic structures. Vibrations of bars, strings, beams, membranes and plates. Emphasis on formulation of self-excited vibration problems and approximate methods for their solution. *Dugundji*

16.92 ***Advanced Aeroelasticity*** **(A)**
Prereq.: 16.91
Year: G (2) 3–0–9
Presentation of field of aeroelasticity from unified viewpoint applicable to all types of flight vehicles throughout range of airspeeds. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Forced response, static and dynamic eigenvalues of simplified systems, one-dimensional structures and two-dimensional structures. Special topics of interest to the aeroelastician, with emphasis on aerodynamic operators. *Ashley*

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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. *Dugundji*

17.
Political Science

17.01T ***Society and Man***
Prereq.: 21.02
Year: U (1, 2) 3–0–6
Introduction to the Social Sciences. Life in the contemporary world examined by such methods as sociological surveys, psychological experiments, mathematical models, and historical and anthropological studies. Focus on the relation of the individual to his society, considering both the individual's capacity to affect his society and his society's affect on him. Attention paid both to rational choice and to unconscious motivations. Particular attention to the demands that industrialization has placed on human beings. *Pool*

17.02 ***The Modern World and Social Science***
Prereq.: 17.01T
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. *Pool*

POLITICAL COMMUNICATION AND BEHAVIOR

17.111 ***Public Opinion and Propaganda***
Prereq.: ——
Year: G (1) 3–0–6
History and development of public opinion as a factor in public policy: relationship of public opinion and private attitudes; organization of political parties and pressure groups; techniques used by them; conditions of effective and ineffective communications. *Pool*

17.112 ***Mass Media and Communication Systems***
Prereq.: ——
Year: G (2) *Arr.*
Examination of the pattern of communication in societies at different stages of development. Comparison of networks of oral communication with systems based on mass media. The role of opinion leaders, informal communication networks, literacy, the press, radio, film, and international communications. *Lerner*

17.12 ***Politics, Society, and Policy-Making***
Prereq.: Any previous social science subject
Year: U (2) 3–0–5
Case material on decision-making examined with a view to seeing what types of persons are likely to take action and in what ways under a variety of conditions. Cases involve conflicts of parties, pressure groups and governmental policy makers in the U. S. Congress and in foreign decision-making bodies. *Fein*

17.121 ***Political Socialization*** **(A)**
Prereq.: ——
Year: G (2) 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. (*Not offered 1966–67.*) *F. W. Frey*

17.122 ***The Analysis of Power*** **(A)**
Prereq.: 17.721
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. (*Not offered 1966–67.*) *F. W. Frey*

17.131 ***Methods of Communication Research*** **(A)**
Prereq.: 17.731 or 17.732
Year: G (2) 3–0–6
Survey analysis, content analysis, with some study of the institutional structure of communications and of communication flows. For students needing to secure or evaluate data about public opinion and attitude formation under the impact of communication. *F. W. Frey*

17.14 ***Power, Influence and Policy Decisions***
Prereq.: 17.12
Year: U (2) 3–0–5
Review of factors shaping such decisions as those examined in 17.12. Systematic analysis of communication flows, the values, motivations and personality traits of political activists, and the structure of power among them. Uses of game theory, operational codes, and elite analysis. (*Not offered 1966–67.*) *F. W. Frey*

17.151T ***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 systems in Asia, the world, including the United States; problems of psychological re-tooling in the new modes of interaction among Americans, Europeans, Asians, and Africans. *Isaacs*

17.161 ***Personality, Society, and Politics***
Prereq.: 17.721
Year: G (1) *Arr.*
The gradual inclusion of the social environment in psychoanalytic theory. The psycho-sexual and psychosocial stages of man in their relation to social institutions. Personality in followership and in leadership. Application to selected political problems. (*Not offered 1966–67.*) ——

17.162 ***Identity and Ideology***
Prereq.: 17.01T
Year: G (2) 3–0–6
Psycho-social and psycho-sexual problems of youth. Identity crisis and identity diffusion. Ideology as a transient necessity for individual maturation and for the rejuvenation of society. Application to political problems. *Pye*

17.191 ***Research Seminar in International Communications*** **(A)**
Prereq.: 17.111 or 17.112
Year: G (1) *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. *Lerner, (17.191); Bonilla, (17.192)*

COMPARATIVE POLITICS

17.21 ***The American Political Process***
Prereq.: 21.02
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 1966–67.)* *Staff*

17.213T ***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 the uniqueness and comparability of the American political system, the organizational structure and functions of the American party system, the executive and legislative power structures, the decision-making process, and representation and public policy. Special attention on contemporary research on American politics and government. *Saloma*

17.214T ***Research Seminar in American Political Behavior*** **(A)**
Prereq.: 17.21
Year: G (2) *Arr.*
Examination of the sociology of American politics. The American political culture and sub-cultural groupings as these relate to the party system. Political parties and political movements. *Fein*

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*

17.222 ***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*

17.223T ***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 1966–67.)* *Weiner*

17.225T ***Comparative Asian Politics—South Asia*** **(A)**
Prereq.: 17.01T; 17.24 or 17.721
Year: G (1) 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.)* *(Not offered 1966–67.)* *Staff*

17.23 ***Seminar: Issues in Contemporary American Politics***
Prereq.: 17.21 or 17.24
Year: U (1) 3–0–5
Analysis of the American political culture; the relation of economic and social institutions to political beliefs, attitudes, and behavior, with special attention given the empirical conditions of democratic theory. *Fein*

17.232T ***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. *W. R. Johnson*

17.24 ***Comparative Political Systems***
Prereq.: 17.01T
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. *Gorden*

(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.

17.242T *Politics in the Transitional Middle East* (A)
Prereq.: 17.24 or 17.721
Year: G (2) 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. (*Not offered 1966–67.*)
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*

17.261 *Soviet Communist System* (A)
Prereq.: 17.24 or 21.512
Year: G (1) 3–0–6
Study of the theory and practice of the communist system in the Soviet Union from the pre-revolutionary struggle for power to the present. Emphasis on three major aspects: the ideological inheritance of Marx and Lenin and its adaptation by Stalin and Khrushchev; the role and organization of the Communist Party in relation to other institutions; and the functioning of the centralized economic system in pursuit of goals set by the leadership. Primary attention to the period between 1917 and 1928 and to the decade after Stalin's death. *Blackmer*

17.262T *Research Methodology in Problems of International Communism* (A)
Prereq.: 17.261 or 17.721
Year: G (2) *Arr.*
Techniques of research into the significance of personnel and ideological changes within the Sino-Soviet camp as indicators of shifts in policy and power relationships within the ruling parties. Attention to developments presaging and accompanying changes of internal, intra-camp, and foreign policy and leadership. Tools and techniques of analytical method with special reference to the period between the death of Stalin and the Sino-Soviet dispute. Problems of interpretation of documentary evidence bearing on the various key developments, personalities, and ideological differences during the period in question. Readings, lectures, and discussions to supplement the primary documentary analysis.
Ra'anan

17.282 *Special Problems in Comparative Politics* (A)
Prereq.: ——
Year: G (2) *Arr.*
Exploration of issues in making cross-national and intra-national comparisons of political systems emphasizing the specific problems raised by the need to use and integrate diverse data bases (historical, economic, organizational, attitudinal). Heavy emphasis on Latin American systems, especially Brazil, Chile, and Venezuela. *Bonilla*

DEFENSE POLICY

17.31 *Postwar U.S. Defense Policies*
Prereq.: 17.52
Year: U (1) 3–0–5
Introduction to the evolution of U.S. defense plans and programs since 1945. Analysis of the changing nature of the major responses made by the U.S. Concentration on the forces and strategies developed for the deterrence of general and limited war. *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 *Current U.S. Defense Problems*
Prereq.: 17.31
Year: U (2) 3–0–5
Introduction to techniques of analysis currently employed in choosing among major defense systems. Application of techniques to selected problems of defense currently confronting the U.S. *Kaufmann*

17.321T *Introduction to Systems Analysis for Defense* (A)
Prereq.: 17.312
Year: G (1) 3–0–6
Introduction to the approaches, concepts, and techniques employed in the analysis of defense problems. Main focus on cost-effectiveness as a means of choosing between major defense alternatives. Application of techniques to defense problems for illustrative purposes. *Iklé*

17.322 *Research Problems in Defense* (A)
Prereq.: 17.321T
Year: G (2) 3–0–6
Application of knowledge and techniques to the analysis of a major defense problem. Definition of the problem and collaborative research and analysis of the solution to the problem by student research teams. *Kaufmann*

17.342T *Bargaining, Negotiation, and the Role of Force* (A)
Prereq.: 17.14 or 17.52
Year: G (2) 3–0–6
Analysis of tacit bargaining and negotiation: the role of threats, bluffs, commitments, and diplomatic customs. The use of military force for bargaining: deterrence, war aims, and war termination. Negotiation in an alliance. Interaction between negotiation and the formulation of foreign policy. (*Not offered 1966–67.*)
Iklé

17.352 *Research and Development and National Security*
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 included, and time spent on similar problems in other countries.
A. G. Hill

SCIENCE AND PUBLIC POLICY

17.412 *Scientific Development and Government Policy* (A)
Prereq.: 17.42
Year: G (2) 3–0–6
Organization of science for support of national policy. Place of science in government policy-making for peaceful and military purposes. Emphasis on problems scientists face in relating research to governmental activities, and problems which critical role of scientists and technology raises for governmental policy makers.
Skolnikoff, Killian

17.42 *Government, Politics and Technology*
Prereq.: 17.21
Year: U (2) 3–0–5
An examination of the impact of science on political ideologies and processes; the major public policy issues which technological advance poses for governments; the ways in which science modified patterns of political activity and institutions; the role of the scientist in political decision-making. Special emphasis on student projects which explore actual cases of political controversy involving technological change. *Skolnikoff*

17.43 *Bureaucracy*
Prereq.: 17.21
Year: U (1) 3–0–5
Nature of public organizations and organizational behavior, with special emphasis on the role of the scientist and professional executive in the administrative process. Examination of major theories of bureaucracies and public administration, by reference to specific cases involving policy-making and execution, and the relation of elected and non-elected officials. *Sapolsky*

17.431 *Science and American Foreign Policy*
Prereq.: ——
Year: G (1) 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. *(Not offered 1966–67.)* *Skolnikoff*

17.441 *Politics and Outer Space* (A)
Prereq.: 17.21 or 17.51
Year: G (1) 3–0–6
Inquiry into some of the urgent problems posed by the opening of the Space Age for international relations, for government and society, and for the individual. Consideration of peaceful uses; economic impact; behavioral aspects; problems for public administration; and relevant issues of international politics, organization, and law.
Bloomfield

17.442 *American Science and Its Development: Current Issues and Problems*
Prereq.: 17.412
Year: G (2) 3–0–6
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. *Bolt, Skolnikoff*

INTERNATIONAL RELATIONS AND FOREIGN POLICY

17.51 *International Relations*
Prereq.: 14.01 or 17.01T or 21.05T
Year: U (1, 2) 3–0–5
Basic factors and trends in contemporary world politics: the new nationalism, struggle between east and west; power politics within the Atlantic Community and the Soviet bloc; neutralism and nonalignment in Asia and Africa; impact of technology and economic growth on politics and defense. Comparative instruments and processes of foreign policy, the United Nations and regional arrangements. *Padelford*

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. *Padelford*

17.513 *Function of Law in the World Community* (A)
Prereq.: 17.511 or 17.521T or 17.53
Year: G (1) 3–0–6
Role of international law in the development of political community at the regional and global level. The nature of community; problems in attainment and functioning. Empirical analysis of regional and mutual security arrangements such as NATO, the European organizations, OAS, SEATO, etc., as instruments for effective international cooperation and development of political community. Principal cases from World Court and other tribunals interpreting the function of law in international relations. *(Not offered 1966–67.)* *Padelford*

17.514 *The UN 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
Analysis of some of the principal problems facing the United States in its present-day foreign relations. National security, relations with the Soviet Union, the North Atlantic Alliance, the Middle East, China, Africa, the U.N. *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. Substantive case problems drawn from recent American foreign policy: economic development and social revolution in Latin America, counter-insurgency in southeast Asia, political-military problems of the Atlantic Alliance, the Berlin and Cuban crises in relationships with the Soviet Union, subsequent efforts towards tension reduction, the use of multilateral instruments, the United Nations Congo operation. *G. E. Hansen*

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17.521T *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, with special attention periodically given to questions arising out of scientific and technological change, such as arms control and outer space diplomacy. (*Not offered 1966–67.*) *Bloomfield*

17.522 *U.S. Foreign Policy — Plans and Strategies* (A)
Prereq.: 17.521T
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 1966–67.*) *Bloomfield*

17.523 *Research: International Relations and Foreign Policy*
Prereq.: 17.521T or 17.522
Year: G (A) 3–0–6
Problem approach to selected areas and issues, based largely on current research in the Center for International Studies, as well as 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, with emphasis on Soviet-Western relations and the United Nations. (*Not offered 1966–67.*) *Staff*

17.54 *Arms Control, Disarmament, and Foreign Policy*
Prereq.: 17.51
Year: U (2) 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.: 17.01T 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 *Traditional Societies* (A)
Prereq.: 17.721
Year: G (1) 3–0–6
Traditional societies as social-cultural-personality systems. Discussion of theoretical and empirical anthropological literature, the concepts of system analysis, and the conditions for persistence of the traditional social system. *Hagen*

17.612 *The Theory of Social Change* (A)
Prereq.: 17.611
Year: G (2) 3–0–6
Application of system analysis to societal change. Review and critique of major sociological theories and analytical concepts. Development of a model incorporating personality; discussion of empirical cases. *Hagen*

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 1966–67.*) *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. *Rustow*

17.631 *Theories of Political Development* (A)
Prereq.: 17.52 or 17.721
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*

17.64T *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 1966–67.*) *Weiner*

17.652T *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. *Staff*

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 Political Behavior***
Prereq.: ——
Year: G (1) *Arr.*
Requirements for testable concepts and innovations in research technique relating to attitudes, institutions, decision-making. Case studies on key problems of national, international, and comparative processes. *Lerner*

17.722 ***Theory of Political Processes***
Prereq.: ——
Year: G (2) 3–0–6
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*

17.731 ***Introduction to Mathematical Models in the Social Sciences***
Prereq.: ——
Year: G (1) 3–0–6
Consideration in detail of three or four models in various areas of social science. Some drilling in the mathematics involved. Specially intended for people with little mathematical background. *(Not offered 1966–67.)* *Lehrer*

17.732 ***Statistics for the Social Sciences***
Prereq.: ——
Year: G (2) 3–0–6
Elementary subject in statistics, with particular emphasis on topics useful in social science. Introductions to descriptive statistics, sampling, estimation, testing of hypotheses, correlation and contingency, and nonparametric methods. No mathematical prerequisites. *Lehrer*

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*

17.75 ***Prediction of Social and Political Change***
Prereq.: 14.02 or 17.01T or 21.403 or 21.525
Year: U (1) 3–0–5
Theories of social change. Trends, fluctuations, and unique events. Technological changes and inventions as causes and effects of social change. Prediction of population trends and their consequences. Psychological biases in prediction. Predictions explicit and implicit in policy making. Interaction with an adversary and problems of intelligence prediction. *Iklé*

18.
Mathematics

18.00 ***Elementary Number Theory***
Prereq.: ——
Year: 1 (1) 2–0–4
Elementary theory of whole numbers, including such topics as divisibility, prime and composite numbers, greatest common divisors, solutions of equations in integers, the congruence notation and its application, sums of squares. Emphasis on mathematical rigor and methods of proof. *Thomas*

18.01 ***Calculus***
Prereq.: ——
Year: 1 (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. *Mattuck*

18.02 ***Calculus***
Prereq.: 18.01
Year: 1 (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. Connections with topology and potential theory. *Mattuck*

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. *(If credit has been received in 18.03 or 18.04, then credit is not permitted in 18.034.)*
L. N. Howard

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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. Thomas, *Calculus and Analytic Geometry*, 3rd Edition; Kaplan, *Ordinary 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.*) *Greenspan*

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.*) *Minsky*

18.163 ***Theory of Computers* (A)**
Prereq.: 18.26
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. *Blum*

18.17 ***Combinatorial Analysis* (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. (*Not offered 1966–67.*) ——

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. *Thomas*

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 1966–67.*) *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*

18.21T *Analysis (A, except XVIII)*
Prereq.: 18.034
Year: U (1, 2); G (1, 2) 3–0–9

18.22T *Analysis (A, except XVIII)*
Prereq.: 18.20 or *18.26;* 18.21T
Year: G (2) 3–0–9

Real numbers and euclidean n-space; open, closed and compact subsets of n-space. Continuous and differentiable functions. Lebesgue integration in euclidean space. The Weierstrass approximation theorem; Fourier series. Jacobians and the inverse function theorem. Change of variables in multiple integrals. Stokes' theorem.
Ambrose (18.21T); K. M. Hoffman (18.22T)

18.23 *Senior Seminar in Mathematics*
Prereq.: 18.21T
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.: 18.22T
Year: U (2) 3–0–9

Plane and space curves. First and second differential form of a surface. Theorems of Meusnier and Euler. Lines of curvature, asymptotic lines, conjugate lines, geodesics. Theorems of Gauss and Codazzi. Developable surfaces, surfaces of rotation, Liouville surfaces. Differential parameters. Problems of mapping. *Guillemin*

18.241 *Introduction to Topology*
Prereq.: 18.20 or *18.25;* 18.21T
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. *Curtis*

18.242 *Riemannian Geometry*
Prereq.: 18.22T, 18.241
Year: U (2) 3–0–9

First and second fundamental forms, geodesics, curvature, spaces of constant curvature, rigidity, Gauss-Bonnet theorem (with emphasis on one- and two-dimensional cases). Riemann surfaces. Algebraic curves.
I. M. Singer

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.
Ambrose (18.25); I. M. Singer (18.26)

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. *Levinson*

18.29 *Intermediate Differential Equations*
Prereq.: 18.21T
Year: U (1) 3–0–9

First-order nonlinear differential equations. Second-order linear differential equations. Existence theorems. Successive approximations and Cauchy polygons. Plane autonomous systems. Theory and methods of numerical integration of differential equations. Nonlinear oscillations. *(Not offered 1966–67.)* *Glimm*

18.292 *Intermediate Differential Equations*
Prereq.: 18.21T or 18.29
Year: U (2) 3–0–9

Regular singular points in the complex domains. Sturm-Liouville systems; special functions; Bessel, Legendre, and related functions. Asymptotic estimates of eigenvalues and eigenfunctions, eigenfunction expansions. Asymptotic integration of linear differential equations. *(Not offered 1966–67.)* *Glimm*

18.31 *Theory of Functions* (A)
Prereq.: 18.21T
Year: G (1) 3–0–9

Complex numbers, Riemann sphere, plane topology, fractional linear transformations. Complex integration, Cauchy's theorem, Cauchy's integral formula, power series, winding numbers, rational functions. Singularities, simple Riemann surfaces, local mapping theorem. Evaluation of definite integrals. Integral and meromorphic functions, special functions. Riemann mapping theorem. *Kotake*

18.32 *Theory of Functions* (A)
Prereq.: 18.31
Year: G (2) 3–0–9

Topics selected by the instructor, e.g., harmonic functions, Dirichlet problem, Green functions, conformal mapping, Riemann surfaces, entire and meromorphic functions, Fourier and Laplace transforms, Wiener-Hopf equations, special functions, prime number theorem, elliptic and automorphic functions. *Kotake*

18.33 *Functions of Complex Variables* (A)
Prereq.: 18.31, 18.35
Year: G (1) 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 1966–67.)*
K. M. Hoffman

18.35 *Functions of Real Variables* (A)
Prereq.: 18.22T
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 con-

(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.

tinuity 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 on L^p spaces. *Knapp*

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 1966–67.*) *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. *Segal*

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. *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, and algebras of such. Illustrative applications, as time permits, to partial differential equations, harmonic analysis, and to quantum mechanics. (*Not offered 1966–67.*) *Segal*

18.37 *Functional Analysis* (A)
Prereq.: 18.27 or 18.31; 18.35
Year: G (1) 3–0–9

General theory of linear topological (especially Banach) spaces and algebras. Spectral theory, especially in Hilbert space; applications to partial differential equations. Structure (multiplicity) theory for abelian operator rings. Harmonic analysis on groups; transformation groups and induced representations. *Goodman*

18.38 *Functional Analysis* (A)
Prereq.: 18.37
Year: G (2) 3–0–9

Introduction to the general theory of partial differential equations; weak solutions, the Soboleff inequalities, nonlinear equations. Generalized functions (including distributions); Fourier analysis in the complex domain. Applications to analysis on groups and manifolds; ergodic theory. Representations of continuous groups, especially Lie groups. C*-algebras; rings of operators. *Goodman*

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 1966–67.*) *Levinson*

18.43 *Partial Differential Equations* (A)
Prereq.: 18.22T
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. *Glimm*

18.49 *Harmonic Analysis and Potential Theory*
Prereq.: 18.21T
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.: 18.22T or 18.49
Year: G (1) 3–0–9

18.54 *Theory of Probability* (A)
Prereq.: 18.53
Year: G (2) 3–0–9

Probability measures, Borel fields, conditional probabilities, sums of independent random variables, limit theorems, zero-one laws, martingales, and topics selected by the instructor, for example, stationary processes, information theory, Markov processes, and their connections with other parts of mathematics, especially with differential and integral equations.
Ray (18.53); Dudley (18.54)

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. (*Not offered 1966–67.*) *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 analogues; equivalence of convergence and stability for linear systems; von Neumann's method of stability analysis in L_2 by Fourier transform; Lax theory of nonlinear conservation laws. (*Not offered 1966–67.*) *Strang*

18.60 *Introduction to Fluid Mechanics*
Prereq.: 18.05 or *18.651*
Year: U (1) 3–0–9

Elements of the theory of perfect fluids; fundamental concepts and basic relations. Theory of potential mo-

tions. Motion of rectilinear vortices. Gravity waves and related free surface problems. Application of the theory of complex variables. Elements of the theory of viscous fluids. Some exact solutions. Low-speed flow. Boundary layer theory. *Pedlosky*

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; nonlinear interactions; wave motions; applications. *Greenspan*

18.612 *Introduction to Geophysical Fluid Dynamics* (A)
Prereq.: 18.60
Year: G (2) 3–0–9
Introduction to the theories of geophysical fluid dynamics. Waves in rotating systems. Concept of potential vorticity. Large scale atmospheric motions. Long atmospheric waves and instability waves in the atmosphere. The theory of quasi-geostrophic motions, and related topics. *Pedlosky*

18.62 *Hydrodynamic Stability and Turbulence* (A)
Prereq.: 18.60
Year: G (2) 3–0–9
Theory of turbulent motion. Review of the basic equations of hydrodynamics. Statistical theory of turbulence, kinematics, correlation, and spectral representations. Dynamics of homogeneous turbulence, similarity concepts, Kolmogoroff's theory, Heisenberg's theories, the quasi-Gaussian approximation. Turbulent diffusion and transfer, molecular theory of diffusion, the problems of random walk and Brownian motion, diffusion and dispersion by continuous movements, empirical methods. Introduction to the theory of hydrodynamic stability. (*Not offered 1966–67.*)

18.63 *Mathematical Theory of Magneto-Fluid Mechanics* (A)
Prereq.: 18.60
Year: G (1) 3–0–9
General introduction. Hydromagnetics: basic equations, kinematic problems, magnetohydrostatics. Pipe flow. Vorticity propagation, linear Alfvén waves, Rayleigh's problem. Two-dimensional flows. Classification of problems. Magneto-gasdynamics: two-fluid model and basic equations. One-dimensional flows, two-dimensional (steady) flows. Small amplitude plane waves, simple waves, shocks, pipe flows. Formulation of equations from the Boltzmann equation, general review of plasma physics. *Wu*

18.634 *Topics in Applied Mathematics* (A)
Prereq.: 18.28
Year: G (2) 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. *Cheng*

18.636 *Stellar Dynamics and Galactic Structure* (A)
Prereq.: 8.711; 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 1966–67.*) *Lin*

18.64 *Kinetic Theory of Gases* (A)
Prereq.: 18.27, 18.653
Year: G (2) 3–0–9
The Boltzmann equation; kinetic models — steady separable solutions; completeness properties of the eigensolutions; connection with the theory of singular integral equations. Boundary value problems; time-dependent problems; connection with the theory of pseudo-analytic functions. Approximate methods of solution: numerical approaches and variational techniques. *Cercignani*

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 1966–67.*) *Crout*

18.651 *Introduction to Applied Mathematics*
Prereq.: 18.20 or 18.25 and 18.26; *18.21T*
Year: U (1) 3–0–9
Interdependence of mathematics and scientific problems, examples; linear and nonlinear problems, deterministic and random processes, Brownian motion and random walk. Scalars, vectors, and tensors; kinematics of a deformable body; functions of several variables; integral theorems. Potential theory, Gauss theorem, equations of Laplace and Poisson, potential of various kinds of distributions. Green's function, minimum principle. Partial differential equations of mathematical physics, solution under prescribed conditions, diffraction of waves, other examples. Jeffreys and Jeffreys, *Methods of Mathematical Physics*, 3d edition. *Lin*

18.652 *Introduction to Applied Mathematics*
Prereq.: 18.651
Year: U (2) 3–0–9
Partial differential equations of mathematical physics, further examples. Fourier series, completeness, Weierstrass theorem, Fourier integral. The general Sturm-Liouville problem, examples; integral equation. Calculus of variations, Lagrange's equations. The maximum-minimum principle of the characteristic value problem, existence and completeness of characteristic functions, Hilbert space. Courant-Hilbert, Vol. I, *Methods of Mathematical Physics*. *L. N. Howard*

18.653 *Methods of Applied Mathematics I* (A)
Prereq.: 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,

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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.
Hunter (18.653); Toomre (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 nonlinear mechanics, free and forced oscillations, sub- and superharmonic responses, stability, equations with periodic coefficients, limit cycles, relaxation oscillations. Singular perturbation theory, matched asymptotic expansions. P.L.K. method, multiple scaling procedures, boundary layer techniques, ad hoc methods, applications to nonlinear problems.
Benney

18.656 *Wave Motion* (A)
Prereq.: 18.655
Year: G (2) 3–0–9
Review of linear waves, phase and group velocity, nonlinear interactions of discrete waves and wave trains, resonances, asymptotic methods for dispersive and nondispersive waves, theory of characteristics, breaking, permanent waves, nonlinear stability theory, spectral analysis of nonlinear random waves, wave propagation in random media, statistical properties and closure, special topics. *Benney*

18.66 *Introduction to Elasticity*
Prereq.: 18.05 or 18.651
Year: U (2) 3–0–9
Elements of stress and strain in two and three dimensions. Hooke's Law, including thermal effects. St. Venant torsion theory. Problems of the elastic half space. *Lardner*

18.67 *Theoretical and Applied Elasticity* (A)
Prereq.: 2.08 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 1966–67.*) *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 1966–67.*) *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.
L. N. Howard

18.721 *Algebraic Geometry* (A)
Prereq.: 18.731
Year: G (1) 3–0–9

18.722 *Algebraic Geometry* (A)
Prereq.: 18.721
Year: G (1) 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.
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. *Larson (18.731); Brieskorn (18.732)*

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.
Quillen

18.74 *Topics in Algebra* (A)
Prereq.: 18.731
Year: G (2) 3–0–9
Content varies yearly so that graduate students may take the subject in successive years. Topics in the past few years have included algebraic groups, noncommutative rings and algebras, Lie algebras, local rings, nonassociative algebras. (*Not offered 1966–67.*) *Schafer*

18.75 *Nonassociative Algebras* (A)
Prereq.: 18.731
Year: G (1) 3–0–9
Nonassociative 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.
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. (*Not offered 1966–67.*) *Iwasawa*

18.77 *Theory of Numbers*
Prereq.: 18.20 or *18.25; 18.21T*
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 1966–67.*) *Ankeny*

18.78 *Topics in the Theory of Numbers* (A)
Prereq.: 18.20 or 18.25; 18.21T
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. (*Not offered 1966–67.*) *Ankeny*

18.80 *Topics in Foundations of Mathematics* (A)
Prereq.: 18.20 or 18.25 or 18.886 or *18.89*
Year: G (1) 3–0–9

Theory of recursive functions with applications to logic and set theory. *H. Rogers*

18.81 *Topology* (A)
Prereq.: 18.241, 18.25
Year: G (1) 3–0–9

18.82 *Topology* (A)
Prereq.: 18.81
Year: G (2) 3–0–9

Fundamental group, covering spaces, simplicial homology, simplicial approximation, manifolds. Homology and cohomology of topological spaces, universal coefficient theorem, plus additional topics to be chosen by the instructor. *Munkres*

18.83 *Advanced Topology* (A)
Prereq.: 18.82
Year: G (1, 2) 3–0–9

Content varying from term to term so that graduate students taking the subject in successive terms may have an introduction to several important phases of topology such as homotopy theory, cohomology theory, fibre spaces, K-theory, combinatorial topology, and/or differential topology. *Anderson*

18.84 *Locally Compact Groups* (A)
Prereq.: 18.35 or 18.37
Year: G (2) 3–0–9

Haar measure, group algebras, unitary representations, harmonic analysis on compact and abelian groups, Plancherel theorem, duality theorem. (*Not offered 1966–67.*) *Iwasawa*

18.85 *Lie Groups and Lie Algebras* (A)
Prereq.: 18.22T, 18.26
Year: G (1) 3–0–9

Lie groups and Lie algebras over complete fields; structure and representation theory. (*Not offered 1966–67.*) *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 semi-simple 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.: 18.22T, *18.81*
Year: G (1) 3–0–9

18.88 *Geometry of Manifolds* (A)
Prereq.: 18.87
Year: G (2) 3–0–9

Real and complex manifolds, Riemannian and Hermitian manifolds, differential forms, connexions and their curvature forms. Study of global properties of complete Riemannian manifolds under various curvature assumptions. The Gauss-Bonnet theorem, the Weil homomorphism, and characteristic cohomology classes. The Hodge theorem on harmonic forms, and its application to Kähler manifolds. Morse theory for Riemannian manifolds. (*Not offered 1966–67.*) *Quillen*

18.881 *Elliptic Operators* (A)
Prereq.: 18.22T, 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 1966–67.*) *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. *Manaster*

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. Brief study of recursive functions, Gödel incompleteness theorem, related topics. *Tharp*

18.892 *Theory of Models* (A)
Prereq.: 18.886 or *18.89* or 21.641
Year: G (2) 3–0–9

Results and methods from the theory of models. Applications to logic and to algebra. Topics on the borderline between logic and algebra. Non-standard analysis. *Platek*

18.893 *Set Theory* (A)
Prereq.: 18.80 or 18.886 or *18.89* or 21.641
Year: G (1) 3–0–9

Formalization of mathematics in axiomatic set theory. Cardinal and ordinal numbers. Consistency and independence results. *Sacks*

18.894 *Proof Theory* (A)
Prereq.: *18.886* or *18.89* or 21.641
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 1966–67.*) *H. Rogers*

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18.90 ***Mathematical Reading*** **(A)**
Prereq.: ——
Year: G (1 or 2) *Arr.*
Reading of advanced mathematical treatises under the supervision of some member of the department. Choice of treatise and allotment of time according to individual cases. For graduate students finding it desirable to do advanced work not provided for in the regular subjects. Open to undergraduates only under exceptional circumstances. *W. T. Martin*

19.
Meteorology

19.003 ***Elementary Meteorology I***
Prereq.: ——
Year: 1 (2) 2–0–4
Introduction to meteorological science through examples from all scales of atmospheric motions; radiation balance and the global circulation; air masses and fronts; cyclones and weather forecasting; hurricanes; sea breeze; thunderstorms; micrometeorology; cloud physics; climatology. Laboratory exercises with weather maps. *J. M. Austin*

19.02 ***Descriptive Meteorology***
Prereq.: ——
Year: U (2) 3–0–6
The general circulation of the earth's atmosphere; the secondary circulations, both tropical and extratropical, including the role of air masses and fronts; the tertiary (local) circulations, including drainage winds, local convection, whirlwinds, showers, thunderstorms, land and sea breeze, large scale turbulence eddies, föhn winds, etc. Willett and Sanders, *Descriptive Meteorology*, 2nd ed.
Willett

19.14 ***Long-Range Weather Forecasting*** **(A)**
Prereq.: 19.45
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 2.201T 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, *19.51*
Year: G (1) 2–0–4
Designed to examine recent developments in statistical weather forecasting and to provide a background for performing and evaluating statistical studies with meteorological data. Statistical forecasting by linear regression, nonlinear statistical forecasting, significance of empirical relations, and hypothesis testing. *Lorenz*

19.35 ***Statistical Problems in Meteorology*** **(A)**
Prereq.: 19.34
Year: G (2) 2–0–4
Seminar in statistical problems in meteorology, including such topics as power spectrum analysis, properties of stationary time series, and evaluation of linear and nonlinear methods of statistical weather forecasting. *(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*, Vol. I, 2nd ed. *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 II*** **(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 probabalistic science. Contemporary operational forecasting as a man-machine system.
Sanders

19.601 ***Introduction to Theoretical Meteorology***
Prereq.: 8.02, 18.02
Year: U (1) 3–0–6
Simplified treatment of atmospheric thermodynamics and dynamics with application to hydrostatics, convection, and the propagation of sound and gravity waves in a stratified atmosphere. *Phillips*

19.62 ***Dynamic Meteorology I***
Prereq.: 19.601
Year: U (2) 3–0–6
Hydrodynamic equations of motion. Streamlines and trajectories, circulation and vorticity, theory of atmospheric turbulence, its effects on the vertical distribution of wind and other meteorological elements. Energy transformations in the atmosphere. *Lorenz*

19.64 ***Dynamic Meteorology II*** **(A)**
Prereq.: 19.62
Year: G (1) 3–0–9
Large-scale atmospheric motions. Examination of recent theories of the general circulation. Research in the application of fluid mechanics to meteorology and oceanography. *Starr*

19.67 ***Planetary Fluid Dynamics*** **(A)**
Prereq.: 18.60
Year: G (2) 3–0–9
Discussion of fluid dynamical problems on the planetary scale with examples drawn from the atmosphere, the oceans and the interior of the earth. Convectively driven circulations in rotating systems and high-speed computational methods for the solution of the governing equations. *Charney*

19.70 ***Elementary Physics of the Atmosphere***
Prereq.: 8.03, *18.02*
Year: U (1) 3–0–6
Treatment of atmospheric radiation, the ozone layer and the upper atmosphere, atmospheric electricity, atmospheric optics, propagation of sound in the atmosphere, and icing of aircraft. *Keily*

19.71 ***Atmospheric Precipitation Processes*** **(A)**
Prereq.: 8.03, 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 aurora pertinent to incident energy stream and interaction. *Newell*

19.83 ***Physical Oceanography***
Prereq.: 8.02, 18.02
Year: U (1) 3–0–6
Structure and physical properties of the oceans. Methods of measurement and an outline of the observational information. Dynamics of oceanic current systems. Wind currents, waves and tides. von Arx, *Introduction to Physical Oceanography.* *Houghton*

19.84 ***Dynamic Oceanography*** **(A)**
Prereq.: 18.05
Year: G (2) 3–0–6
Elementary theory of wave motion in the ocean, including tidal phenomena. Restatement of various principles of fluid mechanics with special emphasis on the effect of the earth's rotation. Theories of large-scale ocean currents. *Starr, Phillips*

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*

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*

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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, Labuza, V. R. Young, Bransome

20.11 ***Food Science and Technology***
Prereq.: 5.41, 5.61
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.
Nickerson

20.111 ***Food Science and Technology Laboratory***
Prereq.: 5.14, 5.61
Year: U (2) 1–4–2
Laboratory exercises designed to demonstrate chemical and physico-chemical principles of importance to food processes and storage. Topics covered include: reaction kinetics, destruction of enzymes, loss of vitamins, thermal processing, browning, lipid oxidation, changes in natural pigments, sorption of water, and measurement of quality.
Tannenbaum

20.15 ***Food Engineering*** **(A)**
Prereq.: 2.641
Year: G (1) 3–3–6
Engineering concepts related to the processing of food materials. Stress on the analytical aspects of the design and operation of systems entailed in food processes. Consideration of such topics as food rheology and its application to flow and heat transfer, characteristics of suspensions, drying, freeze-drying, freezing, certain mathematical aspects of thermal processing, dialysis, extraction, and filtration. *Berk*

20.20 ***Flavor Chemistry and Flavor Methodology*** **(A)**
Prereq.: 5.41, 20.11, 20.32
Year: G (1) 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*

20.30 ***Basic Nutrition***
Prereq.: 7.05
Year: U (2) 4–0–6
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, V. R. Young, Drysdale

20.301 ***Experimental Nutrition*** **(A)**
Prereq.: 20.30
Year: G (2) 1–4–2
Discussion and practice of experimental procedures used in nutrition and biochemical research on animals.
S. A. Miller

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.: 20.30
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. *Scrimshaw*

20.37 ***Endocrinology*** **(A)**
Prereq.: 20.30
Year: G (2) 3–0–6
Review of structure and function of the endocrine glands. The basic nature of abnormalities of the endocrine system which cause disease. Nutritional and genetic influences on endocrine function. *DeGroot*

20.38 ***Factors Influencing the Nutritional Values of Foods*** **(A)**
Prereq.: 20.11, 20.30
Year: G (1) 3–0–3
Discussion of the principles and factors which determine the nutrient content of foods from plant and animal sources during agricultural production (genetic and agronomic factors); which influence the stability, retention and availability of nutrients in foods during growth,

harvesting, processing, storage and preparation; and which minimize destruction or inactivation of nutrients. Discussion of substances naturally present in foods and diets which affect digestion, absorption and utilization of nutrients. Critical evaluation of enrichment or fortification of foods with vitamins, minerals and amino acids. (*Alternate years.*) *R. S. Harris*

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-semester sequence of lectures and discussions of biochemical aspects of nutrition for advanced graduate students, one section being given each semester over a two-year period. Emphasis on nutritional implications of advances in energy, carbohydrate, lipid, protein, mineral, and nucleic acid metabolism. The sequence of topics beginning first semester, 1965–66: nutrition, development and growth; mineral metabolism. (*20.391 and 20.392 not offered 1966–67.*) *Wolf* (*20.391*), *Munro* (*20.392*), *S. A. Miller* (*20.393*), *R. S. Harris* (*20.394*)

20.40 ***Selected Topics in Nutrition and Food Science*** **(A)**
Prereq.: 20.11, 20.30
Year: G (1 or 2) 3–0–4

Detailed discussion of selected topics of current interest. Class work in various fields of nutrition, food science and technology not covered by regular subjects of instruction. *Staff*

20.41 ***Microbiology Laboratory***
Prereq.: 7.05
Year: U (1) 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 10.31; 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 programs 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, 20.30
Year: G (1) 3–0–5

Physico-chemical 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, nonenzymatic browning, lipid oxidation, protein denaturation, and other reactions affecting the acceptability and nutritive value of foods. *Issenberg*

20.52 ***Advanced Food Technology*** **(A)**
Prereq.: 2.642, 20.51
Year: G (2) 2–6–4

Detailed consideration of selected food processing methods from the point of view of scientific and engineering principles. Physical and chemical changes occurring during processing and storage and their control. Process design problems integrating various unit operations. *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 1966–67.*) *Goldblith*

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20.59 ***Food Toxicology*** **(A)**
Prereq.: 20.11, 20.30
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, Shibko

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*

20.63T ***Systemic Physiology*** **(A)**
Prereq.: 20.30
Year: G (1) 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. *Wogan*

20.64 ***Comparative Histology*** **(A)**
Prereq.: 20.63T
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. Not offered 1966–67.)* *Payne*

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. Not offered 1966–67.)*
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

20.66 ***Tissue Culture and Cell Toxicology*** **(A)**
Prereq.: 7.21, 20.32
Year: G (1) 2–4–3
Methods of tissue and cell culture techniques and their application in food toxicology and virology; effects of nutrients, additives, and contaminants on mammalian cell cultures. *Gabliks*

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 ***Intestinal Absorption and Body Composition in Human Biology*** **(A)**
Prereq.: 20.36
Year: G (2) 2–0–4
Physiology and biochemistry of intestinal absorption as it relates to human nutrition and body metabolism. Absorption of basic nutrients, minerals, electrolytes, and vitamins; sites and mechanisms of absorption; pathophysiology of deficiency states resulting from intestinal malabsorption in tropical and non-tropical sprue; endocrine effects of stress; human body composition from the viewpoints of diets, age, nutritional state, and energy expenditure, with emphasis upon methodology and physiology; effects of starvation, infection, and injury upon body composition. *S. Gray*

20.81 ***Public Health Nutrition*** **(A)**
Prereq.: 20.30
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.: 20.30
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.: 20.30
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

20.85T ***Research Management in the Food and Drug Industries*** **(A)**
Prereq.: ——
Year: G (1) 2–0–2
Lectures devoted to laboratory 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. Coordination of research personnel and facilities with the production and sales departments in connection with the development of specific food products. *Goldblith*

20.871 *Research Approaches to Oral Biology* (A)
Prereq.: 7.21, 20.30, 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*

20.872T *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.: 20.30
Year: G (1) 2–0–4

20.89 *Seminar in Oral Science* (A)
Prereq.: 20.30
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. *(Not offered 1966–67.)* *Staff*

21.
Humanities

21.01 *The Greek Tradition*
Prereq.: ——
Year: 1 (1) 3–0–6
Study of writings from the Western Tradition that challenge moral and philosophical assumptions and require responsive and critical understanding. Classroom discussions and written essays based on these works to develop skills of interpretation. Homer, *The Odyssey;* Aeschylus, *The Oresteia;* Thucydides, *The Peloponnesian War;* Plato, *Republic* and other Dialogues; other Greek writings at the discretion of the Instructor. *Staff*

21.02 *The European Tradition*
Prereq.: 21.01
Year: 1 (2) 3–0–6
Continuation of 21.01. Representative works selected by the Instructor from s[illegible] later periods of the Western Tradition as Christian [illegible]tiquity, the Middle Ages, the Renaissance, and the [illegible]nlightenment. *Staff*

21.03T *Literature: Language, Forms and the Individual Author*
Prereq.: 21.02
Year: U (1, 2) 3–0–6
Experience and evaluation of poems, plays, and fiction, particularly from the modern period, emphasizing through analysis the varieties of literary theme, form, and response. Consideration of language as an expressive medium; investigation of lyric, dramatic, and narrative modes. Study in some depth of a single important author such as Conrad, Faulkner, or Yeats. *(Credit given only for 21.03T, or 21.031, or 21.11.)* *Staff*

21.031 *Literature: Self, Nature and Society*
Prereq.: 21.02
Year: U (1, 2) 3–0–6
Introduction to literary analysis through a balanced consideration of text and context. Literature as it expresses man's image of physical nature and social reality, and the ways in which social reality shapes literature. Consideration of literature from ancient times to the present. Examination of the range of contemporary literature from the literature of the "folk" through the pop culture of the mass media to the intellectual quarterlies and little reviews. *(Credit given only for 21.03T, or 21.031, or 21.11.)* *Staff*

21.04T *Philosophy: Classic and Contemporary*
Prereq.: 21.02
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*

21.05T *The Twentieth Century: Revolution, War and "Totalism"*
Prereq.: 21.02
Year: U (1) 3–0–6
Introduction to history through analysis of three complex phenomena significant in the shaping of today's world; revolution, war and "totalism," or the manner in which some modern states have tended to make all activity political and to demand the complete commitment of the individual. Attempt to illuminate the nature of these phenomena and their human meaning by analysis and comparison of contemporary revolutions (*e.g.*, the Russian and Chinese), of major modern wars, and of one or more states (*e.g.*, Nazi Germany). Readings in primary sources, critical scholarly articles, and works of interpretation. *Staff*

21.06T *The Twentieth Century: Society and Consciousness*
Prereq.: 21.02
Year: U (2) 3–0–6
Studies in historical perspective of characteristic forms of twentieth-century thought and consciousness, empha-

(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.

sizing the literature of psychoanalysis 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. *Lamson*

21.071 *History Seminar*
Prereq.: ——
Year: U (2) 2–0–8*
Seminar on selected topic in history. (*Not offered 1966–67.*) *Staff*

21.072 *Literature Seminar*
Prereq.: ——
Year: U (2) 2–0–8*
Seminar on selected topic in literature. (*Not offered 1966–67.*) *Staff*

21.073 *Philosophy Seminar*
Prereq.: ——
Year: U (2) 2–0–8*
Seminar on selected topic in philosophy. (*Not offered 1966–67.*) *Staff*

21.08 *Thesis Preparation and Reports*
Prereq.: ——
Year: U (1, 2) 1–2–3**
Work in conjunction with the S.B. thesis extending over two semesters. Study of problems and methods of research in first term and oral reports on thesis in second term. *Lamson*

ELECTIVES FOR FRESHMEN

21.091 *Philosophy and Scientific Methodology*
Prereq.: ——
Year: 1 (1) 2–0–4
Examination of methods of science and of philosophical problems which are raised by attempts to understand and justify these methods. Mathematical inference, observation, hypothesis, and confirmation. Problems of *a priori* knowledge, induction, status of theoretical entities, and relation between mind and matter. Implications of science for religion and ethics. *Graves*

21.092 *Introduction to Moral and Political Philosophy*
Prereq.: ——
Year: 1 (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 1966–67.*) ——

21.094 *Introduction to Contemporary Philosophy*
Prereq.: ——
Year: 1 (1) 2–0–4
Exploratory study of various trends in present-day philosophy: pragmatism, analytic philosophy, existentialism, psychoanalysis, Marxism, Zen Buddhism. (*Not offered 1966–67.*) *I. Singer*

* 21.07, 21.071, 21.072, 21.073 are open only to Course XXI Juniors or Seniors.
** Credit units are for two terms of work, students registering for 1–0–3 units in the first term, 0–2–0 units in the second term.

21.095 *Composition Workshop*
Prereq.: ——
Year: U (1, 2) *Arr.*
Workshop for any undergraduate having difficulty with written expression in either a humanities or a professional subject. Instruction by individual conferences, insofar as time permits. Criticism of samples of student's writing for organization and style, as well as for errors in composition. Application, through practice and revision, of principles of good writing to specific assignments in the student's field. Formal enrollment unnecessary, since no credit is given. *Staff*

21.096 *English Composition*
Prereq.: ——
Year: 1 (1, 2) 2–0–4
Logic and rhetoric of expository essays. Analytical reading in anthology. Several writing assignments to attain clear organization and precise expression of facts and opinions. *Staff*

SUBJECTS IN WRITING

21.10 *Scientific and Engineering Writing*
Prereq.: ——
Year: U (1, 2) 2–0–4
Instruction in the types of communications that scientists and engineers are called upon to write. Detailed analysis of the problems of conveying technical information to non-technical as well as to technical audiences. Preparation of a formal report as a term project; selection of topic from the student's professional subject or experience. *Rathbone*

21.101 *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. (*Limited to 12 students having instructor's approval.*) *Spacks*

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*

LITERATURE

21.11 *Literary Analysis*
Prereq.: 21.02
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 21.03T or 21.031.*) *Staff*

21.12 *Literary Criticism*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Investigation of some of the best modern criticism: its methods, its antecedents, and the theoretical problems it raises. The critics: Richards, Eliot and Leavis. The antecedents: Coleridge and Arnold. Problems including the relation of theory to practice in criticism, similarities between critical and moral argument, and the critic's concern with tradition and history. *Youngren*

21.13 *The Epic*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Reading of such epics as the *Iliad*, the *Aeneid*, the *Mahabharata*, the *Volsungasaga*, *Beowulf*, the *Song of Roland*, *Morte d'Arthur*, and *John Brown's Body;* discussion of their mythological and ritual backgrounds, shaping and decoration, meanings as documents and examples of art. *W. C. Greene*

21.14 *The Bible*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
Close reading of seminal texts from Old and New Testaments as literary documents illustrating specific kinds and areas of religious experience. Attention to the changing literary form of the encounter between the Bible and Greek philosophy. *Pettit*

21.141 *The Old Testament*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Study of the Hebrew people to the Exile through examination of their literature, emphasizing the traditions of the formative period, and the historical process which forged these traditions into the distinctive conception of the community of God and Man which influences later thinking. *Wakeman*

21.15 *Shakespeare*
Prereq:: 21.03T or 21.031 or 21.11
Year: U (1, 2) 3–0–5
Reading and discussion of ten major plays of Shakespeare. *MacIsaac, Lamson*

21.16 *Chaucer*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
Reading and discussion of *The Canterbury Tales* and *Troilus and Criseyde.* *Lamson*

21.19 *Literature of the English Renaissance*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
The rise and development of English poetry, drama, and prose in the English Renaissance. Reading and discussion of Shakespeare and his contemporaries, Donne, the Metaphysical Poets, Milton, and other selected writers. Consideration of literary traditions and of philosophical and scientific ideas in the Renaissance. *Lamson*

21.20 *Comparative Studies in British and American Fiction*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
The relation between the techniques of fiction and national experience. Readings to include such authors as Dickens, Twain, James, Lawrence, and Faulkner. *Adolph*

21.22 *Romantic Poets*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
A close study of Wordsworth, Byron, Shelley, and Keats. Attention centered on the ways each of these poets uses English poetic tradition to help him articulate (and reshape) characteristically Romantic ideas. *Youngren*

21.23 *Major American Writers of the Nineteenth Century*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Study of selected works by: Irving, Poe, Emerson, Thoreau, Hawthorne, Melville, Whitman, Twain. Excursions into the dime novel and folklore. *T. Wood*

21.24 *Sources of Modernism in Contemporary Literature*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
A study of some representative modern works to determine their relationship to contemporary values and their creation of these values as a reaction to the life, art, and thought of the relevant past. Authors to be read: Beckett, Bellow, Freud, Nietzsche, Carroll, Proust, Verga, Hopkins, Arnold. Some films and works of art to be viewed in class. *Kampf*

21.25 *The Modern Novel*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1, 2) 3–0–5
Discussion of novels by such writers as Beckett, Camus, Duerrenmatt, Hesse, Joyce, Kafka, Mann, Moravia, and Simenon. *(Not offered 1966–67.)* ——

21.26 *Modern Drama*
Prereq.: 21.03T 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*

21.27 *Modern Poets: Yeats, Eliot, and Stevens*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Extensive and intensive study of these three poets, with an eye to developing a general sense of what "modernism" has meant in English poetry. Incidental reading of criticism. *Spacks*

21.28 *Modern American Literature*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
Discussion of fiction and poetry by such writers as Bellow, Capote, Crane, Cummings, Eliot, Fitzgerald, Hemingway, Robert Lowell, Pound, Stevens, Nathanael West, and Wolfe. *(Not offered 1966–67.)* ——

21.29 *The Double Vision of Russian Literature*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Major emphasis on Dostoevski and Tolstoi. Additional readings (varying somewhat from year to year) from such writers as Pushkin, Gogol, Aksakov, Turgenev, Leskov, Chekhov, Bunin, Gorky, Blok, Olyesha, and Pasternak. All works in translation. *Dworsky*

21.291 *Soviet Russian Literature*
Prereq: 21.03T 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. *Pomorska*

21.292 *Gogol and Literary Methodology in Russia*
Prereq: 21.03T or 21.031 or 21.11 or 23.94
Year: U (2) 3–0–5
Gogol's writings as approached by sociological criticism (Belinsky, Shernyshevsky), 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. *Pomorska*

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21.293 ***Tolstoi's "War and Peace"***
Prereq: 21.03T 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. (*Not offered 1966–67.*) *Pomorska*

21.294 ***Mayakovsky and Pasternak***
Prereq: 21.03T 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. (*Not offered 1966–67.*) *Pomorska*

21.30 ***Non-Western Literature***
Prereq.: 21.031T or 21.031 or 21.11
Year: U (2) 3–0–5
Reading of major classics and contemporary pieces, largely from India, China, and Japan. Some illustration of attitudes toward life and art of these nations by use of visual art and reference to religious and philosophical systems. (*Not offered 1966–67.*) *W. C. Greene*

21.302 ***Chinese Literature***
Prereq.: 21.03T 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 21.30 or 21.513 desirable preparation, but not required. *Sivin*

21.31 ***Narrative Fiction***
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Discussion of novels and short stories with a view to determining the reasons — psychological, social, literary — for the human impulse to write, read, and enjoy narrative fiction. Authors to be read: Boccaccio, Dostoevski, Hawthorne, James, Kafka, Laclos, D. Lessing, Robbe-Grillet, Svevo, L. Tolstoy. *Kampf*

21.32 ***Nature of Poetry***
Prereq.: 21.03T 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. *T. Wood*

21.33 ***The Drama as Theatre***
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Close reading and discussion of plays, with emphasis particularly on their theatrical values as they work on the stage. Reading list to include a number of those plays presented in the Boston area during the term by professional, community, and academic organizations. Class discussions assisted by visiting lecturers whenever possible. (*Not offered 1966–67.*) *Gurney*

21.34 ***The Short Story***
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
Study of the precursors of the modern story and the theories of short fiction from Poe onward, emphasizing the variety of the form in the twentieth-century. Readings from Hawthorne, Melville, Flaubert, Chekhov, James, Conrad, Kafka, Maugham, Faulkner, Cheever, Welty, and Powers, with more extensive consideration of the work of Joyce, Hemingway, K. A. Porter, and Bernard Malamud. *Cole*

21.35 ***Theatre Arts: Elementary Stagecraft and Production Studies***
Prereq.: 21.03T 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*

21.351 ***Toward a Theatre of Revolt***
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Study of the rebellion of European playwrights incited by Henrik Ibsen's subversion of both the form and the assumptions of the "well-made" play, symbol of the artistic and moral certitude of the bourgeoisie. Scribe, Ibsen, Schnitzler, Wedekind, and other authors from the early stages of the revolt (to 1914.) (*Not offered 1966–67.*) *Bilborn*

21.36 ***The Nature of the Comic***
Prereq.: 21.03T or 21.031 or 21.11
Year: U (2) 3–0–5
Close reading of such writers as Apuleius, Aristophanes, Shakespeare, Molière, Carroll, and Shaw with discussion of various theories of the comic. *Gurney*

21.37 ***Tragedy***
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Studies in the tragic impulse and the various forms it has taken at different times: conceptions and manifestations of tragedy in such works as *Job*, *Oedipus Rex*, "The Pardoner's Tale," *Macbeth*, *The Dunciad*, *Moby Dick*, *The Waste Land*, *The Trial*, *Man's Fate*, *A Streetcar Named Desire*. *T. H. Jackson*

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

21.401 ***Character and Society in America: From the Puritans to David Riesman***
Prereq.: 21.02
Year: U (1) 3–0–5
Examination of changes in American ideals and attitudes toward religion, work, wealth, intellect, education, individuality, class, etc. and in the way Americans have looked at themselves. Emphasis on our present social situation and values, and on recent sociological, psychological and historical studies of American society. Reading focused mainly on major interpretations of American life (*e.g.*, William Bradford, Franklin, de Tocqueville, Henry Adams, Carnegie, Whitman, Veblen, and Riesman) and on works from our literature (*e.g.*, Fitzgerald's *The Great Gatsby*) clearly reflecting or commenting on American ideals. (*Not offered 1966–67.*) *Kaledin*

21.403 *Development of American Economic Institutions*
Prereq.: 21.02
Year: U (1) 3–0–5
A topical study of the development of the American economy from the simple agrarian one of 1800 to the urban, industrial one of today. Topics for 1966–67; Alexander Hamilton, the New England factory town, the plantation, the labor union, the automobile industry, and the New Deal. *Bryant*

21.404 *American Ideas and Institutions*
Prereq.: 21.02
Year: U (2) 3–0–5
Study of the development of certain religious, political, and philosophical ideas in America and their relation to American institutions. Topics for 1966: Puritanism, Transcendentalism, civil liberties, the Mormons, and Pragmatism. *Bryant*

21.405 *American Intellectual History*
Prereq.: 21.02
Year: U (1) 3–0–5
Examination of classical works in the development of American thought; emphasis on religious, social, and political consciousness of such significant American thinkers as Edwards, Franklin, Jefferson, Emerson, Thoreau, Calhoun, James, Veblen, and Niebuhr. *Hartley*

21.406 *History of Transportation in the United States*
Prereq.: 21.02
Year: U (2) 3–0–5
Study of new modes of transportation such as the canal, the railroad, the steamship, 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 public control of the business of transportation. *Bryant*

21.407 *Totalitarianism*
Prereq.: 21.02
Year: U (1) 3–0–5
Historical and systematic analysis of totalitarianism. Historical roots of totalitarianism in the 19th century, central significance of World War I, establishment of totalitarian regimes, and process of totalization. Nature and function of totalitarian ideology and propaganda, leadership, controls, and organization. Attention given to Fascist Italy, Nazi Germany, Imperial Japan, Soviet Russia, and Communist China. ——

21.501 *Pre-Industrial Europe*
Prereq.: 21.02
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 inter-regional operations. (*Not offered 1966–67.*) *Watson*

21.502T *The Northern Renaissance and the Reformation*
Prereq: 21.02
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*

21.504 *The Italian Renaissance*
Prereq.: 21.02
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 1966–67.*) *Douglas*

21.505 *Intellectual History of Modern Europe*
Prereq.: 21.02
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. (*Not offered 1966–67.*) *Mazlish*

21.506 *Marx, Darwin, and Freud*
Prereq.: 21.02
Year: U (2) 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*

21.507 *Reformation and Revolution*
Prereq.: 21.02
Year: U (1) 3–0–5
A study in resistance to authority in Church and State. The Protestant Revolt, the Wars of Religion, the Peace of Westphalia, the Puritan and Glorious Revolutions, the American Revolution, and the great French Revolution studied with a view to discover how the individual attempted to assert his freedom, and with what success in the face of religious and civil authority. (*Not offered 1966–67.*) ——

21.508 *Reconstruction of Europe, 1945-65*
Prereq.: 21.02
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*

21.509 *War and the Military Institutions of the Modern State*
Prereq.: 21.02
Year: U (1) 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 inter-acting relationship between the military institutions of a state and its political institutions and their effect on civil society. *Ralston*

21.51 *Vienna and Versailles*
Prereq.: 21.02
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*

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21.511 *China, Japan, and the West*
Prereq.: 21.02
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*

21.512 *Russian Revolution and the Soviet Union*
Prereq.: 21.02
Year: U (2) 3–0–5
Nature and meaning of the Soviet challenge to America. Use of historical and intellectual materials in the study of the origins and course of the revolution. Political, social, and economic structure of the USSR and its relationship to recent and contemporary Soviet foreign policy. (*Not offered 1966–67.*) *MacMaster*

21.513 *Introduction to the Far East*
Prereq.: 21.02
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*

21.514 *Science and Natural Philosophy in Chinese Tradition*
Prereq.: 21.513
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. *Sivin*

21.515 *ear Eastern Archaeology: The Foundations of Civilization*
Prereq.: 21.02
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*

21.516 *Spanish Civil War, 1936-39*
Prereq.: 21.05T or 21.06T
Year: U (2) 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*

21.517 *Cultures of the Non-Western World*
Prereq.: 21.02
Year: U (1) 3–0–5
An introduction to anthropology, exploring human variability and uniformity as disclosed in different cultures. Emphasis on the significance of culturally-determined differences in the maintenance of human society, using comparative studies of such peoples as the Crow Indians, the Tikopa of Polynesia, the folk of the Andean Empire of the Inca, and of Westernized non-European societies. Examination of relationships between cultures, particularly those affected by Western industrial technology. Reconsideration of the meanings of "primitivity" and "civilization." (*Not offered 1966–67.*) ——

21.518 *Cultures and Societies of Africa*
Prereq.: 21.02
Year: U (2) 3–0–5
Anthropological examination of sub-Saharan Africa before and after European contact and colonization. Social, political, and religious organization of representative tribes. The effect of European slave trading, missionary activity, conquest, and colonization. Problems of newly-independent states: conflict between tribalism and nationalism, nativistic movements, urbanization, and economic development. Racial conflict in such areas as South Africa and Southern Rhodesia. (*Not offered 1966–67.*) ——

21.519 *Cultures and Societies of the Caribbean Islands*
Prereq.: 21.02
Year: U (1) 3–0–5
An anthropological and historical survey of the peoples of the Caribbean area and their ways of life. Emphasis on the early Westernization of the Islands; the sociological effects of slavery, the plantation regime, and lengthy colonial rule; and on the contemporary ethnic complexity of the Caribbean area. Special attention to modern problems of social and political integration in societies sharply divided by ethnic, behavioral, and economic differences, and to the relevance of African, Asian and European cultural heritages in Caribbean life. ——

21.521 *History of Materials*
Prereq.: 21.02
Year: U (2) 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*

21.523 *History of Engineering*
Prereq.: 21.02
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*

21.524 *History of Engineering*
Prereq.: 21.02
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*

21.525 ***Technology and Economic Growth***
Prereq.: 21.02
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*

21.526T ***Industrialization and Social Protest Since 1815***
Prereq: 21.02
Year: U (2) 3–0–5
Comparative analysis of movements of social protest during the disruption of traditional societies with particular emphasis on the phenomena of "primitive revolution", messianism, etc. *Hobsbawm*

21.528 ***History of Technology in the United States***
Prereq.: 21.02
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

21.535 ***History of Mathematical Astronomy***
Prereq.: 21.02
Year: U (1) 3–0–5
Astronomy as the first model for theories based on mathematical analysis of natural phenomena. The changing relationship of the astronomer with the philosopher. Calendrical and astronomical techniques in ancient Babylonia, Greece, Islam, India, China, and Central America. Astronomical issues leading up to the Scientific Revolution. Emphasis on the role of astronomy in defining the strategies of science. No training in modern astronomy expected. (*Not offered 1966–67.*) *Sivin*

21.539 ***Introduction to Anthropology***
Prereq.: 21.02
Year: U (1) 3–0–5
Anthropology and its sub-fields. Special attention to cultural and social aspects of behavior, with study of the development of the main approaches used to orient research and construct theory. Use of field reports and monographs to supply cross-cultural perspective. Consideration of the impact of industrialization on non-Western peoples. *Diskin*

21.541T ***Cultures and Societies of Latin America***
Prereq.: 21.02
Year: U (1) 3–0–5
Latin America defined through broad cultural and historical experiences. Examination of its pre-Colombian variety, but greater emphasis on post-conquest developments. Consideration of interplay between cultural, demographic, political and economic factors in order to evaluate and describe its contemporary nation-states. Consideration of economic development and politics.
Diskin

21.542 ***The Businessman in American History***
Prereq.: 21.02
Year: U (2) 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*

21.547 ***Peasant Society***
Prereq.: 21.02
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*

21.548 ***Cultures and Societies of Mexico***
Prereq.: 21.02
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*

21.591 ***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.: 21.02
Year: U (1) 3–0–5
Study of central problems in the writings of philosophers from Plato to Kant. (*Not offered 1966–67.*) ——

21.612 ***History of Philosophy II***
Prereq.: 21.02
Year: U (2) 3–0–5
Study of central problems in the writings of philosophers from Hegel to Wittgenstein. (*Not offered 1966–67.*) ——

21.613 ***Classical Philosophy***
Prereq.: 21.02
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*

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21.631 *Problems in Contemporary Philosophy I*
Prereq.: 21.02
Year: U (1) 3–0–5
Main currents in twentieth-century empiricist philosophy. Rise and growth of Logical Positivism and Analytical Philosophy, and the main features of these. Current views about meaning and language, theory of knowledge, the natures of empirical and of mathematical truth, and other topics. (*Not offered 1966–67.*)
Judith J. Thomson

21.632 *Problems in Contemporary Philosophy II*
Prereq.: 21.02
Year: U (2) 3–0–5
Application of the methods and theories of contemporary analytic philosophy, and particularly of Wittgenstein's *Philosophical Investigations*, to traditional problems in the theory of knowledge. Particular attention to the writings of Descartes, Locke, Berkeley, and Hume. (*Not offered 1966–67.*) *James F. Thomson*

21.634 *Phenomenology and Existentialism*
Prereq.: 21.02
Year: U (1) 3–0–5
Study of the phenomenological method in its applications to existential analysis and philosophical psychology, with special reference to the intentionality of consciousness and the body's role in experience. Detailed and comprehensive examination of Sartre's *Being and Nothingness* and Merleau-Ponty's *Phenomenology of Perception.*
Dreyfus

21.638 *Existentialism in Literature*
Prereq.: 21.02
Year: U (2) 3–0–5
Examination of works of Dostoyevsky, Kafka, and Malraux as expressions of Christian, agnostic, and atheist existential attitudes. Study of plays of Ionesco, Pinter, and Beckett. Attempts to find the suitable form to express the existentialist rejection of the traditional notion of reason. (*Not offered 1966–67.*) *Dreyfus*

21.641 *Symbolic Logic*
Prereq.: 21.02
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.*) *James F. Thomson*

21.643 *Theory of Knowledge*
Prereq.: 21.02
Year: U (1) 3–0–5
Classical and modern views on knowledge, belief, perception, and the relation between "common sense" and "scientific theory." *Levensky*

21.651 *Problems in Ethics*
Prereq.: 21.02
Year: U (1) 3–0–5
Study of moral ideals in relation to concepts of friendship, benevolence, sympathy, love, etc. Readings include Plato on *Eros*, Aristotle on *Philia*, Aquinas on *Caritas*, Hume on moral sentiments, etc. (*Not offered 1966–67.*)
I. Singer

21.652 *Moral Philosophy* (A)
Prereq.: ——
Year: G (2) 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; others admitted only by permission of instructor.*) *Judith J. Thomson*

21.653 *Nature and Justification of Liberty*
Prereq.: 21.02
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

21.654 *The Notion, Burden of Proof* (A)
Prereq.: ——
Year: G (2) 3–0–9
Examination of the concept of burden of proof and its connection with the notions of a presumption in favor of X, of justifying X, and of giving reasons for X. The questions of what it means to say that there is a presumption in favor of X and if such presumptions may be justified or overridden. Examples from the law, epistemological arguments, and moral and political arguments. (*Primarily for graduate students in philosophy; others admitted by permission of instructor.*) *Dworkin*

21.655 *Freedom of the Will* (A)
Prereq.: ——
Year: G (1) 3–0–9
Some problems connected with the issue of freedom vs. determinism: future contingencies; action, reason, and cause. (*Primarily for graduate students in philosophy. Undergraduates may be admitted by permission of instructor.*)
Judith J. Thomson

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 may be admitted by permission of instructor.*)

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 may be admitted by permission of instructor.*) *Bromberger*

21.658 *Kant* (A)
Prereq.: ——
Year: G (2) 3–0–9
Clarification of Kant's theory of knowledge and perception in the *Critique of Pure Reason* by examining its fundamental ideas from the perspective of recent developments in some of the sciences, especially linguistics and psychology. The *Critique of Pure Reason* read, along with relevant articles from the sciences concerned. Acquaintance with Continental Rationalism and British Empiricism presupposed. (*Primarily for graduate students in philosophy. Undergraduates may be admitted by permission of instructor.*) *Katz, Fodor*

21.659 *Causation, Space, and Time*
Prereq.: 21.02
Year: U (1) 3–0–5
Examination of certain problems about the concepts of causation, space, and time, as they occur in common sense beliefs and in physical theories. *Ruddick*

21.662 *Philosophy of History*
Prereq.: 21.02
Year: U (2) 3–0–5
Examination of the nature of critical historical thought (*e.g.*, Hempel, Collingwood, etc.), and of the great speculative patternings of the past, involving attention to such thinkers as Vico, Condorcet, Kant, Hegel, Comte, Marx, Spengler, Toynbee, and Freud. Extrapolation from the philosophy of history to the general philosophy of the cultural sciences. (*Not offered 1966–67.*) ——

21.671 *Philosophy of the Arts*
Prereq.: 21.02
Year: U (1) 3–0–5
Nature of art and beauty, particularly problems about the creative process, analysis of a work of art, the aesthetic experience, and standards of evaluation. These and related problems studied both in themselves and in terms of their treatment in the history of philosophy. (*Not offered 1966–67.*) *I. Singer*

21.672 *Philosophy in Literature*
Prereq: 21.02
Year: U (2) 3–0–5
Examination of certain questions concerning human value and human identity in selected writings of Nietzsche, Dostoyevsky, Hesse, Kafka, Malraux, Sartre, Camus and Beckett. *Levensky*

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. *Fodor*

21.691 *Philosophies and Religions of the East*
Prereq.: 21.02
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 *Major Religions of the West*
Prereq.: 21.02
Year: U (2) 3–0–5
Religious heritage of the Near East and West: Judaism, Christianity, Islam, and the ways of life they advocate; how they began and got their scriptures; men who founded and shaped them; developments in their theologies over the centuries; the chief differences between them. (*Not offered 1966–67.*) *H. C. Smith*

21.693 *Philosophy of Religion*
Prereq.: 21.02
Year: U (1) 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. (*Limited to 30 students.*) (*Not offered 1966–67.*) *H. C. Smith*

21.701 *Science and Philosophy from Antiquity to Copernicus*
Prereq.: 21.02
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. *Sivin*

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. *deSantillana*

21.712 *Philosophy of Science*
Prereq.: One philosophy subject above 21.04T
Year: U (2) 3–0–5
Discussion of epistemological problems arising in the natural sciences: foundations of geometry; the hypothetico-deductive method; induction and statistical inference; perceptual data and physical reality; the relations between micro- and macro-physics; science, and metaphysical speculation. ——

21.714 *Philosophy of Mathematics*
Prereq.: 21.02
Year: U (2) 3–0–5
Examination of major philosophies of mathematics — logicism, formalism, intuitionism — on the nature of mathematical proof, existence of mathematical entities, and related issues; views of contemporary philosophers interested in these questions, especially Quine and Wittgenstein. (*Not offered 1966–67.*) ——

21.715 *Philosophy of Physics* (A)
Prereq.: ——
Year: G (1) 3–0–9
Consideration of philosophical problems concerning space, time, matter, cause, and chance in the light of some of the discoveries of modern physics. (*It is strongly suggested that students have taken 8.05 and 8.06 or their equivalents.*) (*For graduate students in philosophy, and for undergraduates having permission of instructor.*) (*Not offered 1966–67.*) *Shimony*

21.716 *Philosophy of Mind*
Prereq.: 21.643
Year: U (2) 3–0–5
Some concepts and problems in the philosophy of mind, such as the relations between minds and bodies, sensation and feeling, thinking, and perceiving. (*Not offered 1966–67.*) *Judith J. Thompson*

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*

21.722 *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

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Chomsky's theory of generative grammar desirable. (*Primarily for graduate students; others admitted only by permission of instructor.*) (*Not offered 1966–67.*) *Katz*

21.732 *Perception* (A)
Prereq.: ——
Year: G (2) 3–0–9
Some questions about perception, recognition, and the role of inference and learning in perception. These questions considered both with reference to recent philosophical discussion and recent work in experimental psychology. (*Primarily for graduate students; others admitted only by permission of instructor.*) (*Not offered 1966–67.*)
Fodor, James F. Thomson

21.78 *Graduate Seminar* (A)
Prereq.: ——
Year: G (2) *Arr.*
Seminar meeting once a week, with graduate students presenting problems and short papers for discussion. (*Second and third year students requested, and first year students invited to attend.*) *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 *Introduction to Music*
Prereq.: ——
Year: U (1, 2) 3–0–5
A subject to familiarize students who have little or no knowledge of music with the language of music and its universal literature. Rudiments of harmony and ear training, and terminology of music. Analysis of representative masterworks through lectures and demonstrations. Listening to recordings, weekly exercises, and readings required. *Staff*

21.812 *Musical Form and Analysis*
Prereq.: 21.81
Year: U (1, 2) 3–0–5
Consideration of differing concepts of musical structure and formal organization, viewed in historical perspective. Study of general procedures and specific applications of these procedures by important composers. Study of scores, listening to recordings and readings. (*Permission of instructor required.*) *D. M. Epstein*

21.82 *Materials of Music*
Prereq.: 21.81
Year: U (1, 2) 3–0–5
Study of the behavior of musical materials in regard to phrasing, dynamics, tensions, melodic and harmonic interactions. Laboratory studies of musical instruments. Ear training, dictation, and creative musical exercises. (*Permission of instructor required.*) *Lay*

21.822 *Music Theory I*
Prereq.: 21.81
Year: U (2) 3–0–5
Second level course studying harmony and counterpoint as developed in the Common-Practice Era (ca. 1600–1870). Readings, weekly exercises and writing assignments, and analysis of the music of important composers during this period. Subject aimed at development of both writing technique and musical understanding. (*Permission of instructor required.*) *D. M. Epstein*

21.83 *Western Music in the Middle Ages and the Renaissance*
Prereq.: 21.81
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. Detailed analysis of compositions by Perotin, Machaut, Dufay, Josquin, Lassus, Byrd. Listening to recordings, weekly exercises, and readings required. *Cook*

21.84 *Western Music in the Baroque Era*
Prereq.: 21.81
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. Detailed analysis of works by Monteverdi, Corelli, Händel, Bach. Listening to recordings, weekly exercises, and readings required. *Cook*

21.85 *Western Music in the Classic Era*
Prereq.: 21.81
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. (*Limited to 30 students.*) *Tucker*

21.86 *Western Music in the Romantic Era*
Prereq.: 21.81
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. (*Limited to 30 students.*) *Tucker*

21.87 *Twentieth-Century Music*
Prereq.: 21.81
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 Schoenberg, Stravinsky, Bartok, Hindemith, Copland, Ives, Prokofieff, Honegger, and other composers. The interrelationship of art music, folk music, and popular music. Concerts, recordings, and discussion. (*Permission of instructor required.*) *Tucker*

21.88 *The Opera*
Prereq.: 21.81
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. *Cook*

21.891 *Seminar in Music*
Prereq.: 21.81
Year: U(1) 3–0–5
Varying topics from year to year. Topic for Fall 1966: A Collegium Musicum on Bach's Brandenburg Concertos. A thorough study of these works through analysis, comparison with similar works, and playing. Careful rehearsal of the concertos, 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.: 21.81
Year: U (2) 3–0–5
Varying topics from year to year. Topic for Spring 1967: A Collegium Musicum on Beethoven's String Quartets. A thorough study of these works through analysis, comparison with other quartets, and playing. Careful rehearsal of the works, 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.*) *Liepmann*

SPECIAL INTERDISCIPLINARY SUBJECTS

21.92T *Lanamarks in Urban Evolution*
Prereq.: 21.02
Year: U (2) 3–0–5
Consideration of the forces, in different periods, which have determined the character and principal functions of cities — military, religious, commercial, political, industrial and utopian. Readings in literary, artistic, and historical sources. Studies of Babylon, Nineveh and Ur; the Thebes of Hatshepsut; Periclean Athens; the Rome of Augustus and Nero; and Rome of Bernini; the Paris of Villon and Zola; the London of Shakespeare, Wren, and Dickens; the Philadelphia of William Penn and Edward Bacon; Canberra, Chandigarh, Brasilia and Islamabad. *Burchard*

21.93T *Seminar: Cosmology, Old and New Problems*
Prereq.: 21.02
Year: U (1) 3–0–5
Changing role of number, rhythm, and harmony in the development of cosmology. The issues of cosmology in classical times. Elements of archaic cosmology preserved in myth; critical interpretation of myth as the technical language of astronomy in pre-literate times. No technical background in astronomy presupposed, but 21.701 desirable preparation. *von Dechend*

21.94T *Philosophical Anthropology*
Prereq: 21.02
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. *Bemis, H. Smith*

21.95T *Poetic and Scientific Discourse in Classical Literature*
Prereq.: 21.03T 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. *Reiche*

21.97T *Biological Bases of Perception and Knowledge*
Prereq.: 21.02
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 metapysical commitment. The mind-body problem in contemporary guise. *deSantillana, Lettvin*

21.98T *History and Psychoanalysis*
Prereq.: 21.02
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 psycho-historical terms. (*Limited to 15 students.*) *Mazlish*

21.99 *Psychology of Literature*
Prereq.: 21.03T or 21.031 or 21.11
Year: U (1) 3–0–5
Readings of poems, fiction, and plays for an understanding of the general psychological processes of response to literature and enrichment of one's own responses in particular. Some of the topics considered from a psychological point of view: the concept of style; the role of meaning, form, and myth or ritual; the feeling of realism; characters and our identification with them. Among the authors read: Arnold, Freud, Hopkins, Lawrence, Marvell, Shakespeare, Swift, Twain, Wordsworth. (*A strong background in literature required.*) (*Not offered 1966–67.*)

21.992T *History and Philosophy of Twentieth Century Physics*
Prereq.: 8.04
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*

21.994 *Human and Mechanical Information Processing*
Prereq.: 21.02
Year: U (2) 3–0–5
Attempt to make explicit and analyze the methodological and philosophical problems involved in programming digital computers to behave intelligently. How machines process information. What we know about human information processing. Associationism. Conscious vs. unconscious processing. Heuristics and algorithms. What are appropriate man-machine analogies? (*Limited to 15 students.*) (*Not offered 1966–67.*) *Dreyfus, Weizenbaum*

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21.995 ***Intellectuals and Social Change***
Prereq.: 21.02
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.: 21.03T 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 ***Shaw, Lawrence, Faulkner: Social Vision in Literary Art***
Prereq.: 21.03T 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*. *(Not offered 1966–67.)* *Merritt*

21.999 ***Analysis of Musical Sound***
Prereq.: 21.81
Year: U (1, 2) 1–2–5
Recording of sounds, waveform analysis, and an evaluation of listening to musical sounds. Lectures and laboratory projects. *Ferretti*

22.
Nuclear Engineering

22.10 ***Elementary Nuclear Physics***
Prereq.: 8.03, 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*

22.20 ***Biological Effects of Nuclear Radiation*** **(A)**
Prereq.: 8.053 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 1966–67.)* *Brownell*

22.21 ***Nuclear Reactor Physics I*** **(A)**
Prereq.: 8.053 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. *Yip, Gyftopoulos*

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. *Kaplan*

22.231 ***Nuclear Reactor Engineering*** **(A)**
Prereq.: 2.50 or 10.31; *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. *E. A. Mason*

22.241 ***Principles of Control Systems*** **(A)**
Prereq.: 8.03, 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 nonlinear problems. *(Alternate years. Not offered 1966–67.)* *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 nonlinear nuclear plant dynamics, development of boundedness and stability criteria for nonlinear systems. Synthesis of control systems. *(Alternate years. Not offered 1966–67.)* *Gyftopoulos*

22.25 ***Selected Topics in Reactor Physics*** **(A)**
Prereq.: 22.22
Year: G (1) 3–0–9
Topics selected from recent advances in the physics of thermal neutron reactors: resonance capture, thermal flux distribution, fast fission effect; neutron energy spectra and thermalization; water-moderated reactors; physics of intermediate and fast reactors. *Kaplan*

22.26 ***Nuclear Reactor Design*** **(A)**
Prereq.: 22.22 or 22.242; 22.231
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. *Fenech*

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. *Benedict*

22.28 ***Fast 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. *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, Driscoll*

22.42T ***Nuclear Reactor Operations*** **(A)**
Prereq.: 22.21, 22.41
Year: G (2) 2–3–3
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. *Thompson*

22.43 ***Reactor and Neutron Physics Laboratory*** **(A)**
Prereq.: 22.41
Year: G (1, 2) 1–5–2
Selected experimental problems in reactor physics and neutron physics; experimental methods of studying reactor lattice parameters, neutron and gamma shielding, nuclear instrumentation, neutron cross sections, gamma ray spectra, neutron spectra, neutron temperatures, neutron diffraction, slow neutrons, and radiation damage; experiments utilizing the M.I.T. Reactor, D_2O moderated exponential lattice, neutron fast chopper, crystal neutron spectrometer, high resolution gamma detectors, shielding facilities, pulsed neutron source, and low-temperature facilities.
Clikeman, Rasmussen, Driscoll, Thompson

22.51 ***Neutral Particle Transport I*** **(A)**
Prereq.: 8.791; or 18.15 & 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. *Yip*

22.53 ***Digital Computers in Nuclear Engineering*** **(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 multi-group methods, S_n methods, Monte Carlo methods, and Spencer-Fano method. *K. F. Hansen*

22.531 ***Digital Computers in Nuclear Engineering*** **(A)**
Prereq.: 22.21
Year: G (1) 1–0–2
Programming aspects of 22.53. *K. F. Hansen*

22.54 ***Radiation Shielding*** **(A)**
Prereq.: 8.053 or 8.532 or 22.10; 22.21
Year: G (2) 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, Rasmussen

22.61 ***Plasmas and Controlled Fusion*** **(A)**
Prereq.: 8.04; 8.053 or 8.06 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*

(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.

22.62 ***Advanced Plasma Principles*** **(A)**
Prereq.: 8.231 or 22.61; 8.72
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. *Lidsky*

22.63 ***Engineering Physics of Plasma and Particle Devices*** **(A)**
Prereq.: 6.03 or 8.08 or *22.61*
Year: G (1) 3–0–6
Principles of accelerators and thermonuclear research devices, including vacuum systems, magnets, acceleration methods, beam transport, ion sources, targets, energy storage, and switching of high currents. Examples from recent practice. *Lidsky*

22.64 ***Plasma Kinetic Theory*** **(A)**
Prereq.: 8.07, 18.15
Year: G (1) 3–0–6
Many-body problem with Coulomb interactions. Random processes, Fokker Planck equation, development of intuitive concepts. Integrated Liouville equation, particle correlations, survey of recent theoretical methods. Derivation of fluid equations, the Vlasov equation, plasma oscillations, instabilities, Landau damping. Thermalization. *Dupree*

22.65J ***Plasma Laboratory*** **(A)**
(Same subject as 6.634J)
Prereq.: 2.274 or *8.231* 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. *D. J. Rose*

22.66J ***Advanced Topics in Plasma Kinetic Theory*** **(A)**
(Same subject as 16.58J)
Prereq.: 22.64
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. Nonlinear 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*

22.71T ***Metallurgy for Nuclear Engineers*** **(A)**
Prereq.: ——
Year: G (2) 2–0–6
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*

22.72 ***Nuclear Fuels*** **(A)**
Prereq.: 3.14T or 22.71T
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 1966–67.*) *Ziebold*

22.81 ***Selected Topics in Radiation and Radioisotope Applications*** **(A)**
Prereq.: 8.053 or 22.10
Year: G (1) 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 special and graduate students who wish to carry out some minor investigation in a particular field. Subject and hours to fit individual requirements. *Staff*

22.91 ***Seminar in Nuclear Engineering*** **(A)**
Prereq.: ——
Year: G (1) 2–0–1

22.92 ***Seminar in Nuclear Engineering*** **(A)**
Prereq.: ——
Year: G (2) 2–0–1
For graduate students engaged on doctoral theses. *Benedict*

23.
Modern Languages and Linguistics

23.011 ***The Greek Tradition***
Prereq.: ——
Year: 1 (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 and tests in French or English. Essays in English. (*Restricted to students with an adequate background in French.*) *Bottiglia*

23.021 ***The Judaeo-Christian Tradition***
Prereq.: 23.011
Year: 1 (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 in French or English. Essays in English. (*Restricted to students with an adequate background in French.*) *Bottiglia*

23.022 *The European Tradition: Goethe Era*
Prereq.: 21.01
Year: 1 (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.: 23.051
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. Essays in English. Tests in French or English. (*Restricted to students with an adequate background in French.*) *Bottiglia*

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*

23.051 *The Twentieth Century: Revolution, War, and "Totalism"*
Prereq.: 23.021
Year: U (1) 3–0–6
Training in the elements of historical method through analysis of major developments in today's world. Focus on political, economic and social phenomena. Some attention to cultural manifestations as well. Readings in primary sources and works of interpretation. Lectures and discussion in French. Readings in French and English. Tests in French or English. Essays in English. (*Restricted to students with an adequate background in French.*) *Bottiglia*

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*

23.15T *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, reports, exercises, and papers in English or German. *Dyck*

23.16T *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, reports, exercises, and papers in English or German. *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*

23.19 *Goethe's "Faust"*
Prereq.: 23.14
Year: U (1) 3–0–5
An intensive analysis of both parts of *Faust*. Instruction in German. Discussion, reports, exercises, and papers in English or German. (*Not offered 1966–67.*) *Dyck*

23.20T *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,

(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.

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, reports, exercises, and papers in English or German. (*Limited enrollment. Not offered 1966–67.*) *Dyck*

23.21T *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, reports, exercises, and papers in English or German. (*Not offered 1966–67.*) *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, reports, exercises, and papers in English or German. (*Not offered 1966–67.*) *Dyck*

23.35 *Spanish Drama*
Prereq.: ——
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.*) *Michaux*

23.36 *Twentieth-Century Spanish Literature*
Prereq.: ——
Year: U (1) 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.*) *Michaux*

23.37 *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. (*Admission only by consent of instructor. Limited enrollment.*) *J. W. Harris*

23.38 *Intensive Spanish II*
Prereq.: 23.37
Year: G (2) 4–0–8
Continued training in speaking and understanding Spanish, with attention to professional needs. Increased practice in reading. Continued use of language laboratory. (*Admission only by consent of instructor. Limited enrollment.*) *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. *Ricardo*

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. *Ricardo*

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. *Black*

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. *Black*

23.56 *French Drama*
Prereq.: 23.54
Year: U (2) 3–0–5
Intensive analysis of works by such masters as Corneille, Molière, Racine, Beaumarchais, Claudel, Giraudoux, etc.Co nducted in French. *Black*

23.57 *Scientific French*
Prereq.: ——
Year: G (2) 3–0–6
Intensive preparation for graduate language requirement in French. No previous study of French required. Group meetings for discussion of ways to facilitate comprehension of grammatical and syntactical difficulties. Section meetings by Courses for reading material in the field of the student. (*Open to graduate students only. No credit given.*) *Bon*

23.59 *French Prose Fiction*
Prereq.: 23.54
Year: U (1) 3–0–5
Intensive study of selected novels (e.g., *Le Père Goriot*, *Madame Bovary*, *La Condition humaine*, *La Peste*), tales by Voltaire, and short stories by Maupassant and others. Conducted in French. *Black*

23.61 *Seventeenth-Century French Literature*
Prereq.: 23.54
Year: U (1) 3–0–5
Concentrated study of major figures: Corneille, Molière, Racine, Pascal, Bossuet, La Fontaine, La Rochefoucauld, La Bruyère, etc. Conducted in French. (*Not offered 1966–67.*) *Black*

23.62 *French Poetry*
Prereq.: 23.54
Year: U (2) 3–0–5
Close analysis of selected works drawn from such major French poets as Villon, Ronsard, Chénier, Hugo, Leconte de Lisle, Baudelaire, Rimbaud, Mallarmé, and Valéry. Conducted in French. (*Not offered 1966–67.*) *Black*

23.701T *Crucial Problems in Linguistics*
Prereq.: ——
Year: G (1) 2–0–7
The Moscow school-Fortunatov, Trubetzkoy, further stages — and its place in world linguistics. *Jakobson*

23.702 *Seminar in Linguistics*(A)
Prereq.: ——
Year: G (2) *Arr.*
Special problems in linguistics. Permission of instructor required. *Staff*

23.703 *Linguistics and Poetics*
Prereq.: ——
Year: G (1) 2–0–7
Prosodic patterns in word-and-sentence phonology; their utilization in metrics; prosodic and metrical typology. Metrical role of inherent distinctive features. Morphological and syntactic constituents of verse. (*Not offered 1966–67*). *Jakobson*

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. *Chomsky, Halle*

23.732 *Structure of English II* (A)
Prereq.: 23.731
Year: G (1) 3–0–9
Detailed study of the grammatical structure of sentences in contemporary English. Special reference to formal correlates of traditional grammatical statements about English syntax, such as those by Jespersen, Poutsma, and Curme. *Ross*

23.733 *History of the English Lanugage*
Prereq.: ——
Year: G (1) 3–0–9
Introduction to the external and internal history of the language and to the history of its study from Old English to the present. A reading knowledge of Old and Middle English desirable. *Sledd*

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*

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.*) *Kiparsky, Ross*

23.751 *Introduction to Linguistics*
Prereq.: ——
Year: G (1) 3–0–5
Introduction to the scientific study of human language. Outline of syntactic theory; brief survey of English syntax. Elementary data on production and physical nature of speech. The phoneme and distinctive features. Phonemic systems. Morphology: review of some morphological devices. Languages of the world, their historical relationships and structural classification. Speech and writing. Language, culture and cognition. *Halle*

23.752 *Linguistic Structure*
Prereq.: ——
Year: G (2) 3–0–9
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. *Ross*

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. *Kiparsky*

23.756 *Introduction to Indo-European Accentuation*
Prereq.: ——
Year: G (2) 2–0–10
Discussion of the accentual systems of the major Indo-European language groups and inquiry into their historical evolution. Particular attention to Balto-Slavic accentuation. (*Not offered 1966–67.*) *Kiparsky*

23.762 *Problems of 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*

23.764J *Speech Communication*
(Same subject as 6.36J)
Prereq.: ——
Year: U (2) 3–0–6
For well-qualified students with a serious interest in speech communication. Survey of structural properties of natural languages with special emphasis on the sound pattern. 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. Perception of speech: the auditory capabilities of man; the role of set in perception; analysis by synthesis. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. *Halle, Stevens*

(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.

23.766J *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*

23.771 *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. *Staff*

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 (1) 3–0–9
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. *Kiparsky*

23.782 *Survey of General Linguistics II* (A)
Prereq.: 23.781
Year: G (2) 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 *Typology of Grammars*
Prereq.: 23.731 or 23.752
Year: G (1) 2–0–10
Study of the grammars of languages belonging to divergent families with a view to reaching a sharper characterization of universal features of grammatical structure, with the majority of examples to be drawn from non-Indo-European languages. *Matthews*

23.785 *Linguistic Change* (A)
Prereq.: 23.731, 23.762
Year: G (1) 3–0–9
Review of instances of change in phonology, morphology, and syntax. Examples to be drawn from various language families, Indo-European as well as others. An attempt to develop a general theory of linguistic change.
Klima, Matthews, Kiparsky

23.786 *Seminar on Linguistic Change* (A)
Prereq.: 23.785
Year: G (2) 2–0–10
Continuation of 23.785. *Klima, Matthews, Kiparsky*

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 1966–67.*) *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 1966–67.*) *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. *M. Z. Freeman*

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. *M. Z. Freeman*

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.
M. Z. Freeman

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 (1, 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 (1) 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 1966–67.*) *Pomorska*

23.96T *Seminar in Modern Russian Poetry*
Prereq.: 23.941
Year: U (2) 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*

23.97 *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*

23.98T ***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 1966–67.*) *Pomorska*

23.99T ***Seminar in Russian Prose***
Prereq.: 23.941
Year: U (1) 3–0–5
Concentrated study of one of the following authors: Gogol, Tolstoy, Dostoevskij, Chekhov. Conducted in English or Russian, depending on individual student needs and abilities. (*Not offered 1966–67.*) *Pomorska*

(See also 21.641, SYMBOLIC LOGIC; 9.59, PSYCHOLOGY OF LANGUAGE AND COMMUNICATION; and 6.574, TRANSMISSION OF INFORMATION.)

AS

Aerospace Studies

AS11 ***World Military Systems***
Prereq.: ——
Year: 1 (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. Defense Department 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: 1 (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. The one hour laboratory period required of men in the four-year program. (*Restricted to students selected for A.F.R.O.T.C.*) *Pettigrew*

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. One-hour laboratory period required of men in the four-year program. (*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. One hour laboratory period required of men in the four-year program. (*Required for students selected for A.F.R.O.T.C.; others admitted with permission of instructor.*) *Gamache*

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MS
Military Science

MS11T ***Military Science***
Prereq.: ——
Year: 1 (1) 2–1–1
The fundamentals of Army organization in terms of the management and control of military forces; familiarization with individual weapons including marksmanship training; introduction to military equipment and weapons systems; training to develop the characteristics of leadership such as initiative and self-confidence. *Staff*

MS12T ***Military Science***
Prereq.: MS11T
Year: 1 (2) 2–1–1
Principles of the art of warfare as exemplified in an historical study of the early evolution of the American Army; study of the relationships of the Army with other departments of the national government and of the Army's employment as an instrument of national policy; leadership training with emphasis on development of the individual's self-confidence and initiative. *Staff*

MS21T ***Military Science***
Prereq.: MS12T
Year: U (1) 2–1–1
Continuation of the development of the military arts and modes of war in the expanding technological environment of the late nineteenth and twentieth centuries. Leadership training with emphasis on the responsibilities and functions of the junior leader. *Staff*

MS22T ***Military Science***
Prereq.: MS21T
Year: U (2) 2–1–1
The study of maps and aerial photographs to include the application of principles emphasizing terrain appreciation and evaluation; the missions and principles of employment of military teams; leadership training. *Staff*

MS31 ***Advanced Military Science***
Prereq.: MS22T or Basic Summer Camp
Year: U (1) 2–1–1
Military leadership with emphasis on psychological, physiological and social factors which affect human behavior, application of the principles of leadership to commonplace problems; educational psychology as pertains to the five stages of instructional technique, student presentations of selected subjects; unconventional warfare as used in counter-insurgency operations; the role of various branches in the overall mission of the Army. 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*

MS32 ***Advanced Military Science***
Prereq.: MS31
Year: U (2) 2–1–1
Leadership laboratory with emphasis on the responsibilities of the junior officer; principles and fundamentals of small-unit tactics and their application in combat systems used in brigades. *Staff*

MS41 ***Advanced Military Science***
Prereq.: MS32
Year: U (1) 2–1–1
Leadership laboratory with emphasis on practical application of principles of discipline and morale; planning and conducting military training; principles of military operations; doctrines and principles of logistical support. *Staff*

MS42 ***Advanced Military Science***
Prereq.: MS41
Year: U (2) 2–1–1
Philosophy and application of principles of military justice; principles and procedures of military administrative management; the role of the U. S. in world affairs; orientation on service life and customs of the service. *Staff*

NS
Naval Science

NS11 ***Orientation and Sea Power***
Prereq.: ——
Year: 1 (1) 3–1–5
NS12 ***Orientation and Sea Power***
Prereq.: NS11
Year: 1 (2) 3–1–5
Fundamentals of naval knowledge. Concepts of use of sea power from geographical, geopolitical and national strategical considerations. Influence of sea power in shaping world affairs socially, politically and economically. *Clifford*

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. *Clifford*

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. *Craiglow*

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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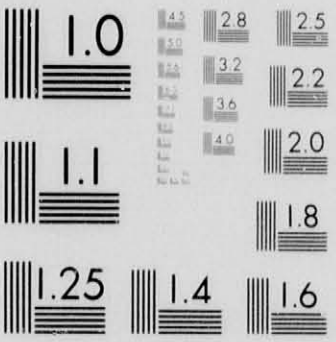
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Executive Vice President of the Alumni Association
Assistant Dean of the School of Engineering
Associate Dean of Student Affairs
Assistant to the President

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 awards include some combination of scholarship and loan.

Both these forms of financial aid are in addition to the assistance plans 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 Foundation Scholarship (1965)
One award of $750 for needy and deserving undergraduate students in architecture.

Alumni Regional Scholarships (1926)
As a means of cooperating with M.I.T. alumni in various centers in attracting to the Institute students of exceptional ability and promise, several Regional Scholarships, carrying an award based on demonstrated need for the freshman year, are offered in Chicago, Denver, Detroit, District of Columbia, Kansas City, Los Angeles, New York, New Jersey, Northern Ohio, Philadelphia, Pittsburgh, Portland, Ore., Rochester, N.Y., San Francisco, St. Louis, Seattle, Schenectady, Southern Ohio, and Westchester County, New York. These are open to American citizens of good character and health whose standing in their preparatory school studies has been high and who have satisfied with high standing all entrance requirements.

American Machine & Foundry Company Scholarship (1960)
This two-year grant of $750 is awarded annually to a member of the junior class majoring in mechanical or electrical engineering. Recipients are chosen on the basis of academic achievement, demonstrated need, extracurricular activities, leadership, and citizenship. Preference is given to residents of New England, New Jersey, New York, and Pennsylvania.

American Smelting and Refining Company Scholarships (1946)
This gift of the Company was made to establish a scholarship of $500 to a student in metallurgy, with preference to third- or fourth-year students.

American Society for Metals Award (1954)
A grant of $500 is awarded annually to a second-year student in metallurgy under this scholarship. Selection is made on the recommendation of the Department of Metallurgy to the Student Financial Aid Committee from among students who have applied for assistance for the sophomore year and who have demonstrated good ability and need.

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.

Anonymous (1948)
This gift of an alumnus is used for scholarship purposes.

Anonymous P (1959)
This gift is to assist needy and worthy students.

Louie G. Applebee Fund (1942)
This bequest is "to be expended in assisting deserving students."

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.

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 was established by Mrs. Mary E. Atkins of Boston with a gift of $5,000.

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 of $20,000 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.

John B. Bezazian Fund (1960)
This fund was established by the bequest of John B. Bezazian to furnish grants, including tuition and assistance toward living expenses, according to demonstrated financial need, for male students majoring in engineering or science. First preference is given in the selection to any qualified American male student of Armenian extraction residing in the United States of America; second preference to male students residing in the metropolitan or suburban area of Chicago, Illinois.

Billings Student Fund (1900)
A bequest of $50,000 from Robert C. Billings founded the Billings Student Fund. "Any student receiving benefit from this fund is expected to abstain from the use of alcohol or tobacco in any of their varied forms."

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 of $10,000 from Frank W. Boles in memory of his father, Levi Boles, is "applied annually to the assistance of needy and deserving students."

Jonathan Bourne Fund (1915)
This bequest of $10,000 from Hannah B. Abbe constitutes a fund "known as the Jonathan Bourne Scholarship Fund, the income only to be used in aid of deserving students."

Albert G. Boyden Fund (1931)
This bequest of $40,000 from Elizabeth R. Stevens is a permanent fund, known as the Albert G. Boyden Fund, "income only to be awarded as scholarships to assist worthy and needy students, preference to be given to young men or women residents of the town of Swansea or the city of Fall River."

Bertram Brewer Scholarships (1952)
The income from this bequest under the will of Bertram Brewer is used "to provide annual scholarships for deserving undergraduates of good character and ability. . . ."

Bridgeport Scholarship (1932)
Established by the Institute through a bequest from Horace T. Smith '98, this is known as the Horace T. Smith Scholarship Fund. A scholarship, carrying a stipend based on demonstrated need with a maximum of full tuition for the freshman year, is annually offered to a graduate of the high schools of Bridgeport, Connecticut. Application should be made to the Director of Student Aid.

Hubert D. Broderic (1965)
This fund has been established by Stuart C. Broderic '47 and Mrs. Guyetta G. Custance in memory of Hubert D. Broderic. The income only 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."

Cabot Endowed Scholarship (1955)
The income from this endowment, a gift of Godfrey L. Cabot, Inc., is used as scholarships for undergraduate students of the Institute in accordance with the general Institute practices and procedures.

Cabot Foundation Scholarships (1955)
The income of a fund established by the Cabot Foundation, Inc., provides scholarships for children (sons *and* daughters) of employees of Godfrey L. Cabot, Inc., and its subsidiary and associated companies. Candidates are required to have certification of their eligibility for scholarship grants by first applying to the Personnel Office of Godfrey L. Cabot, Inc., and are expected to comply with the usual policies governing the award of Institute scholarships.

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 of $25,000 from Caroline S. Freeman is "known as Mabel Blake Case Fund, income to be used to aid deserving students (preferably women) who are in need of assistance."

Nino Tesher Catlin Fund (1926)
A gift from Maria T. Catlin established this fund in memory of her son, Nino T. Catlin '18, the income "to be awarded to needy and deserving students."

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."

Thomas L. Clark Memorial Scholarship (1956)
The income from this endowment, established in memory of Thomas Lynn Clark '59, by a number of his friends at M.I.T., is used to assist a worthy and needy student at the Institute as determined by the Student Financial Aid Committee.

A. V. Clarke Fund (1950)
The proceeds of this gift by Mr. Clarke are "used for student aid at the discretion of the Student Financial Aid Committee."

Class of 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 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 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 (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 (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)
Gifts from the Class of 1938, "the income for scholarships."

Fred L. and Florence L. Coburn Fund (1932)
The income of this bequest of $5,000 from Fred L. Coburn "shall be expended by said Trustees in giving aid and assistance to students of M.I.T. . . . preference being given by said Trustees to students residing in Somerville, Massachusetts."

Coffin Memorial Fund (1929)
This gift from the executors of the estate of Charles A. Coffin — a bequest — carried out the wishes of Mr. Coffin. The fund is used for loans or other aid to students as determined by the Executive Committee of the Corporation.

College of William and Mary Scholarship (1904)
Established by the Institute in commemoration of the early association of President William Barton Rogers with the College of William and Mary, this scholarship provides a stipend of $400 per year; it is granted to a student nominated by the faculty of the College of William and Mary.

W. A. Conant Scholarship Fund (1943)
A bequest of $150,000 was made "for the purpose of establishing a permanent fund to be known as the W. A. Conant Scholarship Fund, the income therefrom to be used for the education of native born American Protestant boys of New England of American Protestant parents, who are graduates of some high or preparatory school, public or private, in New England, preference to be given to the graduates of the public schools of Brookline, Massachusetts, but without limitation thereto, and whose parents are financially unable to send them to the

Institute and whose own means are insufficient to allow them to attend the Institute." One scholarship, carrying a grant of full tuition for each of the four undergraduate years, is annually offered to an entering freshman.

Albert Conro Scholarship Fund (1943)
This bequest of Mary T. Conro, sister of Emma O. Conro '84, in memory of their uncle, is "for the purpose of establishing and maintaining a scholarship . . . to be known as the Albert Conro Scholarship."

The George R. Cooke Fund (1939)
Established by a gift in memory of George R. Cooke '08, the income of this fund is awarded preferably to a student in civil engineering or a related field. Consideration is given to those who have had experience through employment in a field before undertaking formal study; the recipient need not necessarily be a candidate for a degree. Grants will be based on character, achievement, need, and future promise.

John G. Crane Scholarships (1951)
This gift of J. G. Crane '90 is for undergraduate awards.

Allen S. Crocker Memorial Fund (1961)
The income of this fund, established as a memorial by the wife of Allen S. Crocker '97, is used to assist worthy and needy young men. Stipendiary awards will be according to demonstrated financial need up to a maximum of tuition in any one year. First preference in the selection is given to students domiciled in the Rochester, New York area. Any unused income from this fund in any one year shall revert to the principal of the fund.

Lucretia Crocker Fund (1916)
By the will of Matilda H. Crocker, the Institute was made the residuary legatee of her estate "for the establishment of one or more scholarships for women in memory of my sister, Lucretia Crocker . . . the income to aid one or more young women in need of pecuniary assistance in obtaining instruction at said Institute."

Eunice McLellan Cruft Fund (1949)
This bequest of Eunice McLellan Cruft was made "to assist young men whose means are inadequate to pay their expenses at the Institute."

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 of $5,000 from James H. Danforth for scholarship purposes was a memorial to his brother, Isaac Warren Danforth.

The Delafield Memorial Fund (1960)
This fund was established by the parents of Benjamin T. Delafield '60 to be used to assist needy and deserving students at M.I.T. and at the discretion and judgment of the Director of Student Aid.

Orville B. Denison Memorial Fund (1960)
The income of this fund, donated by the members of the Class of 1911 as a memorial to Orville B. Denison '11, is used to assist worthy and needy undergraduates at the Institute.

Carl Pullen Dennett Memorial Scholarship Fund (1956)
Established by a gift in memory of Carl Pullen Dennett, this fund provides an award for students in the School of Science, either graduate or undergraduate, who are deemed qualified by scholastic performance, intelligence, character, and promise. The annual selections are made by the Director of Student Aid and the Dean of Students.

Thomas C. Desmond Scholarship (1952)
Established by the gift of Thomas C. Desmond '09, a tuition scholarship for the freshman year is available to a student who plans to study 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 four-year grants to students who maintain academic ranking in the top quarter of the class and demonstrate continued need for financial assistance. A number of these awards are for full tuition, others for three-quarters tuition, and some for half tuition. They are open to all candidates from secondary schools. Application for renewal of these awards for each succeeding year should be made to the Student Financial Aid Committee.

Ann White Dickinson Fund (1898)
This bequest of $40,000 from Ann White Dickinson was made "to establish free scholarships in M.I.T. . . . such persons enjoying benefit . . . shall be worthy young men of American origin."

Fred C. Dobbs Fund (1960)
The income of this fund, established in the name of Dr. F. C. Dobbs by his friends, is used to assist undergraduates to meet their expenses at the Institute. Selection is limited to citizens of the United States who have demonstrated a need for financial assistance and have given evidence of promise.

Dormitory Fund (1903)
This fund was raised by miscellaneous subscriptions; it was formerly known as Students' Aid Fund.

Henry C. Dresser Fund (1965)
Established from the bequest of Henry C. Dresser '92, the income to be used for scholarships, preference being given to students residing in Southbridge, Massachusetts.

Thomas Messinger Drown Scholarships (1928)
A bequest of $50,000 from Mary Frances Drown was designated "to establish scholarships for deserving undergraduate students, to be known as the Thomas Messinger Drown Scholarships."

East Bridgewater Scholarship (1932)
Established by the Institute through a bequest from Horace T. Smith '98, this grant is known as the Horace T. Smith Scholarship Fund. A scholarship carrying a stipend depending on demonstrated need, with a maximum of full tuition for the freshman year, is annually offered a graduate of the High School of East Bridgewater, Massachusetts.

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 funds 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.

William Emerson Fund (1959)
The income of the bequest of the late William Emerson, Dean of the School of Architecture, is used for scholarships in the Department of Architecture.

Fall River and Swansea Scholarships (1932)
These scholarships were established by the Institute through a bequest of Elizabeth R. Stevens, to be known as grants from the Albert G. Boyden Fund. A limited number of scholarships for the freshman year, carrying stipends based on demonstrated need, are annually offered to qualified applicants residing in Fall River or Swansea, Massachusetts.

Leola M. Farnham Scholarship Fund (1966)
Bequest for the purpose of supporting part tuition or full tuition for students in the field of science.

Farnsworth Fund (1889)
This fund was founded by Mrs. Mary E. Atkins of Boston with a gift of $5,000.

Charles Lewis Flint Fund (1889)
This bequest of $5,000 from Charles L. Flint is for the "support of some worthy student, preference to be given to some graduate of the English High School, Boston."

Sarah S. Forbes Fund (1913)
Originally a fund of $2,800 given in trust in 1868 by Sarah S. Forbes to William Barton Rogers and Henry S. Russell, trustees, this fund was transferred in 1913 to the Institute "for the maintenance and education of a scholar in M.I.T."

Clara and F. Joseph Ford Scholarship (1951)
The income of a fund established by Mr. and Mrs. Joseph F. Ford is awarded "to worthy and well-qualified students who have demonstrated a democratic and tolerant spirit and who are well disposed toward people of all creeds and races."

Foundry Educational Foundation Scholarships (1947)
Established by the Foundry Educational Foundation, which represents the American Foundrymen's Association, the Gray Iron Founders' Society and the Malleable Founders' Society, and the Foundry Equipment Manufacturers Association, these awards are open to third- and fourth-year students in business and engineering administration, mechanical engineering, and metallurgy.

Arthur E. Fowle Fund (1956)
The income of this fund established under the will of Arthur E. Fowle '93 is to be used for undergraduate scholarships.

Evert W. Freeman Scholarship Fund (1956)
The income of this fund, established by bequest of Evert W. Freeman '20," shall be awarded annually to a student . . . who shows promise of substantial accomplishment but is in financial need."

Freshman Competitive Scholarships (1932)
These awards cover part tuition for the first year. There are no geographical restrictions of eligibility, and any candidate for admission to the freshman class directly from secondary school may apply. Competition is based upon academic records and evidences of non-academic merit of the competitors, and no special examinations are required.

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. Seven 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 of $10,000 from Arthur B. Gilmore is ". . . for the purpose of assisting needy students who shall be members of the Beta Theta Pi fraternity . . . said net income to be divided among not more than two students in any one year."

James R. Glazebrook Fund (1959)
The income of this fund is to be used to assist needy and worthy undergraduates at the Institute.

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 Foundation, Inc. is granted to a male U.S. citizen majoring in engineering in his junior or senior year. Awards will be made on the basis of academic standing, character and leadership qualities, and financial need.

Barnett D. Gordon Fund (1942)
The income from this gift of $23,500 from 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 aerospace, including those of the 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."

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 the purposes of student aid.

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 student's first year at the Institute.

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 C. Hill in memory of her husband, Bancroft Hill '11. The income is used for scholarship assistance to students in civil engineering who are in need of financial help.

George Hollingsworth Scholarship (1916)
A bequest of $5,000 from Rose Hollingsworth founded this George Hollingsworth Scholarship.

Loren C. Holm Scholarship Fund (1950)
Established by Marie Holm in memory of her father, this fund is designated for worthy and needy students.

Elias Howe, Jr., Scholarships (1949)
The income from a fund established under the will of Julia Howe Stockwell Smith "shall be available for aiding such students and in such amounts as shall be recommended by the Faculty."

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 of $3,000 from T. Sterry Hunt, for seven years Professor of Geology at M.I.T., was designated to found a scholarship in his name. The award is restricted to students in chemistry, and preference is given to those in the higher years.

William F. Huntington Fund (1892)
From Susan E. Covell the Institute received a gift of $5,000 to constitute a fund in memory of William F. Huntington '75, the "income to apply to payments of tuition of needy and deserving students . . . preference to be given to students in civil engineering."

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 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.

I-T-E Foundation Scholarship (1952)
Established by the Harrison Jules Louis Frank and Leon Harrison Frank Memorial Corporation in memory of the founders of the Bulldog Electric Products Company, this $700 scholarship is designated for a needy and worthy junior or senior in electrical engineering who is interested in the field of distribution and/or control of electricity.

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 of $25,000 from Colonel David L. Jewel is "to be used to pay part of the tuition charges for five young men who may be selected by the President or Board of Trustees of the Institute as worthy of assistance, and who, were it not for such assistance might be unable to pursue their studies at such Institute."

Edward A. Jones Scholarship Fund (1947)
A bequest of $25,000 from Edward A. Jones was designated to be used for the establishment and maintenance of one or more scholarships."

Joy Scholarship (1886)
Established by the gift of Nabby Joy, this scholarship was created pursuant to a decree of the Supreme Judicial Court of Massachusetts for the benefit of "one or more women studying Natural Science at M.I.T."

Sarah Maude Kaemmerling Fund (1952)
This fund was established by a gift of $20,000 in 1952 and subsequently added to by a testamentary bequest in 1959. The income is used for scholarships or some alternate form of student aid.

William R. Kales Scholarship Fund (1953)
This fund, endowed by a gift of the Whitehead and Kales Company for scholarship purposes, provides income to assist worthy and needy undergraduates.

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, which is in the process of accumulation, has been established by the Class of 1933 as a memorial to Robert M. Kimball '33.

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 undergraduates in the Schools of Engineering and Science. Consideration in selection is given to eligible individuals recommended by the Kollsman Instrument Corporation.

Kurrelmeyer Fund (1947)
This fund was raised by contributions "for an undergraduate scholarship award to a needy student."

Y. T. Li Fund (1959)
The income of this fund, established by Y. T. Li '38, is used to assist a worthy and needy student enrolled in the Department of Aeronautics and Astronautics; second preference is given to a student of Chinese origin.

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."

Link Foundation Scholarship (1962)
This annual grant from the Link Foundation is made to assist one or more members of the junior class who are enrolled in some branch of engineering closely related to aerospace studies.

Paul Weeks Litchfield Scholarship (1954)
Established in honor of Paul W. Litchfield '96, this scholarship fund aids worthy and needy students at the Institute. Preference in selection is given to those students who have been members of the Boy Scouts of America.

William Litchfield Scholarship (1910)
A bequest of $5,000 from William Litchfield established "a single scholarship . . . known as William Litchfield Scholarship, income to be awarded and paid annually to such student in said Institute as may, upon a competitive examination, be determined by the President of said Institute to be entitled thereto for excellence in scholarship and conduct."

Littmann Foundation Scholarship (1960)
This four-year grant, supplied by the Littmann Foundation, is available in alternate years to a male student desiring to pursue a course of study either in engineering or management as related ultimately to manufacturing. First preference in the selection is given to a well-qualified secondary-school graduate, resident either in the general area of St. Louis, Missouri or Charles City, Iowa. The amount of the award is based on demonstrated need up to the amount of tuition.

Charles E. Locke Memorial Fund (1923)
Preference in making awards from this fund, which was established by the Class of 1896, is given to descendants of members of the Class of 1896, including freshmen.

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 of $5,000 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. Applications must be filed at the Office of the Director of Student Aid.

Percival Lowell Scholarships (1955)
The income of this gift is used for scholarships awarded from time to time at the discretion of the President of the Massachusetts Institute of Techno'ogy 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.

H. W. McCurdy Scholarship (1957)
Established by the Puget Sound Foundation in honor of H. W. McCurdy '22, this gift provides one scholarship for an entering freshman who plans to follow a career in naval architecture or mechanical engineering. Preference will be given to a student from the Seattle area.

Eugene and Margaret McDermott Scholarship Fund (1960)
The income of this fund, established by Mr. and Mrs. McDermott, is used for four-year scholarship grants for students resident in the southwest who wish to study in the earth sciences and allied fields. First preference is given to students resident in Texas, with the next preference to Arizona, New Mexico, or Oklahoma. Grants vary from an honorary award of $200 to a maximum of $2,500.

Alice Maclaurin Scholarship (1951)
Gifts created a scholarship in memory of Mrs. Richard C. Maclaurin.

George 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 and 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 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 Company Scholarship (1954)
This fund of $25,000 functions as an endowment to provide scholarships for male students majoring in fields of study identified with the Martin Company's operation. Students from the Baltimore, Maryland; Washington, D.C.; Denver, Colorado; and Orlando-Cocoa, Florida, 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 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.

Samuel A. Marx Scholarship (1964)
Established by gifts in memory of Samuel A. Marx '07, the income for an annual full or partial scholarship in the School of Architecture.

Margaret A. Matthews Fund (1947)
The income of this bequest from Margaret A. Matthews is "for the benefit of such of the women students at M.I.T. who intend to become teachers."

George H. May Fund (1914)
A gift of $5,000 from George H. May '92 provides a scholarship "to assist graduates of the Newton High Schools who are students at M.I.T. and who have been recommended as eligible by the Superintendent and Head Master of the Newton High Schools." Beneficiaries under this fund are expected to issue notes agreeing to repay, without interest, the amounts received.

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 of $70,000 was made as "an endowment fund under the title of 'The Robert W. Milne Fund,' the income thereof to be used and applied for the assistance of worthy and needy students in obtaining an education in said Institute."

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 of $2,500 from James Buchanan Mirrlees of Glasgow, Scotland, constituted a scholarship in memory of his son, James Henry Mirrlees, who died in 1886 while attending the Institute. The income is awarded to the "student in the third or fourth year of the Mechanical Engineering Course most deserving pecuniary assistance."

M.I.T. Alumni Fund National Scholarships (1957)
These four-year scholarships were established by the M.I.T. Alumni Fund Board to give opportunity to well-qualified young people in the continental United States to come to the Institute. Grants are made on the basis of demonstrated financial need, and continued awards depend upon achievement as well as need for assistance.

M.I.T. Boston Stein Club — New England National Scholarship Fund (1955)
The income of this fund is granted to qualified applicants for the freshman year only. One or more awards are available to New England residents as well as to residents of other parts of the United States. There are no restrictions as to sex, religion, race, or color.

M.I.T. Club of Chicago Scholarship Fund (1944)
This gift of $6,000 was made by Harold B. Harvey '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 Physics Department. Grants are equivalent to one term's tuition and are continued to a recipient for the entire undergraduate period.

Fred W. Morrill Scholarship Fund (1941)
The income from this bequest of Hattie B. Morrill is to be used "for the purpose of providing financial assistance to some student or students at the discretion of the Trustees of said Institute. . . ."

Frederick Taft Moses Scholarship Fund (1959)
This scholarship provides four-year awards ranging from a $200 honorary prize to $2,000 annually, and is offered to young people of superior talent and promise.

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. Holders of these scholarships are given opportunities to work in the marine field during summer vacations as part of their total education. In the selection of candidates, first preference is given to sons of merchant seamen and ships' officers who lost their lives in the line of duty during wartime. In other cases, candidates' fathers must be regularly employed in a seagoing capacity or, if deceased, so last employed. These awards are not limited to courses in marine engineering and naval architecture, but consideration may be given to the desire of qualified candidates to pursue careers in these fields.

Nichols Scholarship (1895)
This bequest of $5,000 from Mrs. Betsy F. W. Nichols constitutes the Nichols Scholarship in memory of her son, William Ripley Nichols '69, for sixteen years Professor of General Chemistry at the Institute. Preference is given to students in the C urse in Chemistry.

Charles C. Nichols Scholarship (1904)
This bequest of $5,000 from Charles C. Nichols constitutes a scholarship.

William E. Nickerson Scholarship Fund (1949)
The income from this fund, established by the Nickerson Trust, is used for a scholarship for a worthy student.

Howard A. Noble '97 Scholarships (1955)
The income of a fund established under the will of Katherine B. Noble and enriched by the bequest of Howard A. Noble, is used to maintain one or more scholarships in engineering.

John Felt Osgood Scholarship (1909)
This bequest of $5,000 was made by Elizabeth P. Osgood "to establish and maintain a scholarship in electricity in memory of my husband, John Felt Osgood."

Louise Parks Knight and Charles F. Parks Memorial Fund (1952)
Established as a memorial to Louise Parks Knight and her father, Charles F. Parks '75, this fund is "used for the aid of poor but worthy students who have already entered upon a course of study but are unable to finish owing to lack of funds."

George L. Parmelee Fund (1921)
This bequest from George L. Parmelee of "one third of my property and estate" specified that "interest thereof be used for tuition of worthy students, either special or regular, according to the direction of the Faculty."

Langdon Pearse Memorial Scholarship (1958)
This fund was established by gift of Mrs. Langdon Pearse in memory of Langdon Pearse '01. Income from the fund is used toward the tuition of graduate students in the field of sanitary engineering, with second preference for undergraduate students in the field of civil engineering.

Frank Stetson Pecker Fund (1947)
This fund was established by the wills of Frank Stetson Pecker and Annie J. Pecker for a scholarship.

Richard Perkins Fund (1887)
The income from half of this bequest of $100,000 from Richard Perkins is available for the "support of free scholarships in said Institute."

Charles H. and Helen Bartlett Pray Fund (1950)
Established under the wills of Charles H. and Helen Bartlett Pray, this fund provides "for scholarships for needy young men."

Florence E. Prince Fund (1943)
This bequest of Florence E. Prince is "for the aid of worthy students who may need assistance in the matter of maintenance and living expenses while pursuing their studies."

Procter and Gamble Scholarship (1955)
One four-year scholarship, covering tuition plus an added amount for books and supplies, is sponsored 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 of $10,000 from Julia A. Read was designated "to establish the Thomas Adelbert Read Scholarship, in memory of my late brother of that name; the income of said fund to be awarded to some worthy and needy student of that institution, preferably to a resident of Fall River. . . ."

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. Richard's Fund (1939)
This bequest of approximately $30,000 is "known as the Charles A. Richard's Fund . . . the income only for assistance of poor Protestant students in the Institute."

Frederick L. Richards Memorial Fund (1960)
The income of this fund, established as a memorial to Frederick L. Richards '95 by his sister, is used to provide scholarship assistance to undergraduate students in chemistry, chemical engineering, or other curricula based on chemistry.

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 of $2,400 from Emeline Roach constitutes a fund "to be known as the John Roach Scholarship Fund, the income to be used to provide an annual scholarship to a needy and deserving student pursuing the Course in Naval Architecture and Marine Engineering."

Karl Robbins Scholarship (1951)
First preference for this scholarship, a gift of the Robbins Foundation, is for either a graduate or undergraduate in textile technology; second preference is to a student in mechanical engineering.

Willard F. Rockwell Scholarship Fund (1961)
The income of this fund, established in honor of Willard F. Rockwell '08, is used to assist needy and worthy undergraduates.

William Barton Rogers Scholarships (1947)
A limited number of four-year grants established in honor of William Barton Rogers, founder of the Institute, enable young men of superior ability and future promise but of limited financial means to pursue an education in either engineering, science, or architecture. A stipend of full tuition plus $300 is granted for the first year. Successful applicants who maintain honor standing will continue to hold full-tuition awards for their undergraduate course and are eligible to apply to borrow up to the amount of tuition annually from the Technology Loan Fund. These scholarships are open to all freshmen with no restrictions of geographical location.

Richard Lee Russel Fund (1904)
The income from this gift of Theodore E. Russel is used to assist a worthy and needy student of high standing in the Department of Civil Engineering, either undergraduate or graduate.

William P. Ryan Memorial Fund (1935)
The income from this fund, established by friends of the late Professor William P. Ryan '18, is used for scholarship aid (graduate or undergraduate) in chemical engineering, the award to be made on recommendation of the Head of the Department of Chemical Engineering.

John P. Schenkl Fund (1922)
This bequest of $20,000 from Johanna Pauline Schenkl is "to be held in trust to establish one or more scholarships in the Department of Mechanical Engineering" in memory of her father, John P. Schenkl.

George Scher Fund (1949)
This gift establishes aid for needy and worthy students.

Science Scholarship (1956)
Donated by friends of M.I.T., this scholarship is designated to assist a needy and promising student in the field of science after the completion of his freshman year. The award is made to citizens of the United States up to the amount of tuition.

Science Teaching Scholarships (1955)
Established by the Institute to encourage young people who wish to follow a career in science teaching in secondary schools, these scholarships are open to students who have completed two years at the Institute and plan to follow a curriculum in science and mathematics teaching. Grants are based on demonstrated need, with a maximum of full tuition.

Paul D. Seghers, Jr., Scholarship (1948)
This award was established by the estate of May Towles Kirk Seghers in memory of Second Lieutenant Paul Dotrenge Seghers, Jr., '45, U.S. Army Corps of Engineers, who was killed in action in the Asiatic area on July 11, 1945, to aid worthy and needy students at the discretion of the Institute.

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 (1371)
Founded with a gift of $5,000 from the English High School Association in memory of Thomas Sherwin, this scholarship is limited to graduates of the English High School of Boston who are pursuing a regular course at the Institute.

Sloan National Scholarships (1953)
Established by the Alfred P. Sloan Foundation, Inc., these scholarships provide aid for students in science and engineering and are open to male students resident throughout the continental United States. Sloan National Scholars hold positions of academic honor at the Institute. Awards are made to men of high character, sound personality, leadership potential, and academic promise. Grants range from a $200 prize scholarship to $2,000 per annum. Awards are renewable each year, subject to performance and in accordance with changing financial need.

G. H. Miller Smith Fund (1945)
Established by Mr. and Mrs. George Blackwell Smith of Lookout Mountain, Tennessee, "as a memorial to their son, G. H. Miller Smith '43, late Lieutenant, U.S. Army, killed in action in France during World War II . . . the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Tennessee."

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 reviewed annually upon application.

Sons and Daughters of New England Puritan Colony Scholarship (1931)
Holders of this scholarship, made possible by a gift of $600 from the Sons and Daughters of New England Puritan Colony, must be of New England ancestry.

Anna Spooner Fund (1939)
The income from this bequest of approximately $7,500 is used "in assisting meritorious students."

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.

Wentworth Stevens Fund (1957)
One-half of the income from this fund, established by William Wentworth Stevens '98 in honor of his mother and father, is added to principal; the remainder is made available for scholarship aid.

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.

Tile Council of America Scholarship (1962)
An annual scholarship of $500 is provided for a student in the School of Architecture who has completed the second year, is a citizen of the United States, and intends to enter the professional practice of architecture.

Samuel E. Tinkham Fund (1924)
Established by the Boston Society of Civil Engineers, this fund is to aid a worthy student in civil engineering.

F. B. Tough Fund (1924)
This fund was established "for the purpose of extending financial assistance to worthy students." Preference is given to students in mining or oil production.

Arthur L. Townsend Fund (1960)
Income of this fund, established by the bequest of Professor A. L. Townsend '13 of the Department of Mechanical Engineering and Director of Lowell Institute, is used exclusively for M.I.T. scholarships. Preference is given to worthy and well-qualified graduates of Lowell Institute who are in good standing and taking a regular full-time day program, preferably in mechanical or electrical engineering.

Y. T. Tsai Memorial Scholarship (1955)
This fund for worthy and needy students was established by gift.

John L. Turner Fund (1960)
Income of this fund, established by John L. Turner '31, is used to assist needy and worthy young men. First preference is given to students who are direct relatives of the donor or residents of the State of Mississippi; second preference to students domiciled in the Southeast.

Union Carbide Engineering Scholarships (1960)
This grant from the Union Carbide Educational Fund is used for four year tuition grants in either mechanical, chemical, or metallurgical engineering.

United States Rubber Company Foundation Scholarships (1957)
These grants, established by a gift from the United States Rubber Company Foundation, are awarded to students who demonstrate need for financial assistance, who show capacity for higher education, and who are interested in a career in industry. The Foundation expects that beneficiaries will assume a moral obligation to repay a part of their grants after graduation and over a reasonable period of time; such repayments will be made to the Institute's scholarship fund and will then be used to help other needy students.

Susan Upham Fund (1892)
This gift of $1,000 from Susan Upham is "to assist students deserving financial aid."

Samson R. Urbino Fund (1927)
This bequest of $1,000 from Samson R. Urbino is "to be used to aid students who need assistance, Germans preferred."

Vermont Scholarship (1924)
This scholarship "in memory of Vermonters who, having received their education at the Institute, served as engineers in the Armies of the Allies in the World War" was founded by a gift of $76,000 from Redfield Proctor '02. The income is awarded annually "to worthy students . . . preference to any *bona fide* residents of Vermont doing undergraduate work at the Institute, and also Vermont students doing graduate work, or students who are graduates of or transfer from Middlebury College or Norwich University . . . who shall meet regular scholastic and other requirements."

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 of $25,000 "plus one half of the remainder of my estate" was designated "to establish free scholarships in M.I.T. . . . such persons enjoying benefit . . . shall be worthy young men of American origin."

Arthur M. Waitt Fund (1925)
This bequest of $10,000 from Arthur M. Waitt was designated for "assisting needy and deserving students in the second-, third-, and fourth-year classes of the Mechanical Engineering Course."

Grant Walker Fund (1943)
The income from this bequest of $50,000 is used "for scholarships for deserving students."

Muriel Alvord Ward Fund (1960)
The income of this fund, established by the gift of Mrs. Ferrari P. Ward, is used to assist needy and worthy undergraduates.

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 of $4,000 from Louis Weissbein was designated "to found a scholarship to be awarded each year to a promising student, preference to be given a Jewish boy in making the award."

Western Electric Scholarships (1956)
These two scholarships in engineering, established by the Western Electric Company, are awarded on the basis of need and ability, with a maximum grant of $800.

Frances Erving Weston Fund (1912)
This bequest of Frances Erving Weston is "to aid a native-born American Protestant girl of Massachusetts."

Samuel Martin Weston Fund (1912)
This bequest of Frances Erving Weston was made to found a scholarship in memory of her husband, Samuel Martin Weston, "to aid a native-born American Protestant boy, preference to be given one from Roxbury."

Archer E. Wheeler Scholarship Fund (1957)
This fund is a bequest of Archer E. Wheeler '95; its income is used for scholarship towards fees for undergraduates at the Institute.

Ray Hill White Memorial Fund (1956)
Income from this fund, established by Frances French White in memory of Ray Hill White '05, is used for scholarship assistance for poor and needy students.

Amasa J. Whiting Fund (1927)
This bequest of $2,000 from Mary W. C. Whiting was designated "to constitute a fund to be known as Amasa J. Whiting Fund . . . the income . . . to pay or help to pay tuition of deserving students whose means are limited. . . . Preference shall be given to students coming from the town of Hingham, Massachusetts."

Granger Whitney Fund (1957)
Income of this bequest, made by the will of Julia Whitney in the name of Granger Whitney '87, is used to assist worthy students of the Institute, with first preference being given to students nominated by the Detroit M.I.T. alumni club

Thomas H. Wiggin '95 Fund (1965)
Established by the bequest of Thomas H. Wiggin '95, the income 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.

Morrill Wyman Fund (1915)
The income from this bequest of Morrill Wyman is "applied in aid of deserving and promising students, but without exclusion in regard to rank, upon the understanding that if in after life the person receiving aid shall find it possible, he shall reimburse the said fund for moneys so applied, but there shall be no legal obligation to make such reimbursement."

Conrad Henry Young Scholarship Fund (1957)
Established by the will of Abby W. Young in memory of Conrad Henry Young '96, the income of this fund is used for scholarships.

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.

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 post-graduate courses.

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.

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; 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 post-doctoral students.

AERONAUTICS AND ASTRONAUTICS

AC Spark Plug Division, General Motors Corporation
For a graduate student in instrumentation; tuition plus $1,900.

Aviation Week
For a male U.S. citizen enrolled for an advanced degree, renewable as long as a satisfactory academic rating is maintained; tuition plus $1,490.

Bendix Corporation
For an outstanding graduate student in automatic controls or control system components; tuition plus not less than $2,100.

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.

Sperry Gyroscope Company
Fellowship for a graduate student in aeronautics and astronautics; tuition plus $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 and Frances Emerson
Gift of $5000 by Dean and Mrs. William Emerson, the income to support graduate students in City 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 semester each in the School of Chemical Engineering Practice; tuition plus $500.

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.

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 $2,100.

Minnesota Mining and Manufacturing Company
For a graduate student in chemistry; tuition plus $2,100.

Monsanto Chemical 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 $1,800 single; tuition plus $2,100 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 $1,800.

ECONOMICS

Center for International Studies
For graduate students interested in economic development and international economics; tuition plus $2,100.

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.

Economics and Industrial Relations
For candidates for the doctorate in these fields; several, tuition plus $1,800.

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 $2,200.

MANAGEMENT

Lord Heyworth
For a full-time student studying for the Master's degree in management; tuition plus $1,000.

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.

Alfred P. Sloan Fellowship in Executive Development
For training in executive development for industrial executives of some experience who are nominated by their employers, a twelve months' program with grants.

United States Steel Foundation
A graduate fellowship for a U.S. student in the area of management; tuition plus $2,400.

MATERIALS

American Can Company
For a pre-doctoral 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.

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.

Shell Companies Foundation
For a candidate for the S.M. or the doctorate, preference being given to a doctoral candidate in his last year of work; tuition plus $2,000 single, $2,600 married with one or more children, for 9 months. For 12 months, $2,500 single, $3,200 married with one or more children.

METALLURGY

Abex Foundation
For a graduate student in the field of metals processing or physical metallurgy; tuition plus stipend.

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.

General Electric Foundation
For a graduate student in the field of ceramics; 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; tuition plus $2,250.

National Steel Corporation
For a graduate student in metallurgy whose research is in the general field of the plastic behavior of steel; tuition plus $2,250.

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.

METEOROLOGY

Bureau of Commercial Fisheries, U.S. Department of the Interior
For a U.S. student in oceanography; tuition for 12 months plus $3,000, with an additional $1,000 for a married student with one or more children.

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

Bureau of Commercial Fisheries, U.S. Department of the Interior
For a U.S. student in fishery technology; tuition for 12 months plus $3,000, with an additional $1,000 for a married student with one or more children.

Miles Laboratories, Inc.
Fellowship for a Graduate in Medicine from a Latin American university; $4,800 per year.

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.

Shell Companies Foundation
For a graduate student in physics, preference to be given to a student in his last year of work for a doctorate; tuition plus not less than $2,000 single or married with no children, $2,600 married with children. For 12 months, $2,500 single, $3,200 married with children.

POLITICAL SCIENCE

International Business Machines Corporation
For a graduate student in political science; tuition plus $1,800 single or married with no children, $2,500 married with 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 Gyroscope Company
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 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

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 $9,000,000 in loans from this Fund.

The following regulations govern loans from the Technology Loan Fund: The amount loaned to a student cannot exceed $7,600. A student may be awarded a loan of up to full tuition in his freshman year; and, in his upperclass years, he may receive amounts which, considering his past awards and the number of years remaining until graduation, will not cause him to incur a debt greater than the $7,600 limit. The repayment rate on these loans is $150 every six months after graduation. Students who continue studies in graduate school (whether or not at M.I.T.), or who are in an active military status, may apply for deferment of repayment until they have completed their programs. Loans carry 1 per cent per annum interest during enrollment and 2 per cent per annum after graduation or termination of enrollment.

NATIONAL DEFENSE STUDENT LOAN FUND

The National Defense Student Loan Program, administered by M.I.T. in conjunction with the Technology Loan Fund, makes loans available on terms quite similar to those described above. The maximum available to an undergraduate 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. Repayment commences six months after the completion of studies and is spread over a ten-year period. A student may apply for deferment of repayment if he enters 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 the loan may be forgiven if the borrower chooses a career in teaching. Loans carry no interest while the student is enrolled, and 3 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 inquiries should be made to the Director of Student Aid.

Boston Stein Club Freshman Loan Fund (1953)
Established by the M.I.T. Boston Stein Club, this fund is designed to assist needy students resident in the Greater Boston area. It is open only to first-year students who show good promise, and, in general, grants are for less than full tuition. Recipients are required to sign notes to repay amounts granted, without interest, after graduation.

Denison K. Bullens Fund (1958)
Gift of D. K. Bullens '09, the income of this fund is used as a loan to assist needy and worthy undergraduates, with first preference to a student in metallurgy.

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.

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.

Ford Foundation Loan Program (1960)
Loan grants up to a maximum of $3,300 annually to certain candidates for the doctorate in an engineering field are made from this fund established by a gift of the Ford Foundation. The grants are open only to residents of the United States and Canada; to qualify for consideration an individual must plan a career in teaching engineering at the college or university level and be recommended by the Dean of Engineering.

Ethel I. Fryer Scholarship Loan Fund (1951)
This fund was a gift of H. Fryer '11 to establish a loan scholarship for deserving students from the states of Washington, Oregon, and California. Grants are limited to $600 per student and are repayable within five years of graduation.

Nathan R. George Loan Fund (1943)
This bequest of $29,000 from Professor Nathan R. George of the Department of Mathematics is "to be loaned to undergraduates of M.I.T. who are either citizens or who intend to become citizens" and who are members of the third- or fourth-year classes.

John A. Grimmons Fund (1930)
In memory of John A. Grimmons '21 through a deed of trust executed by the late C. Lillian Moore, the Institute received a sum of money to be "used in making loans to undergraduates who are preparing to make electrical engineering their life work; such loans to be known as given from the John A. Grimmons Perpetual Loan Scholarship; such loans are not to exceed $600 to any one student in any one year and are to be made on condition that the loans shall bear interest at five per cent and shall be repaid within ten years, and that repaid loans shall be treated as income to revert into the Perpetual Loan Fund and to be reloaned from time to time; such loans are to be protected by life insurance. . . . Loans are to be awarded to male, white, native born citizens of the United States, who are loyal to the State and Nation, are of sound physical body, and show steadiness of purpose and zeal in educational acquirements."

Gerald L. Hartstein Memorial 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 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 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 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 of $5,000 from Elizabeth H. Lamson is used in aiding a worthy student of excellent character who "must have shown not only respect for his parents but also proper consideration for the rights of others." Students thus aided shall repay if and when they find themselves able to do so.

Harry J. and Iolia R. Lohbiller Fund (1962)
This loan 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 J. Mead Fund (1951)
This bequest of George J. Mead '16 is for loans to students in aeronautics and astronautics and mechanical engineering.

Arthur T. Nelson, Jr. Memorial Fund (1962)
Established by a gift of Mrs. Arthur T. Nelson and the Trustees of Arthur T. Nelson, Jr., this fund is used for student loans administered under the regular procedures adopted by the Institute.

Michael Joseph Pollock Student Aid 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.

M. H. Rogers 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 Student Aid Fund (1960)
This gift of the Technology Matrons is used to assist needy and worthy students with loans.

Robert Kelley Thulman Student Aid Fund (1963)
The gift of the wife of Robert Kelley Thulman '22, this fund is designated for loans to students.

Richard H. Tingey Memorial Loan 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. Grants to undergraduate students from this fund are administered in the same manner as those from the Technology Loan Fund.

Frank P. Wakefield Fund (1955)
One-fourth of the income of this fund is available for loans to needy and worthy students majoring in chemistry, chemical engineering, and biology.

APPENDIX B: 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" to undergraduates on the basis of essays written on topics approved by the Department of Humanities. The prizes are made possible by a bequest of $5,000 from Robert A. Boit.

Borden Freshman Prize (1956)
This $200 prize established by the Borden Company Foundation is awarded to the student who has achieved the 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 semesters 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 Mechanical Engineering Department, Class of 1911, endowed awards totalling $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
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 $50 is made to the most meritorious senior who has shown outstanding originality in his work in the regular Course in Chemical Engineering.

CHEMISTRY

Merck and Company Prize
Awarded to the outstanding student in the senior class in chemistry.

CIVIL ENGINEERING

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.

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.

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 three 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 Mechanical Engineering Department, 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.

Lubrizol Awards (1963)
Prizes totalling $400 are awarded to students in the second-year subject in ENGINEERING DESIGN AND MANUFACTURE (2.861), under a grant of the Lubrizol Foundation of Cleveland, Ohio.

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.

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

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.

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 Nuclear Engineering Department.

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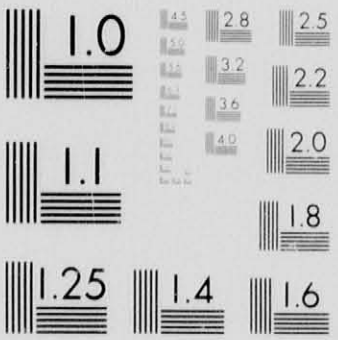
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