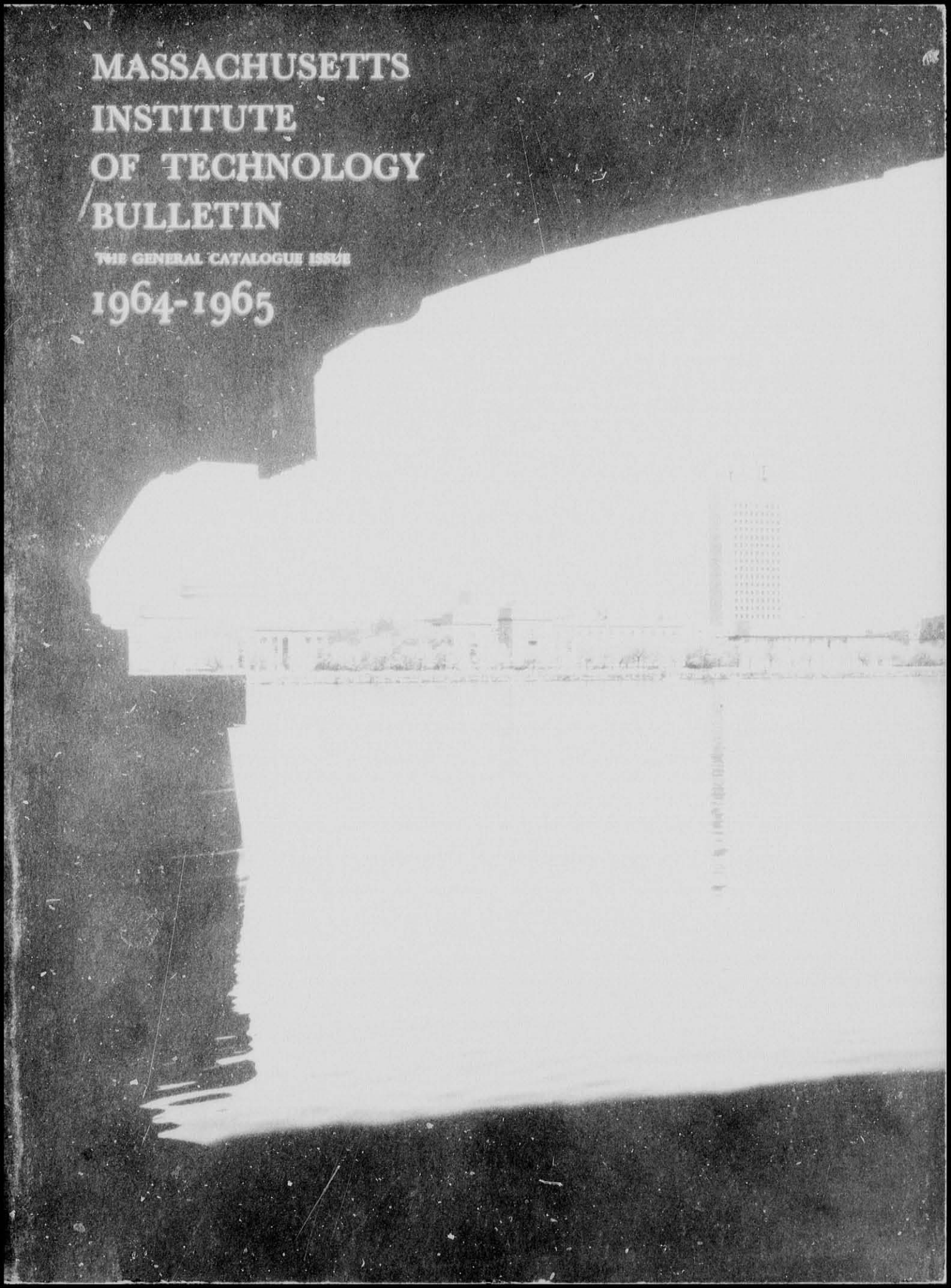
MASSACHUSETTS INSTITUTE OF TECHNOLOGY BULLETIN

THE GENERAL CATALOGUE ISSUE

1964-1965



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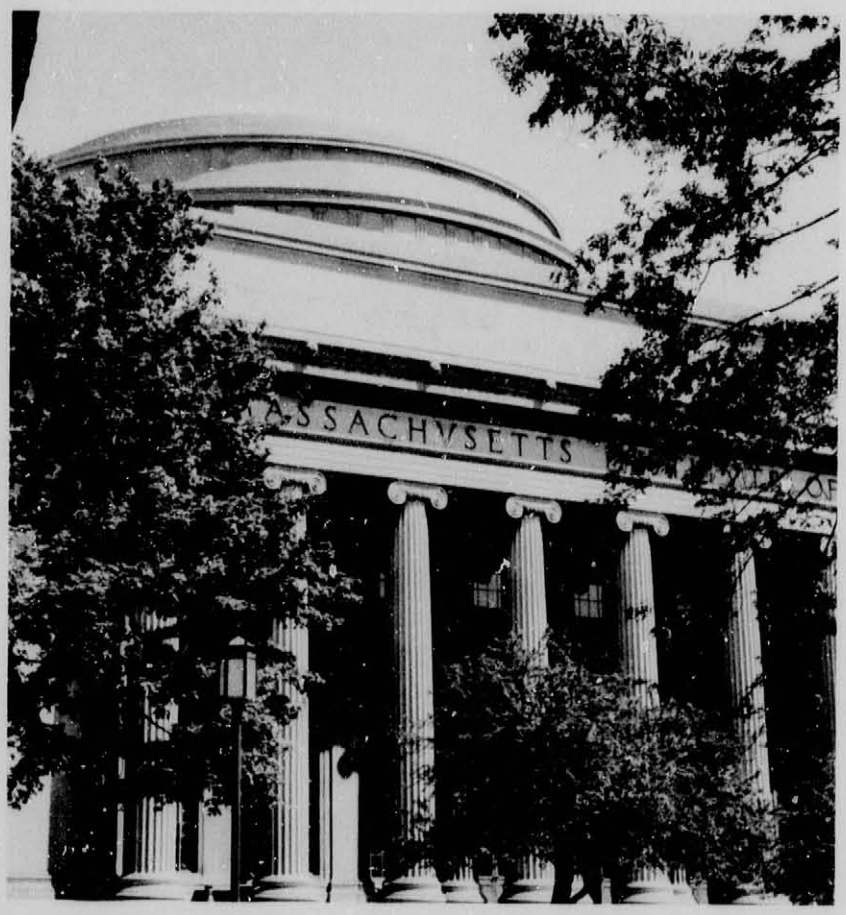

The Massachusetts Institute of Technology Bulletin is published five times yearly by the Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139, in March, May, July, September, and November. Issues of the Bulletin include the Reports of the Treasurer and of the President, the Summer Session Catalogue, the Undergraduate Catalogue, and the General Catalogue.

Volume 99, Number 5, July, 1964. Second class postage paid at Boston, Massachusetts.

Send undeliverable copies and changes of address to 211 Massachusetts Avenue, Cambridge, Massachusetts, 02139.

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

AERONAUTICS AND ASTRONAUTICS

ARCHITECTURE

BIOLOGY

CHEMICAL ENGINEERING

CHEMISTRY

CITY AND REGIONAL PLANNING

CIVIL ENGINEERING

ECONOMICS AND SOCIAL SCIENCE

ELECTRICAL ENGINEERING

GEOLOGY AND GEOPHYSICS

HUMANITIES

INDUSTRIAL MANAGEMENT

MATHEMATICS

MECHANICAL ENGINEERING

METALLURGY

METEOROLOGY

MODERN LANGUAGES

NAVAL ARCHITECTURE AND MARINE ENGINEERING

NUCLEAR ENGINEERING

NUTRITION AND FOOD SCIENCE

PHYSICS

PSYCHOLOGY

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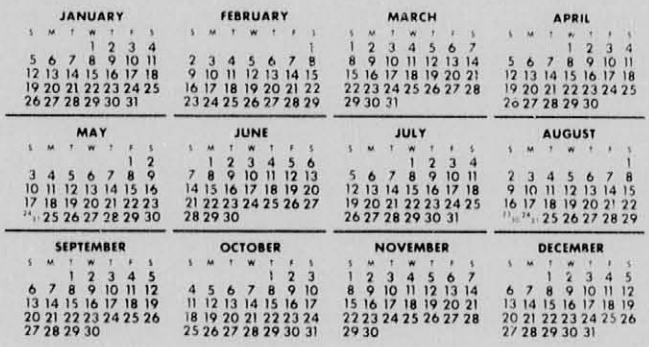
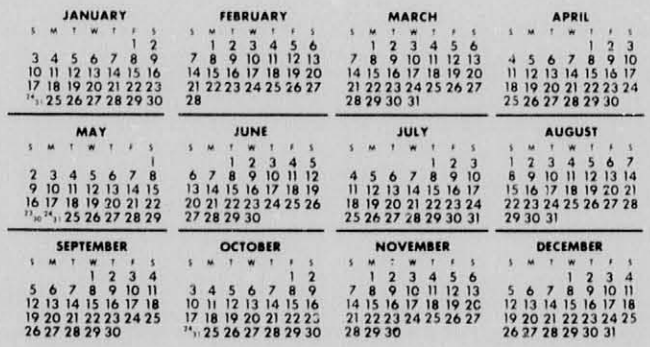
ACADEMIC CALENDAR

1964



SEPTEMBER 17	FIRST TERM BEGINS FOR FRESHMEN
SEPTEMBER 21	FIRST TERM BEGINS FOR UPPERCLASSMEN AND GRADUATE SCHOOL (*Registration Day*)
OCTOBER 12	COLUMBUS DAY (*holiday*)
NOVEMBER 11	VETERANS' DAY (*holiday*)
NOVEMBER 14	FIELD DAY (*exercises omitted*)
NOVEMBER 26 *through* NOVEMBER 29	THANKSGIVING VACATION
DECEMBER 19 *through* JANUARY 3	CHRISTMAS VACATION

1965



JANUARY 20	LAST EXERCISES OF THE FIRST TERM
JANUARY 21 *through* JANUARY 23	READING PERIOD
JANUARY 25 *through* JANUARY 29	EXAMINATION PERIOD
FEBRUARY 8	SECOND TERM BEGINS (*Registration Day*)
FEBRUARY 22	WASHINGTON'S BIRTHDAY (*holiday*)
MARCH 29 *through* APRIL 4	SPRING VACATION
APRIL 19	PATRIOTS' DAY (*holiday*)
MAY 25	LAST EXERCISES OF THE SECOND TERM
MAY 26 *through* MAY 28	READING PERIOD
MAY 29 *through* JUNE 4	EXAMINATION PERIOD
MAY 30	MEMORIAL DAY (*holiday*) (*exercises omitted Monday, May* 31)
JUNE 11	COMMENCEMENT DAY
JUNE 21	SUMMER SESSION 1965 BEGINS
SEPTEMBER 20	FIRST TERM 1965 BEGINS

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To Educate for Leadership

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

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

M.I.T. has been built upon these convictions. It has grown in stature and influence as science and engineering have become increasingly interwoven with the whole fabric of our economic, political, and social life — indeed, as they have become basic elements of our national culture, affecting ever-widening areas of human endeavor.

Our central mission is to send forth men and women of highest professional competence, with the breadth of learning, the understanding, and the char-

acter to deal creatively with the increasingly complex problems of our time. Accordingly, to the fields of our traditional competence — engineering, architecture, and the physical and life sciences — the Institute has now undertaken teaching and research in those of the social sciences that relate most directly to modern technology. M.I.T. has thus passed from the limited stage of an institute of technology to the broader scope of a modern university centered in science — a literal expression of our belief in the unity of contemporary society.

The basic purposes of M.I.T. are to teach and to contribute a share to the enlargement of knowledge and understanding. We propose to fulfill these purposes with energy and imagination, and within our own fields we shall be content with nothing less than a quality of effort that sets new standards of excellence for American education.

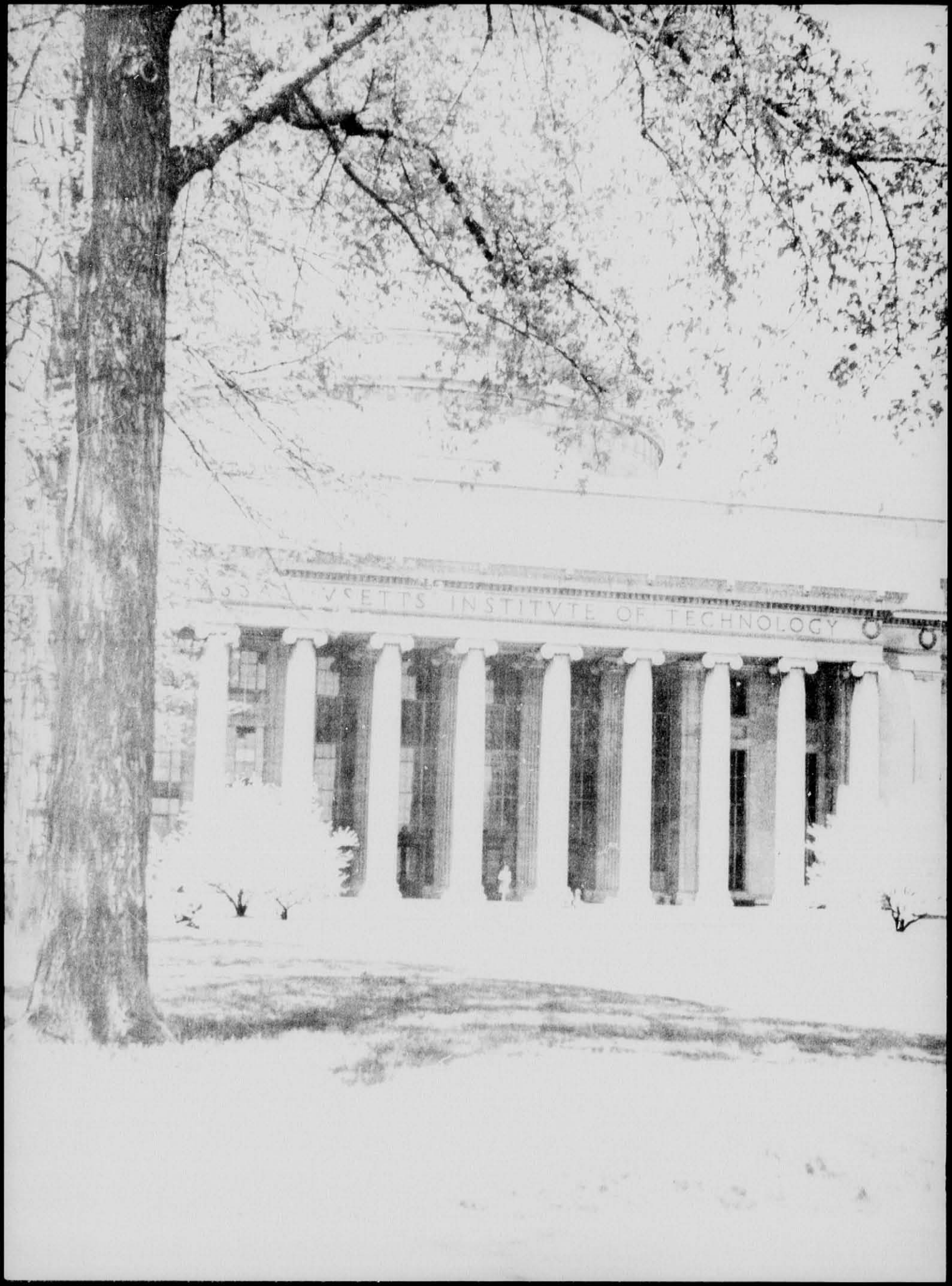
Throughout the entire history of the Institute, much of the strength of our educational plan has been derived from the rigor and thoroughness of our method. From the day he enters as a freshman, the undergraduate learns to work in depth and to be held accountable for the results. He learns also to work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

But rigor and discipline are not enough. We recognize it as our duty to guide each student along paths that will excite him, to capture his mind and enthusiasm, to provide him with abundant examples of fine scholarship, and to develop in him a consuming interest in knowledge and understanding.

We also accept an obligation to cultivate a moral and physical — as well as an intellectual — environment in which will thrive qualities of judgment, fortitude, and integrity. By precept and example we must convey a respect for moral values, a sense of the duties of citizenship, a feeling for taste and style, and the capacity to recognize and enjoy the first rate.

Whether or not an education can be called liberal or technical is far less a question of subject matter than one of attitude, treatment, and approach. And in these terms our aim for education at M.I.T. is indeed liberal and profoundly relevant to the central problems of our age. The measure of our greatness will truly be determined by our capacity to educate for leadership.

JULIUS A. STRATTON


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 Sciences, Management, and Science — and a number of interdisciplinary groups. There are about 7,000 students (including nearly 200 women), more than 3,500 of them studying for undergraduate degrees; about 800 members of the faculty; and a supporting teaching staff of 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 27 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. Continuing search for new methods of teaching, the 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 75 foreign nations; the proportion of foreign students at the Institute (about 12 per cent) is one of the highest at any 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

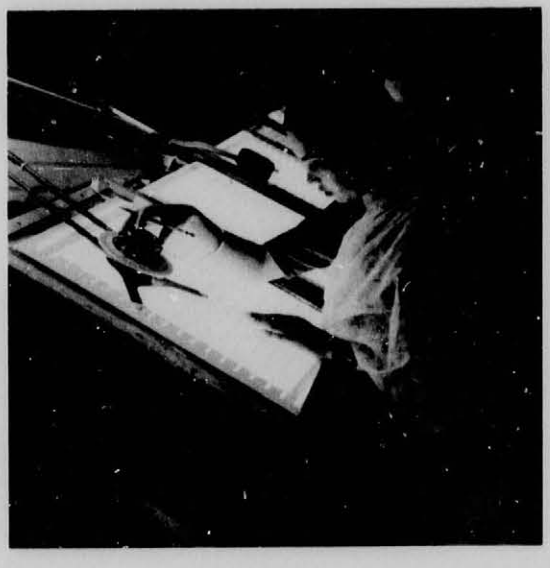
The scope of M.I.T. has always been wider than its title, "institute of technology," might suggest, and today the Institute's commitments to the humanities and social sciences are providing an entirely new dimension of scholarship. The increasing impact of science upon our social institutions and upon 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.

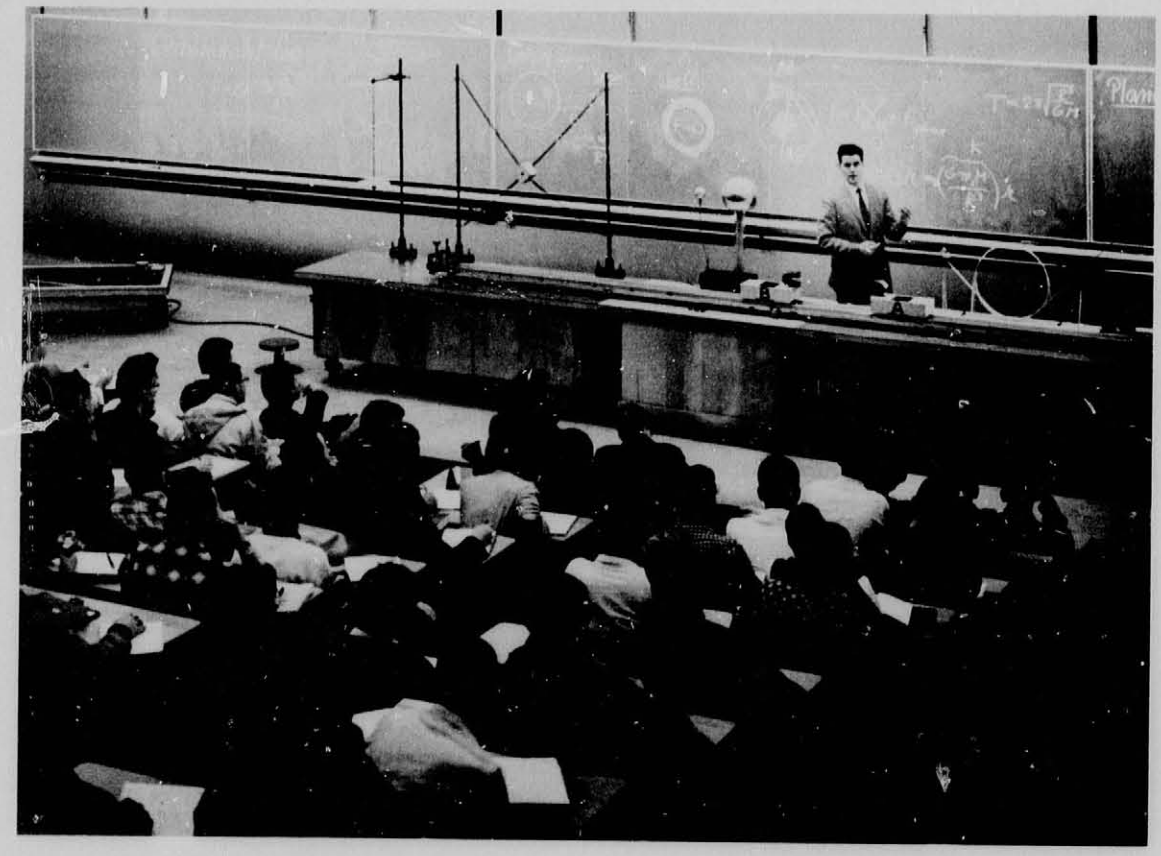
Every M.I.T. undergraduate must study one subject each semester in the humanities program — approximately 20 per cent of his undergraduate work — and he may if he chooses take two more humanities subjects as electives in the last

two years of any professional course. 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."





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

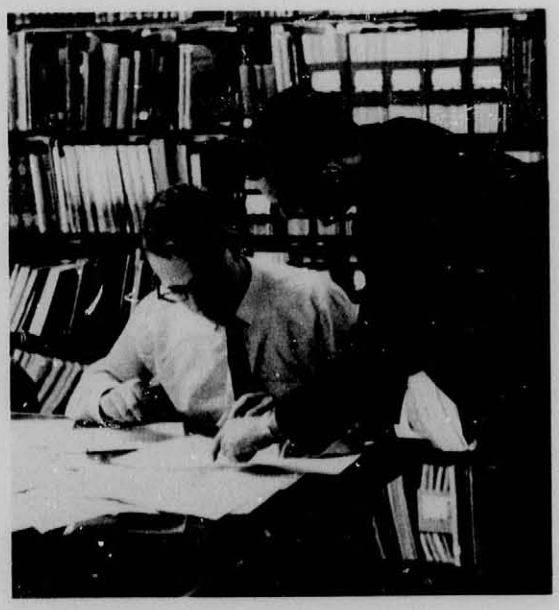
The chart on the following pages shows schools, departments, undergraduate and graduate Courses and degrees, and Course numbers. Undergraduate Courses, including Cooperative Courses which provide periods of on-the-job experience in industry, require four years of full-time study for the Bachelor of Science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

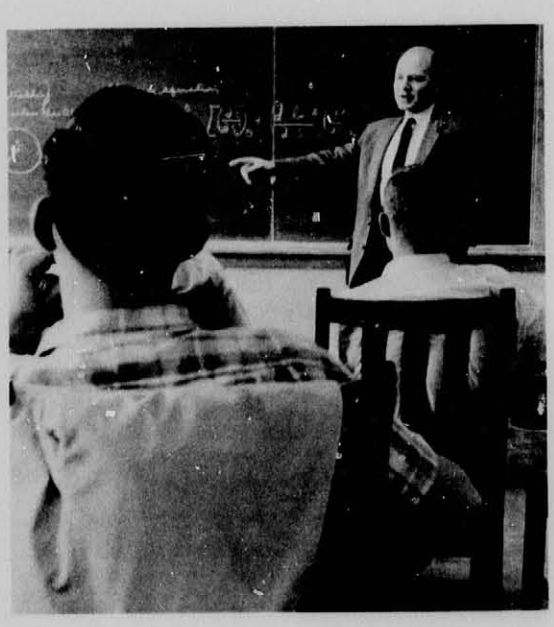
Undergraduate Courses and degree requirements are described in Section 2 of this Catalogue; graduate fields of study and degree requirements, in Section 3. The statements of each department in Sections 4, 5, 6, 7, and 8 should be consulted for detailed information about the degrees offered.

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

[1] 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 1.07 indicates a subject given in the Course in Civil Engineering.

[2] The Engineer degrees include Chemical Engineer (CHEM.E.), Civil Engineer (C.E.), Electrical Engineer (E.E.), Engineer in Aeronautics and Astronautics (E.A.A.), Marine Mechanical Engineer (MAR.MECH.E.), Materials Engineer (MAT.E.), Mechanical Engineer (MECH.E.), Metallurgical Engineer (MET.E.), Mineral Engineer (MIN.E.), Naval Architect (NAV.ARCH.), Naval Engineer (NAV.E.), and Nuclear Engineer (NUCL.E.).



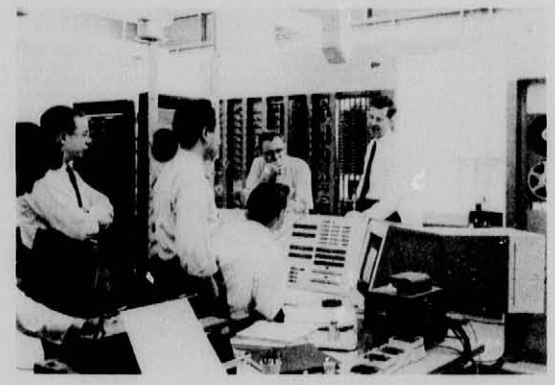


SCHOOLS, DEPARTMENTS, COURSES, AND DEGREES

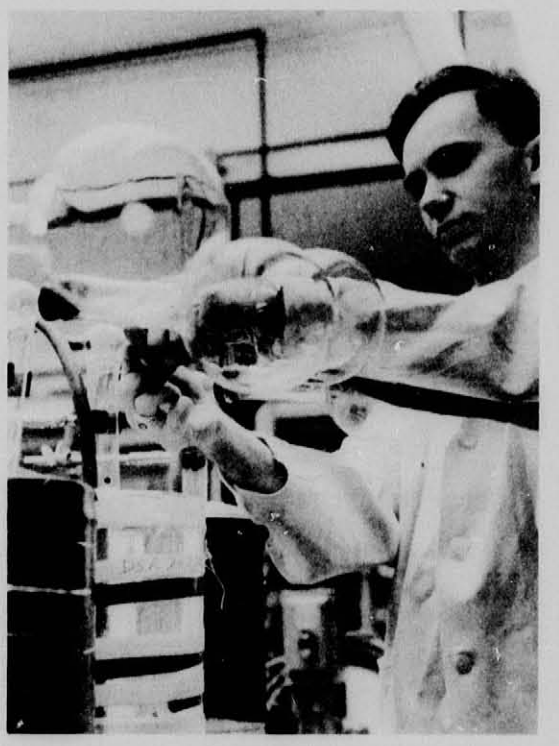
Schools and Departments	*Undergraduate Courses (and Course Numbers)*	*Bachelor's Degrees*	*Graduate Courses*	*Graduate Degrees*
School of Architecture and Planning				
Department of Architecture	ARCHITECTURE[1] (IV-A)	B.ARCH.	ARCHITECTURE (IV-A)	M.ARCH.
Department of City and Regional Planning			CITY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

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

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 SHIP-BUILDING MANAGEMENT[3,4] (XIII-B)	S.B.	SHIPPING AND SHIP-BUILDING MANAGEMENT (XIII-B)	S.M.
			NAVAL CONSTRUCTION AND ENGINEERING[3] (XIII-A)	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 and Social Science	ECONOMICS, POLITICS, AND ENGINEERING (XIV-A)	S.B.	ECONOMICS AND SOCIAL SCIENCE (XIV)[3]	S.M., PH.D.
	ECONOMICS, POLITICS, AND SCIENCE (XIV-B)	S.B.		
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			LINGUISTICS (XXIII)	PH.D.
Department of Psychology			PSYCHOLOGY (IX)	PH.D.
Alfred P. Sloan School of Management	INDUSTRIAL MANAGEMENT (XV)	S.B.	INDUSTRIAL MANAGEMENT (XV)	S.M., PH.D.
School of Science				
Department of Biology	LIFE SCIENCES (VII)	S.B.	BIOLOGY[3] (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[3] (XII)	S.B.	GEOLOGY AND GEOPHYSICS[5] (XII)	S.M., PH.D., SC.D.
	GEOLOGY AND GEOPHYSICS[3,4] (XII-A)	S.B.	GEOLOGY AND GEOPHYSICS[3,4] (XII-A)	S.M.
Department of Mathematics	MATHEMATICS (XVIII)	S.B.	MATHEMATICS (XVIII)	S.M., PH.D., SC.D.
Department of Meteorology			METEOROLOGY[5] (XIX)	S.M., PH.D., SC.D.
Department of Nutrition and Food Science			NUTRITION AND FOOD SCIENCE[3] (XX)	S.M., PH.D., SC.D.
Department of Physics	PHYSICS (VIII)	S.B.	PHYSICS (VIII)	S.M., PH.D., SC.D.



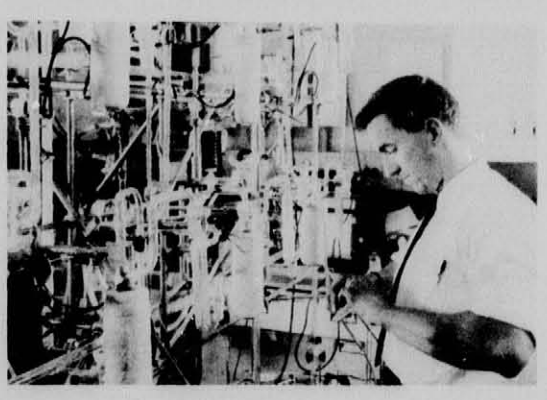
THE TX-O DIGITAL COMPUTER



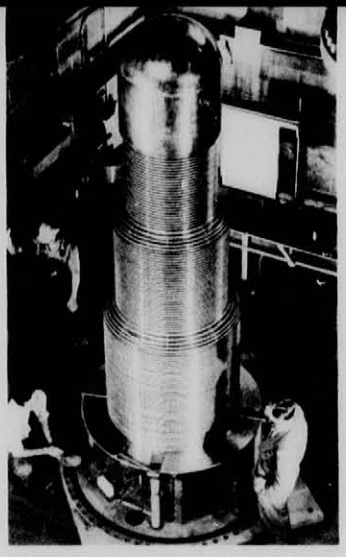
IN THE FOOD SCIENCE LABORATORIES

A COUNTER IN THE RADIOACTIVITY CENTER

POWDER METALLURGY IN THE METALS PROCESSING LABORATORY

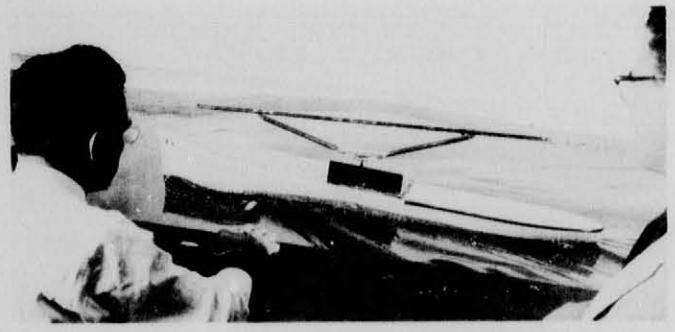


IN THE DEPARTMENT OF GEOLOGY AND GEOPHYSICS



THE ROCKEFELLER VAN DE GRAAFF GENERATOR

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, many of its staff are faculty members of the Department of Economics and Social Science; the Center provides research opportunities which 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, scheduled for completion in the spring of 1965, will provide 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 will provide 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 research 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 1966; both the building and the research program are financed in part from a grant 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 forty-five 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 has shared with M.I.T. the cost of the I.B.M. 7094 computer in the Computation Center, 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.

Cooperative Computing Laboratory

The Cooperative Computing Laboratory contains an I.B.M. 709 Computer with associated off-line equipment and facilities for on-line Flexowriter input, visual display, and real-time processing of analogue data. In addition, the laboratory has an I.B.M. 1401 system used as an off-line facility and a Photon S-560 paper-tape-driven photocomposing unit for use in mechanized documentation studies. Originally established to meet the heavy computational requirements of certain research groups at the Institute, the Laboratory now provides an Institute-wide computational facility used for

research and for some teaching and administrative work. There is particular emphasis on applications in mathematical physics and on non-numeric uses of computers.

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

The Joint Center was established in 1959 to link research activities of M.I.T.'s Department of City and Regional Planning 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. The Laboratory is engaged entirely in basic research. Among many projects are theoretical studies of the atomic nucleus; studies of the photoproduction of mesons and other high-energy phenomena; studies of the new fundamental particles involving broad experimental endeavors using bubble chambers, 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 National Laboratory. 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. 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

A major national program of research on advanced computer systems and their exploitation is under way at M.I.T. under the project name MAC, an acronym derived from two titles: machine-aided cognition, expressing the broad project objective, and multiple-access computers, describing its major tool. The broad goal of the Project is the development of new ways in which on-line use of computers can aid people in their creative work, whether research, engineering, design, management, or education; a major part of the Project 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. The Project 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; and a program of basic research aimed at providing better theoretical tools for describing, analyzing, and synthesizing complex logical structures and procedures.

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.

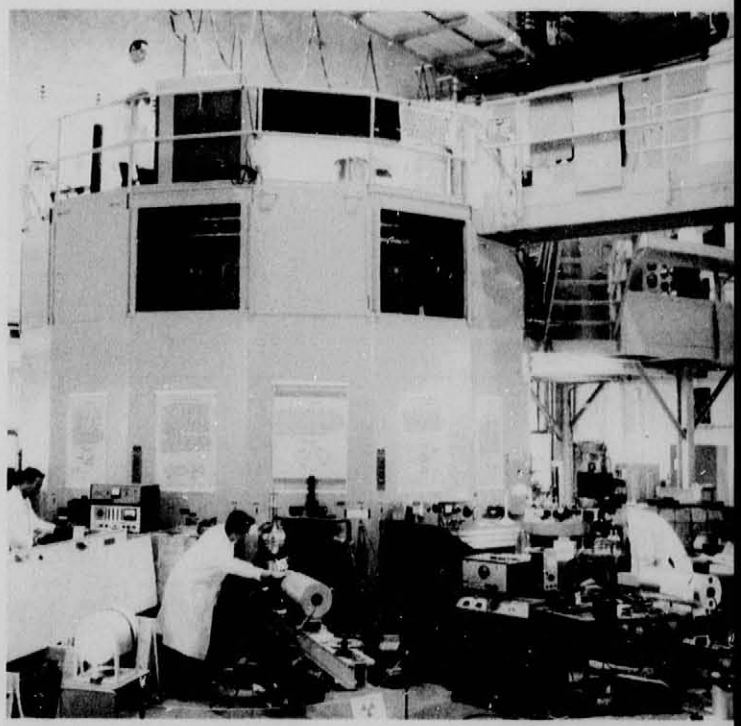
National Magnet Laboratory

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.

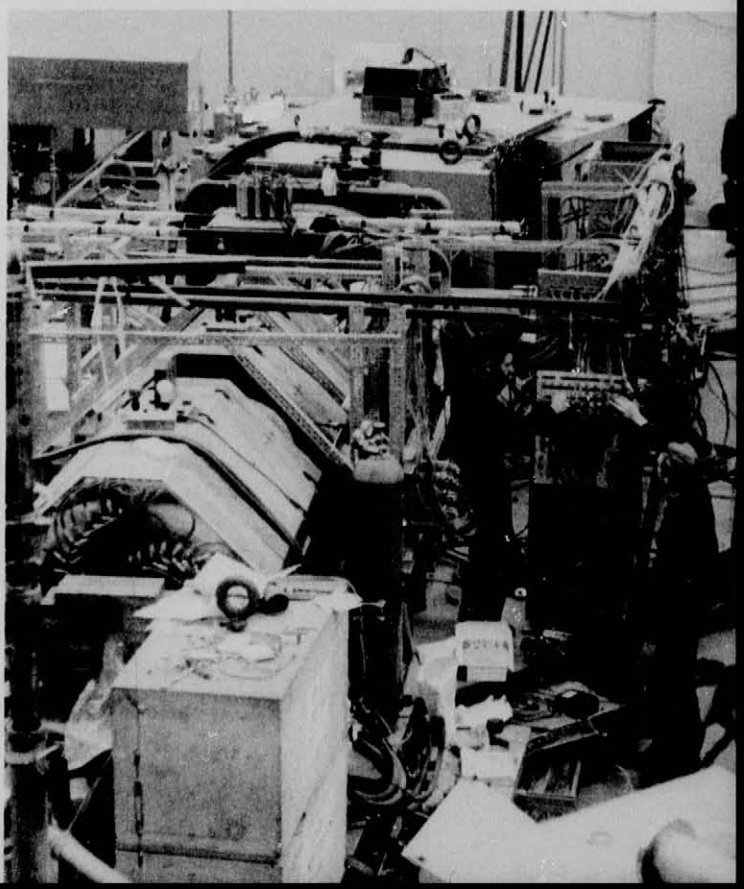
Operations Research Center

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 pro-



THE M.I.T. REACTOR

A LARGE SCINTILLATION COUNTER AT THE CAMBRIDGE ELECTRON ACCELERATOR



vide 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. Other graduate students who desire to concentrate more heavily in operations research 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

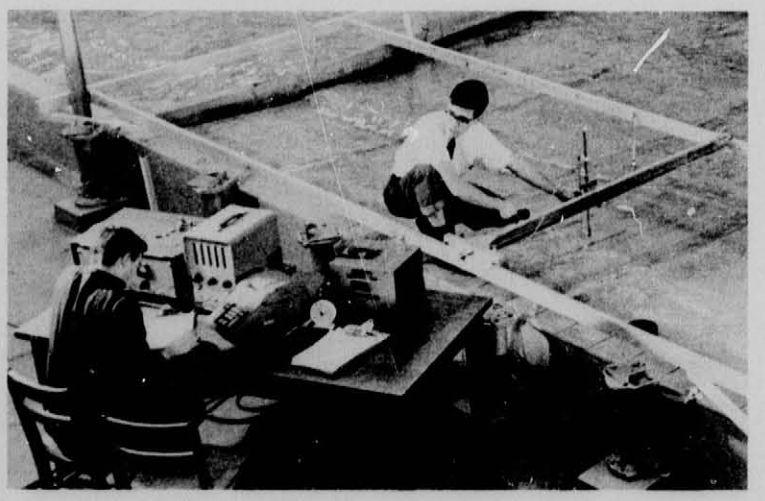
The Spectroscopy Laboratory has pioneered in the ruling of large, high-performance diffraction gratings and in designing, building, and utilizing high-resolution spectrometers. These instruments are used in studies of molecular geometry, of the properties of solids, and of complex atomic spectra. Investigations in the application of masers to such problems as the generation of radiation in the far infrared region and simulated Raman 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 on page 323 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.

HYDRODYNAMICS LABORATORY



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 resources in excess of 850,000 volumes, the M.I.T. Libraries are a vital resource for the support of both teaching and research. Nearly 7,000 current journals and serials and 1,400 government document series, together with extensive back files, provide comprehensive holdings in all major fields. These are enriched by numerous special collections, 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, and three branches: The Rotch Library of Architecture and Planning; the Dewey Library (economics, industrial management, and industrial relations); the Engineering Library (with a separate aeronautics and astronautics branch); the Humanities Library (with a branch Music Library and a reserve book room); and the Science Library (with the Lindgren Library for the earth sciences).

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

The libraries serve primarily Institute students, faculty, staff members, and their families. Visiting scholars and 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 New Gallery in the Hayden

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

Library. Here the work of recognized contemporary painters and sculptors can be enjoyed by students, faculty, and visitors to the Institute. Through gifts and purchases a permanent art collection is being assembled, and these works are displayed in living areas and public spaces in the Institute buildings.

In addition, the Francis Russell Hart Nautical Museum containing a magnificent collection of ship models and the Allan Forbes and Arthur H. Clark print collections, has ample quarters of its own. The collections of ceramics and of minerals, though not fully displayed in public, are also distinguished.

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.

Walker Memorial, built in memory of President Francis Amasa Walker, is the center of student social life. Nearby are the Alumni Swimming Pool and squash courts. A new Student Center with social rooms, offices for student activities, and a number of stores, will be ready in the fall of 1965.

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

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

Auditorium and Chapel

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

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

Endicott House

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

SCIENCE LIBRARY READING ROOM

ENDICOTT HOUSE

Other Teaching Facilities

The Institute's philosophy of "learning by doing" sometimes carries its teaching program beyond the Cambridge campus. Three departments (Aeronautics and Astronautics, Electrical Engineering, and Mechanical Engineering) have Cooperative Courses of study, Courses combining academic work at M.I.T. with on-the-job practice in industry. 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 nearby Bayway Refinery of the Humble Oil Company.

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

Organization of the Institute

The governing body of the Institute is a board of trustees known as the Corporation, over which the Chairman presides. Its members include more than sixty distinguished leaders of science, engineering, industry, and education and (*ex-officio*) the President, Vice 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 six Vice Presidents. The academic program is directed by the President, the Provost, and five deans, each responsible for the undergraduate and graduate programs in one of the five academic schools.

The Dean of Student Affairs is directly concerned with all aspects of student life, and the Dean of the Graduate School is concerned with coordinating educational policies of the graduate program. Officers concerned with the administration of academic affairs meet regularly in the Academic Council. Other administrative officers join them to form the Administrative Council.

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

The President presides over the faculty of the Institute, which consists of all professors, associate professors, assistant professors, certain professors emeriti, certain designated instructors and research associates, and a number of administrative officers ex officiis.

The academic staff of the Institute — including instructors, research associates, and teaching, research, and technical assistants who are not members of the faculty — totals about 2,600.

SCHOOL OF CHEMICAL ENGINEERING PRACTICE

Student Housing

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

In a typical year, nearly half of the undergraduate student body lives in Institute Houses on the campus. Another 30 per cent live in fraternities. About 20 per cent of M.I.T.'s graduate students live in the Graduate House, and there are modern apartment accommodations for a number of married students and their families.

DORMITORIES

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

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

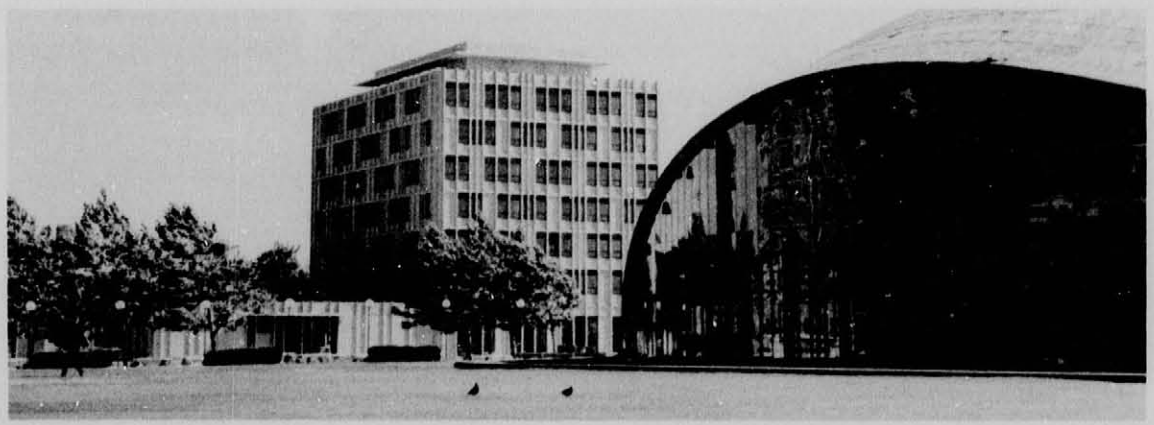
The Houses for Undergraduate Men

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

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

Residence for Women Students

McCormick Hall, M.I.T.'s first on-campus residence for women, includes accommodations for 116 women students and four guests, a House Master's suite, dining, conference-seminar, and lounge rooms, garden court, penthouse, and sun deck. There are five double and twelve

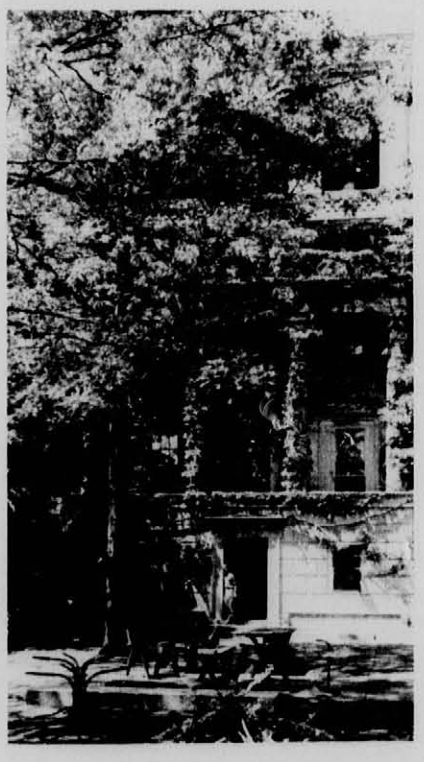


BURTON HOUSE

BAKER HOUSE

WESTGATE

SENIOR HOUSE



MC CORMICK HALL *(below and opposite)*

single rooms on each of the residence floors of the building, and each floor includes a small lounge, kitchenette, and laundry facilities. In addition to the public rooms on the first floor, the eighth-floor penthouse provides community study and lounge space for residents.

Residence in this new dormitory, including commons meals in the House dining room, is required of all women students who entered in September, 1963, or after, unless they live at home.

The Graduate House

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

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

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

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

General Information

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

OTHER HOUSING FACILITIES

Fraternities

Recognized fraternities at the Massachusetts Institute of Technology include twenty-eight chapters situated on private property in Cambridge, Boston, and Brookline. Fraternities participate in M.I.T. student government through the Interfraternity Conference. Each house has one or more members of the Institute faculty or alumni as advisers. Each has its own dining room and provides experience in community planning and living similar to that achieved in the Institute Houses. Further information may be obtained from the Interfraternity Conference, Walker Memorial, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.

Cooperative Living

The M.I.T. Student House, organized by several alumni, is a cooperative living group for undergraduate men. In the interest of economical living, students operate and maintain the house themselves — aside from cooking and major repairs — thus substantially reducing the total of board and room expense. For information about membership in this group, write directly to the President, M.I.T. Student House, 111 Bay State Road, Boston, Massachusetts, 02115.

Residence for Married Students

On-campus housing for 210 student families is provided in Westgate, a coordinated development of five buildings at the west end of the campus containing 90 one-room, 60 one-bedroom, and 60 two-bedroom apartments and a number of community facilities, including a pediatric clinic associated with the M.I.T. Medical Department. The project is designed specifically so that rentals may be lower than prevail for similar modern accommodations elsewhere in the Greater Boston area. Further information and rental applications may be obtained from the Office of the Dean of Residence.

In addition, students will find a wide variety of local real estate listings at the Housing Bureau maintained by the Dean of Residence.

Nonresident Students' Association

Excepting foreign students, any single male undergraduate not affiliated with an M.I.T. dormitory, M.I.T. fraternity, or the M.I.T. Student House is considered a member of the Nonresident Students' Association. Other students, particularly foreign students, are welcome to join the organization should they so desire.

All members are subject to a house tax of $2.50 per term payable with other Institute fees.

The Association maintains a fully furnished building at 318 Memorial Drive on the west campus with lounges, study areas, eating and kitchen conveniences, showers, and bunk room for overnight contingencies. An Institute graduate student serves as resident Tutor.

The Association sponsors social, athletic, and scholastic programs for its members throughout the academic year.

Campus Activities

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

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

Athletics

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

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

Excellent facilities for these sports are provided by the du Pont Athletic Center, Rockwell Cage, Briggs Field, du Pont Tennis Courts, the Alumni Swimming Pool, and the Sailing Pavilion and boat house on the Charles River. There are also pistol and rifle ranges on campus.

Drama

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

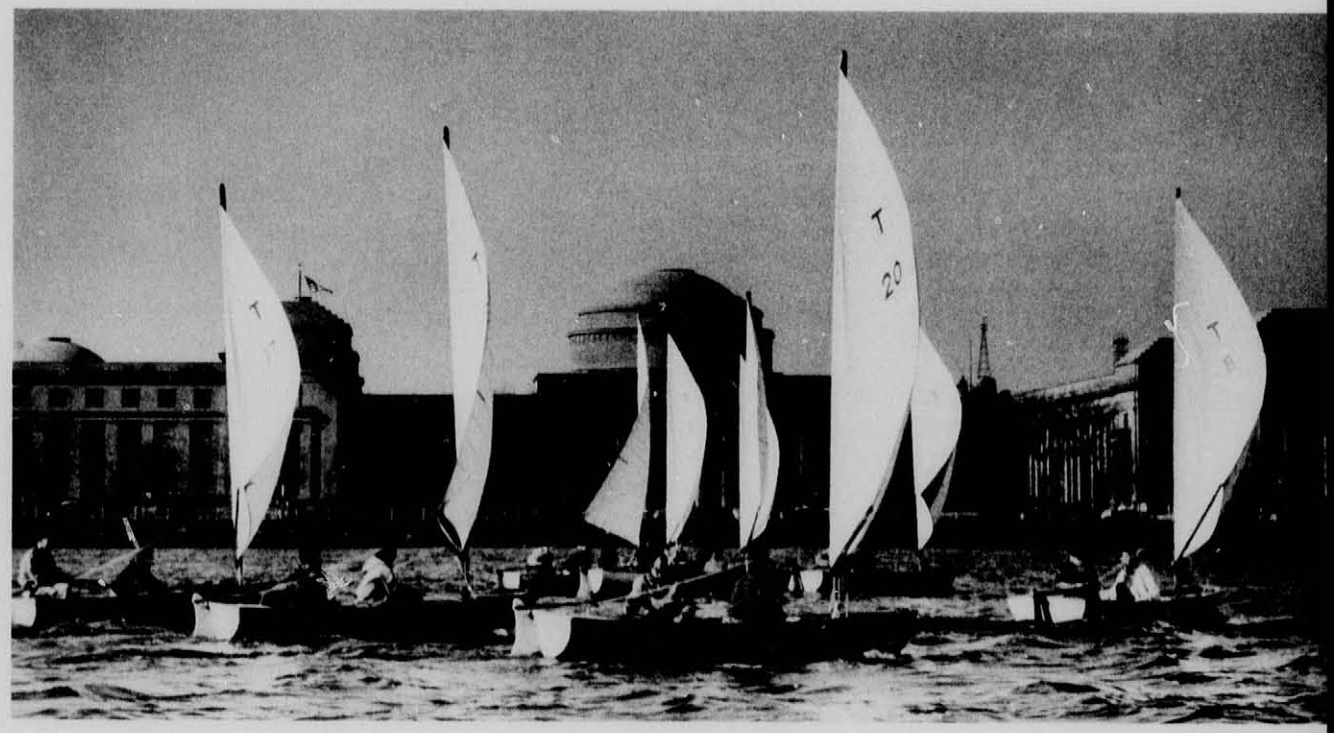
The M.I.T. Community Players, a group of graduate students and staff and their families, present under professional direction a number of plays each year. Tech Show is a musical comedy written and produced by students.

Lecture Series Committee

The Lecture Series Committee offers three different types of program for the M.I.T. community: the Entertainment Film Series and the Classic Film Series, which show current popular and older films, respectively; and a strong program of guest lecturers. Recent lecturers have included Senator Barry Goldwater, 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, Choral Society, Symphony Orchestra, Concert Band, Woodwind and Brass Ensembles, a jazz band — the Techtonians, — and a barber shop octet — the Logarythms, all out-of-classroom activities which 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 at Smith, Vassar, and Mount Holyoke; and the Concert Band goes frequently on concert tours in the U. S. as well as in Canada.

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

Lowell Institute School

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

Religious Organizations

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

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

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

The Technology Community Association

With the help of a permanent staff, T.C.A. conducts a diversified program of year-around service 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 clothing drives are a few of the activities sponsored by the student members.

Student Government

Many of the activities described above — and many more in which M.I.T. students are active — are the responsibility of M.I.T. students through their elected student government. The M.I.T. Undergraduate Association controls a budget of about $60,000, provided by the Institute in support of student activities, and there is a similar organization for graduate student government.

Student Publications

Student publications at M.I.T. include *The Tech*, the campus newspaper; *Technique*, year-book; *Tech Engineering News*, monthly magazine of engineering students; *Tangent*, a literary review; and *Voo Doo*, humor magazine. There are less formal outlets for journalism talents in the newspapers of the Institute Houses and in departmental newsletters of many kinds. The Graduate Student Council sponsors publication of *A Guide to Graduate Life*, and the Technology Community Association prepares an undergraduate guide, *The Social Beaver*.

Other Student Activities

There are more than sixty student activities and clubs at M.I.T., many of them open to both

CHORAL SOCIETY

DRAMASHOP

OUTING CLUB

TECH SHOW

undergraduate and graduate students. Among the most active are the Outing Club, the Model Railroad Club (with its own railroad, the Tech Nickel Plate, on the campus), the Hobby Shop (complete facilities for woodworking, printing, photography, and other activities), the Debating Society, and the Radio Society.

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

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

The Technology Dames

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

The Technology Matrons

Wives of the faculty and senior staff, as well as women members of the faculty and 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.

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 two floors are doctors' offices and special facilities for minor surgery, ophthalmology, otolaryngology, 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 provide medical care for both students and their dependents. This comprehensive Program provides therapeutic and diagnostic services by the Institute Medical Department and hospitalization in the Homberg Memorial Infirmary. Student families living in the Cambridge area may use the M.I.T. ambulatory pediatric clinic in Westgate. In addition, the Student Health Program includes commercial hospital and accident insurance coverage for students and their dependents which offers excellent protection against the expense of hospitalization or accident anywhere in the world. The cost of the Student Health Program per half-year is $35 for a single student; $82.50 for a student and spouse; $95 for a student, spouse, and children; and $112.50 for a student and family wishing ambulatory pediatric care. Students who do not wish to be enrolled in this plan must sign a waiver at the time of registration. Students entering M.I.T. at the start of the second term and enrolling in the Student Health Program will be covered from the date of registration through August 31.

A student and his wife may receive routine medical care in the clinic without charge. However, unless he is enrolled in the Student Health Program, a fee will be charged for diagnostic services, care in the specialty clinics including the pediatric clinic, 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. However, students requiring such treatment will be referred to private psychiatrists or psychiatric clinics in the Boston area.

The Student Health Program covers the cost of Infirmary care. Infirmary charges are $24 per day for ward accommodations and $27 per day for a private room. Charges at Boston

or Cambridge hospitals, which may be used by students, wives, or children on recommendation of the Medical Department, are the responsibility of the student; but if he is enrolled in the Health Program a student is insured for hospital room charges up to $25 per day to the limit of the policy and ancillary charges to $500 per illness.

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

Other Services

Among the other important Institute services are:

Alumni Association

The M.I.T. Alumni Association has a complete program for keeping 52,000 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.

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.

M.I.T. Women's Association

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

Personal Deposits Office

While students are encouraged to maintain their own checking accounts in commercial banks, the 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.

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 is a university press, a division of the Institute, serving M.I.T. While it tends to specialize in titles in science and technology, books of The M.I.T. Press 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. Since its founding in 1933 the Press has published over 220 titles, including monographs, textbooks, experimental teaching materials, and general works; the rate has recently increased to between 20 and 30 new titles per year. A catalog of current books is available on request to The M.I.T. Press, 238 Main Street, Cambridge, Massachusetts, 02142.

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 and (for first- and second-year students) from 9 a.m. to 1 p.m. on Saturdays. During the Summer Session most classes are held between 8 a.m. and 5 p.m., on weekdays only.

Registration

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

Faculty Counselors and Registration Officers

Every student is assigned to a member of the faculty who serves as his academic adviser. Each student's program must be approved by this faculty member, and changes may be made only with his approval. 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 copies of these reports.

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

Final Examinations

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

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

Condition Examinations

A conditional grade received by a student as a term record entitles the student to a re-examination. Examinations for this purpose are held each year in March for conditions of the first term, 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 drawing.

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

Withdrawal

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

Conduct and Discipline

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

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

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

Faculty-Student Relations

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

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

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

Official Notices

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

Fees, Deposits, and Payments

The regular tuition for full-time undergraduate and graduate students in the first and second terms is $850 per term. Special tuition rates apply to the Summer Session; these are published each year in the Summer Session Catalogue, available about March 25.

Regular students (other than doctoral students and academic staff appointees) and Special Students[1] (inciuding M.I.T. sponsored research staff appointees) who take only a few subjects and apply to the Bursar for a reduction will be charged at the rate of $26 per unit taken either for credit or as listeners. Except for thesis, the minimum tuition is $160 for regular students and for Special Students who are employed by the Institute, and $320 for other special students. The maximum tuition is $850 per term.

The tuition fee for any doctoral student other than academic staff, irrespective of the number of units, is $850 per regular term, except for thesis presentation. If such a student requires only part of a term to complete his thesis, he must pay, initially, tuition for the entire term; but after his thesis grade is reported to the Registrar, his tuition will be adjusted on the basis of a charge of $85 per week from the starting date of the term, with a minimum of $170. Tuition fees for members of the academic staff are described below.

The tuition fee for thesis research for the Bachelor's, Master's, or Engineer degree is $26 per unit credit in either regular term, with a minimum of $125 and a maximum of $850. 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 $160 applies to the total tuition for the term. Special Students are not permitted to register for thesis.

The tuition fee for thesis presentation only is $85 for the Bachelor's, Master's, or Engineer degree and $125 for the Doctor's degree. Thesis

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

presentation refers to those necessary academic events beginning with the actual delivery of the completed document. Registration for thesis presentation is appropriate only on Registration Day and then only if the completed document has been delivered. Any work on thesis prior to presentation should be covered by normal thesis registration.

The tuition fee for a student taking cooperative work in electrical engineering (Course VI-A) for the twelve-month period, July 1 to June 30, is $1,700, payable $850 on or before August 1 and $850 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 $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 $850. For a single field station of the School of Chemical Engineering Practice, the fee is $500.

Tuition Fees for Academic Staff Appointees

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

Staff Appointment	*Normal Registration*	*Maximum Registration*	*Tuition per Term*[1,2]
Full-time	24 units	26 units	$425
Half-time	32 units	36 units	$575
Third-time	38 units	43 units	$675

[1] In cases where assigned research is also approved for thesis, a full-time or half-time staff appointee occasionally has the opportunity to progress at a rate faster than that tabulated. In such a case, as determined by the staff appointee's department and approved by the Dean of the Graduate School, the staff appointee (whether full-time or part-time) who has the opportunity to progress on thesis research at the rate of a full-time student shall pay the full tuition fee ($850 per regular term) and shall be permitted to register for a full academic load of 48 units. A staff appointee who can progress on thesis research at the rate of a half-time or a third-time appointee shall pay a tuition fee of $575, or $675, per regular term, and shall be permitted to register for a maximum of 36 units or 43 units, respectively. In intermediate cases, the tuition principle may normally be satisfied by an appropriate combination of thesis research registration and tuition fee for a full-time and part-time appointee in successive terms. The increase in academic load above the range normal for the academic appointment is limited to thesis.

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

The fee for thesis presentation only is $85 for a Master's or Engineer degree and $125 for a Doctor's degree. Thesis presentation refers to those necessary academic events beginning with the actual delivery of the completed document. Registration for thesis presentation is appropriate only on Registration Day and then only if the completed document has been delivered. Any work on thesis prior to presentation should be covered by normal thesis registration.

When only thesis registration is necessary for completion of a Master's or Engineer degree, the tuition for staff shall not exceed the corresponding tuition for other regular students: namely, $26 per credit unit with a minimum of $125. If a doctoral student requires only part of a term to complete his thesis, he must pay, initially, tuition for the entire term; but after his thesis grade is reported to the Registrar, his tuition will be adjusted from the starting date of the term on the basis of a weekly charge of one-tenth of his initial tuition, with a minimum of $170.

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

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

No bills are sent. All payments are to be made to W. A. Hokanson, Bursar, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139, by the time specified in the registration instructions issued prior to the opening of each

term. Many students choose to make their payments on installment or credit plans, described later on.

Tuition Refunds

Full-time students withdrawing during the term will be charged $85 per week from the starting date of the term; for others the charge will be proportionately adjusted, using ten weeks as a basis. A student is financially obligated to the Institute for the fees appropriate to the program approved by his Faculty Counselor or Graduate Registration Officer at the first of the term. Any subsequent reduction in fees is based on the date that notice of cancellation of a subject or withdrawal from the Institute is received at the Registrar's Office.

Dormitory Rentals and Meals

All term rentals, both for the Graduate House and all undergraduate Houses, and all fees for commons meals are to be paid to the Bursar at the beginning of each term. Students may arrange to make periodic payments, as with tuition fees; such arrangements should be made at the Bursar's Office, Room 4-103 or 4-106, before the beginning of the term. *No bills are sent.*

Application Fee

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

Other Fees

A charge of $10 is made for each condition or special examination and $10 for the completion of incomplete work. The fee for the Student Health Program, which is required of all students who do not sign waivers, is $35.00 per half-year in the case of a single student; $82.50 for a student and wife; $95.00 for a student, his wife, and children; and $112.50 for a student family desiring pediatric treatment.

Late Registration or Payment Fine

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

Deposits for Chemical Supplies and Military Uniforms

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

1. All first-year students and students taking MILITARY SCIENCE or AIR SCIENCE requiring uniforms.
2. All undergraduate and graduate students taking subjects requiring supplies from the Office of Chemical Laboratory Supplies.

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

Financial Aids

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

Budget Payment Plan for Fees

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

An example of a maximum arrangement for the 1964–65 fees for men students is shown below.

EXAMPLE OF BUDGET PAYMENT PLAN

Fees		*Payments*		
Tuition	$1,700.00	September	18	$ 351.50
Average dormitory rent	440.00	October	15	350.00
		November	15	350.00
Commons meals	478.50	December	16	350.00
Medical insurance	70.00[1]	February	3	335.00
Laboratory and/or military equipment deposit	50.00	March	2	334.00
		April	1	334.00
		May	1	334.00
	$2,738.50			$2,738.50

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

Deferred payment applications will be included with each student's registration material.

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

Installment Credit Plan for Tuition

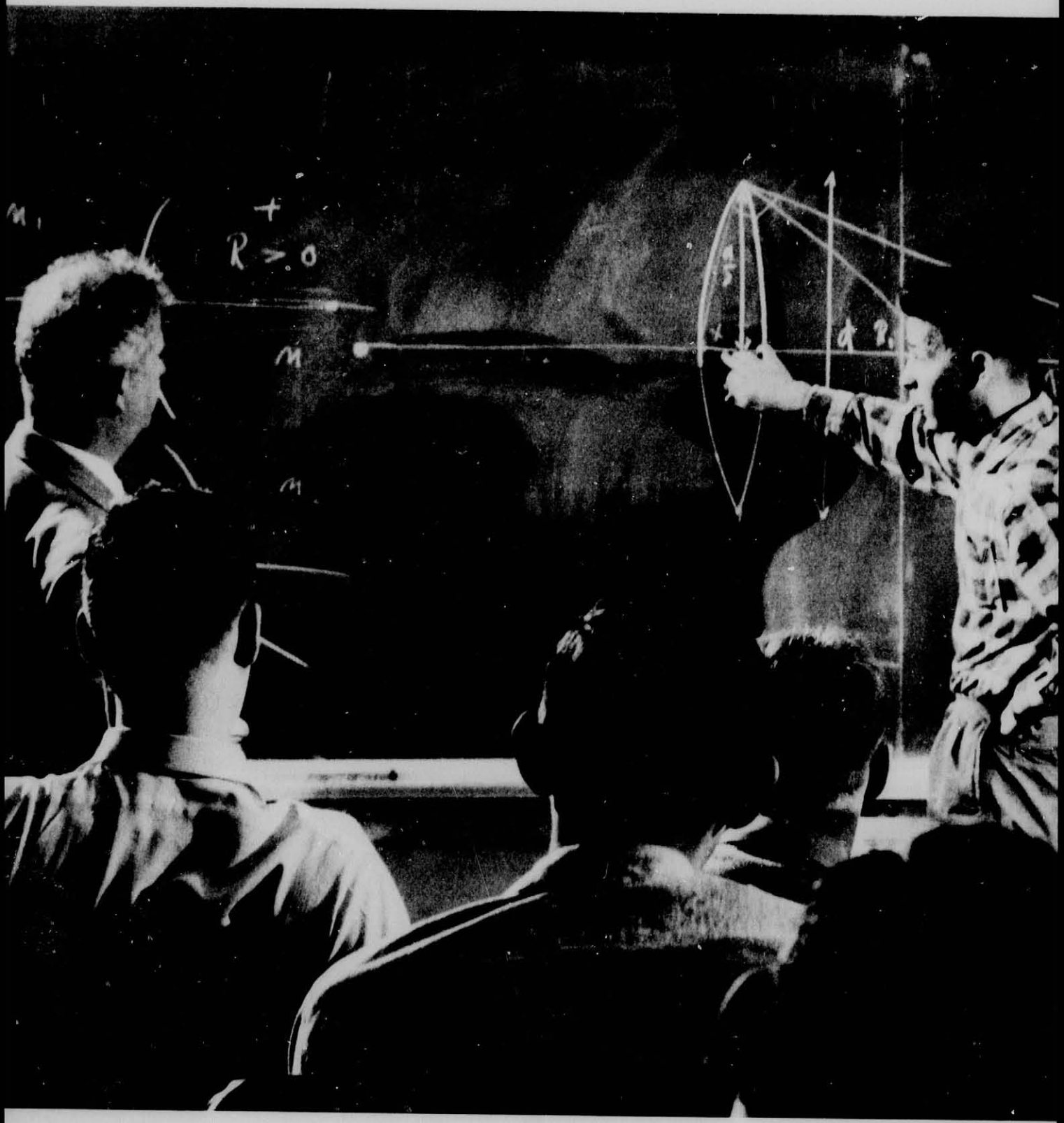
An optional Installment Credit Plan for the payment of part of the M.I.T. tuition fee is also available to help reduce the burden of educational costs for students and their parents. Under this plan, any tuition cost in excess of $1,000 may be met by applying to the Director of Student Aid for credit in amounts of up to $700 for an academic year. Thus a student may use the Credit Plan to obtain a maximum four-year credit of $2,800.

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

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

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

Application for credit under this plan should be made to the Director of Student Aid no later than one week prior to the opening of the term for which the credit is desired. No Parents' Financial Statement need be submitted, and no collateral is required. However, students who are minors will be asked to have a parent or guardian co-sign their applications. Further information and complete repayment schedules are available from the Student Aid Center.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UNDERGRADUATE EDUCATION: *A Tradition of Excellence* 2.

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

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

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

Electives within these Departmental Programs permit undergraduates to prepare themselves for advanced degrees in areas in which M.I.T. gives no undergraduate degrees, such as ceramics, city and regional planning, meteorology, oceanography, nuclear engineering, and others. In the same way, M.I.T. offers undergraduate preparation for advanced study in interdisciplinary fields such as astrophysics,

communications science, and space science and technology, and in such professional fields as medicine, law, and teaching.

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

The Undergraduate Programs

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

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

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

A complete list of undergraduate and graduate Courses and degrees is given in Section 1.

Selection of Course

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

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

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

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

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

Premedical Education

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 pre-medical program fully meets the specifications of the Association of American Medical Colleges.

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

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 M.I.T. education fits well with the preferences of the leading schools, students may wish to consult the Institute's prelaw adviser regarding preparation for law school. The prelaw adviser 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 five-year programs combining studies at the Institute and at the Harvard Graduate School of Education. Programs are coordinated by the Department of Humanities, and further information may be obtained from Professor 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 Secretary of the Graduate School as a candidate for the Master's degree. He must be enrolled at least one term as a graduate student and complete the requirements for both the Bachelor's and Master's degrees, including a single thesis of not less than 30 units for both degrees, or a Master's thesis of not less than 20 units in addition to satisfying the undergraduate thesis requirement in his department. The requirements for the various cooperative, honors, and other five-year Courses leading to the S.B. and S.M. degrees are specified under the appropriate department statements.

Subject Registration

It is not usually necessary to restrict the number of students admitted to a subject. If an unexpectedly large number 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: recitation and lecture; laboratory, drawing, or field work; and preparation. Each unit represents 15 hours of work. The total unit credit for a subject is obtained by adding together all the units shown. One unit of recitation or lecture credit, and two units of laboratory or drawing credit, are each equivalent to one semester hour. The typical undergraduate student load, based on a four year program, is 45 to 50 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 lecture (or recitation), laboratory (or drawing), and preparation is shown in the Descriptions of Subjects.

Degree Requirements

To be recommended for the degree of Bachelor of Science or Bachelor in Architecture, a student must have attended the Institute not less than one academic year, which ordinarily must be the year of his graduation. He must have completed satisfactorily a program of study approved in accordance with 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 General Institute Requirements include:

1. Successful completion of certain required subjects, as specified by each of the five academic schools in Sections 4, 5, 6, 7, and 8 of this Catalogue.

2. Completion of the first-year elective requirement, described on page 37 of this Catalogue.

3. Completion of the upperclass requirements in humanities and social sciences, described beginning on page 40 of this Catalogue.

4. Completion of the physical education requirement, described below.

5. Completion of an undergraduate thesis or project of not less than 9 units (except for students in Mathematics, Course XVIII, for which no thesis is required), described below.

The Undergraduate Thesis

The ability of each student to perform independent, responsible work is considered an important part of his qualifications as a graduate of M.I.T., and an undergraduate thesis or project of not less than 9 units is required for the Bachelor's degree in all Courses except Mathematics. This requirement is interpreted variously in different fields of study; it may involve laboratory research, library research, design, field investigation, or a combination of these activities, and it may involve creative and original work. Its purpose is to give each student the opportunity of drawing upon his academic resources to solve a specific problem. Most students begin work on the thesis during the first term of their fourth year, completing the project during the second term.

Physical Education

The Institute expects each student to gain experience in recreational athletics during his first two years at M.I.T.; by the end of this period he must have compiled at least 8 points of athletic credit. These points may be acquired by participating in a physical education class (2 points per quarter) or by membership on one of the 18 intercollegiate 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 approximate dates and 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, 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 instructors' program.

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 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, these athletic requirements are modified accordingly.

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

The First-Year Program

For students entering M.I.T. with only the preparation implied by the entrance requirements, the first-year program consists of a core of required subjects in mathematics, physics, chemistry, and humanities (all part of the General Institute Requirements), and electives. The core subjects, totalling 78 of the 90 units in a standard program, provide an appropriate preparation for all the Courses of undergraduate study offered at M.I.T.

There is an exception to this first-year program for students who plan to enter Architecture (Course IV-A), as indicated below.

The program for the two terms of the first year is, as follows:

First Term

		Units
5.01	GENERAL CHEMISTRY[1]	4 2 5
8.01T	PHYSICS I	5 0 6
18.01	CALCULUS	3 0 6
21.01	THE GREEK TRADITION	3 0 5
	Elective subject[2]	6
	Total	**45**

Second Term

5.02	GENERAL CHEMISTRY[1]	4 2 5
8.02T	PHYSICS II	5 0 6
18.02	CALCULUS	3 0 6
21.02	THE EUROPEAN TRADITION	3 0 5
	Elective subject[2]	6
	Total	**45**

[1] Students who plan to enter Architecture (Course IV-A) are not required to take chemistry; 4.021 and 4.022, FORM AND DESIGN (0–6–4, 0–6–4) are required, and GENERAL CHEMISTRY (5.01, 5.02) may be taken as elective.

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

ELECTIVE SUBJECTS

The first-year elective requirements (12 units) may be met by enrolling in subjects expressly designed for this purpose (the regular Freshman Electives and the Undergraduate Seminars), by taking foreign language subjects for which the student is qualified, by taking upper-class electives in humanities without prerequisites, or by taking upper-class electives 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 may be counted only toward this requirement. If upper-class electives are taken in their place, the units in excess of 12 may be applied toward the total degree requirements.

The Regular Freshman Electives and the Undergraduate Seminars

Both the elective subjects and the seminars provide opportunities to explore fields of potential interest. Some of the descriptions of departmental curricula include suggestions of electives which certain departments consider particularly appropriate as background subjects. Freshman Advisers stand ready to assist with respect to their selection and to ways in which additional freshman electives or seminars, although taken without credit, may contribute toward a student's overall educational program.

The following subjects are available, subject to possible restriction of enrollment where demand exceeds facilities.

First Term

2.101 COMPUTER MODELS OF PHYSICAL AND ENGINEERING SYSTEMS I (2–2–2)
2.711 ENGINEERING GEOMETRY (0–4–2)
2.721 GRAPHICAL CONCEPTS (0–4–2)
2.722 DESCRIPTIVE GEOMETRY (0–4–2)
2.723 ELEMENTARY NOMOGRAPHY (2–0–4)
3.09 STRUCTURE OF MATERIALS (3–0–3)
3.10 STRUCTURE AND PROPERTIES OF MATERIALS LABORATORY (1–2–3)
4.011 GRAPHICS LABORATORY I (0–3–2)
6.41 INTRODUCTION TO AUTOMATIC COMPUTATION (2–0–4)
12.001 ASTRONOMY I (3–0–3)
18.09 ELEMENTARY NUMBER THEORY (2–0–4)
21.091T PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–0–4)
21.096 ENGLISH COMPOSITION (2–0–4)
AS 11 [1]EVOLUTION OF WARFARE (3–1–3)
MS 11 MILITARY SCIENCE (2–1–0)
MS 21 MILITARY SCIENCE (2–1–0)
NS 11 [1]ORIENTATION AND SEA POWER (3–1–5)
SEM 11 [2]UNDERGRADUATE SEMINAR (0–6–0)
SEM 12 [2]UNDERGRADUATE SEMINAR (0–6–0)

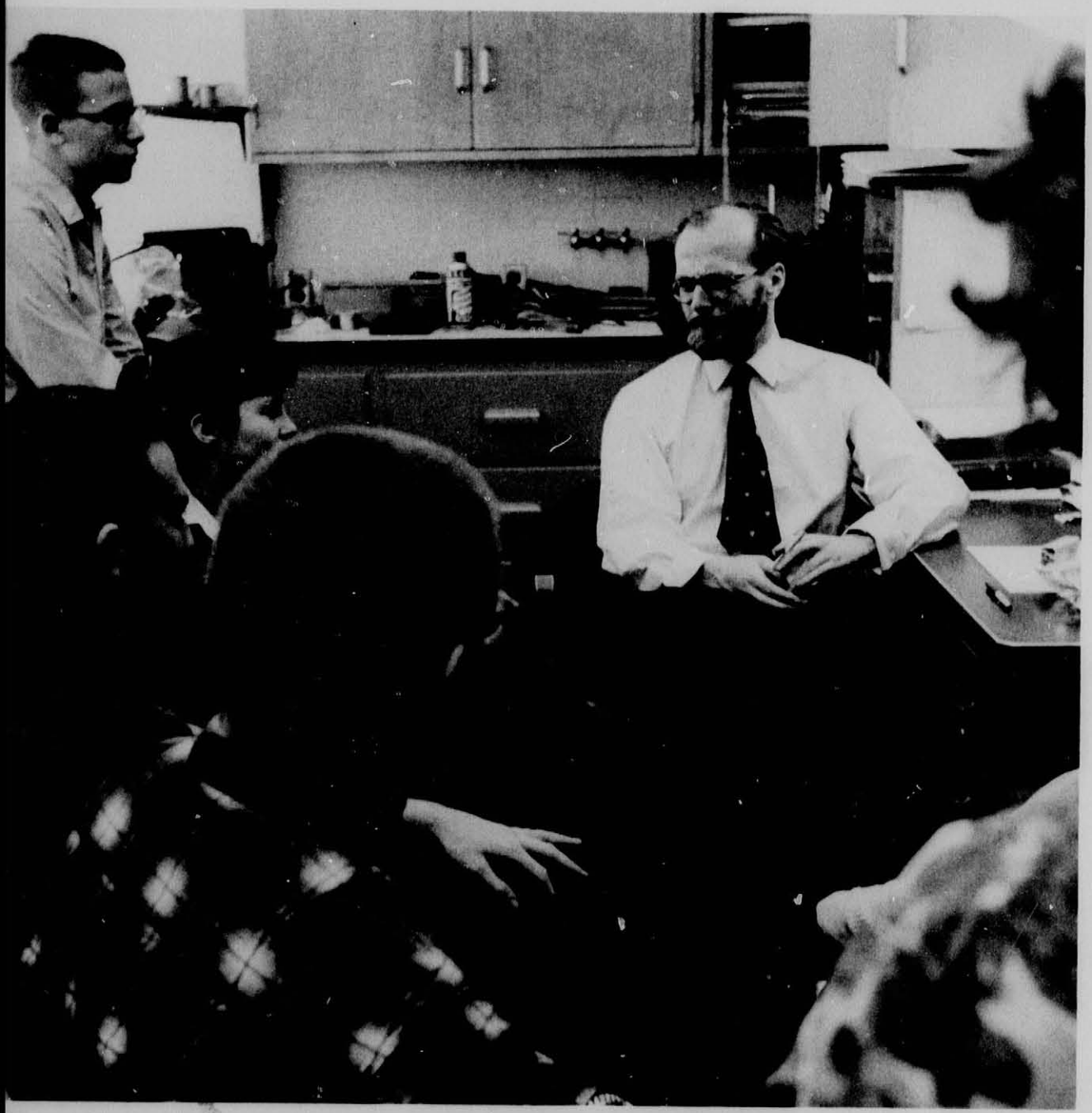
Second Term

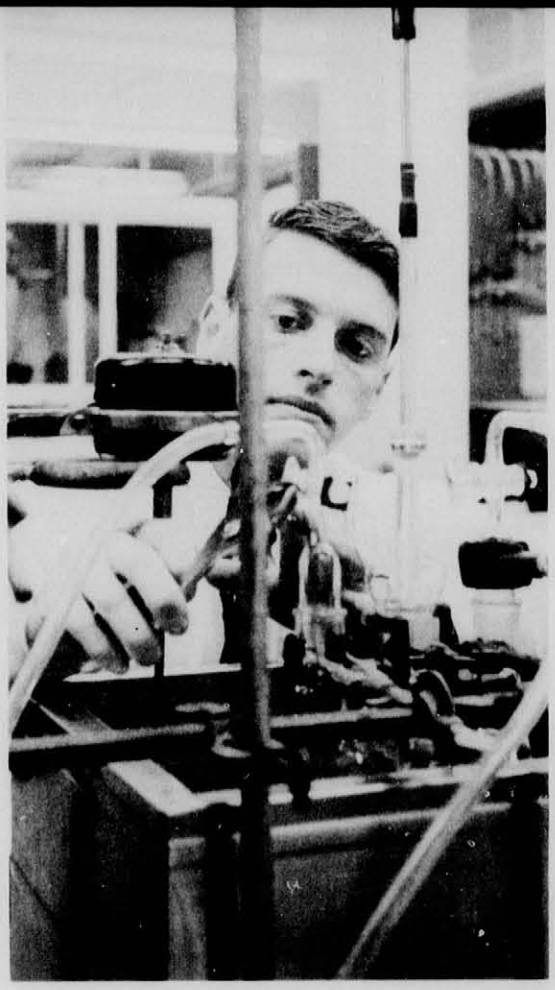
2.00 INTRODUCTION TO ENGINEERING SYSTEMS (2–0–4)
2.101 COMPUTER MODELS OF PHYSICAL AND ENGINEERING SYSTEMS I (2–2–2)
2.711 ENGINEERING GEOMETRY (0–4–2)
2.721 GRAPHICAL CONCEPTS (0–4–2)
2.722 DESCRIPTIVE GEOMETRY (0–4–2)
2.723 ELEMENTARY NOMOGRAPHY (2–0–4)
3.09 STRUCTURE OF MATERIALS (3–0–3)
3.10 STRUCTURE AND PROPERTIES OF MATERIALS LABORATORY (1–2–3)
4.012 GRAPHICS LABORATORY II (0–3–2)
6.41 INTRODUCTION TO AUTOMATIC COMPUTATION (2–0–4)
7.00T PERSPECTIVES IN LIFE SCIENCE (2–0–4)
12.00 EARTH SCIENCE (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) (2–0–4)
19.003 ELEMENTARY METEOROLOGY I (2–0–4)
21.092T INTRODUCTION TO MORAL AND POLITICAL PHILOSOPHY (2–0–4)
21.094 INTRODUCTION TO CONTEMPORARY PHILOSOPHY (2–0–4)
21.096 ENGLISH COMPOSITION (2–0–4)
AS 12 [1]FOUNDATIONS OF AIR POWER (3–1–3)
MS 12 MILITARY SCIENCE (2–1–0)
MS 22 MILITARY SCIENCE (2–1–0)
NS 12 [1]ORIENTATION AND SEA POWER (3–1–5)
SEM 11 [2]UNDERGRADUATE SEMINAR (0–6–0)
SEM 12 [2]UNDERGRADUATE SEMINAR (0–6–0)

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

[2] 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 the 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 with the registration material.

Other Electives

All subjects offered by the Department of Modern Languages are open to qualified freshmen, and any language subject may be chosen as a Freshman 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.

In addition, students with special interests and background preparation equivalent to that implied in the stated prerequisites may, with the consent of the instructor in charge, register for any subject offered at the Institute which is not part of the General Institute Requirements or Departmental Programs and count it as a Freshman Elective.

VARIATIONS IN THE FIRST-YEAR PROGRAM

Not all freshmen take the standard program. Those with degree credit at entrance in one or more of the core subjects may substitute more advanced subjects in the same areas or may use the time thus made available for electives. If the credit is in the required prerequisites, the student may take elementary work in a professional field 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.

For freshmen with strong records in the first term, some subjects in the 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. Regular language subjects paralleling those completed in secondary school and freshmen electives cannot be completed

through Advanced Standing examinations.

The standard program of 90 units (45 each term) is considered by the Faculty to be the typical student load, based on a four-year program. A heavier or lighter program can be carried by the student with the approval of his Freshman Adviser. No change in tuition fees is made either for carrying an extra subject or for omitting a subject in the standard program.

In the academic year 1963–64, approximately 33 per cent of the entering class had degree credit at entrance; 6 per cent took Advanced Standing Examinations during the first year; and about 10 per cent carried overloads. These groups overlap somewhat; in all, about 44 per cent of the class had programs which varied in some degree from the standard.

The Undergraduate Program in Humanities and Social Sciences

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

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

In 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

(*text continues on page 43*)

HUMANITIES FIELDS AND SUBJECTS

FIRST YEAR

First Term

THE GREEK TRADITION (21.01)

Second Term

THE EUROPEAN TRADITION (21.02)

SECOND YEAR

THE NATURE OF LITERATURE (21.03T)
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
THE MODERN WORLD AND SOCIAL SCIENCE (14.003)

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) †
THE UNITED STATES IN EUROPEAN CIVILIZATION: COLONIAL TIMES TO THE PRESENT (21.402) †
DEVELOPMENT OF AMERICAN ECONOMIC INSTITUTIONS (21.403) †
AMERICAN IDEAS AND INSTITUTIONS (21.404) †
THE DEVELOPMENT OF MARKET ECONOMIES IN EUROPE (21.501) †
THE DEVELOPMENT OF EUROPEAN ECONOMIC INSTITUTIONS (21.502) †
THE ITALIAN RENAISSANCE (21.504) †
INTELLECTUAL HISTORY OF MODERN EUROPE (21.505) †
MARX, DARWIN, AND FREUD (21.506) †
REFORMATION AND REVOLUTION (21.507) †
WAR AND THE MILITARY INSTITUTIONS OF THE MODERN STATE (21.509) †
VIENNA AND VERSAILLES (21.51T) †
CHINA, JAPAN, AND THE WEST (21.511) †
RUSSIAN REVOLUTION AND THE SOVIET UNION (21.512) †
SCIENCE AND NATURAL PHILOSOPHY IN THE CHINESE TRADITION (21.513) †
SCIENCE AND NATURAL PHILOSOPHY IN THE CHINESE TRADITION (21.514) †
THE CULTURES OF THE NON-WESTERN WORLD (21.517) †
THE 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, ECONOMIC GROWTH AND SOCIAL CHANGE (21.525) †
ENGINEERS IN HISTORY (21.526) †
INNOVATION AND CONTINUITY IN THE HISTORY OF SCIENCE (21.531) †
SCIENTISTS AND SOCIETY (21.532) †
HISTORY OF BIOLOGY (21.533) †
HISTORY OF MATHEMATICAL ASTRONOMY (21.535) †
PHILOSOPHY OF HISTORY (21.662) †
SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS (21.701) †
SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT (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) †
ARISTOTLE (21.614) †
HEGEL AND KIERKEGAARD (21.616) †
PROBLEMS IN CONTEMPORARY PHILOSOPHY I (21.631) †
PROBLEMS IN CONTEMPORARY PHILOSOPHY II (21.632) †
PHENOMENOLOGY AND EXISTENTIALISM (21.634) †
SYMBOLIC LOGIC (21.641) †
THEORY OF KNOWLEDGE (21.643) †
PROBLEMS IN ETHICS (21.651) †
PHILOSOPHY OF HISTORY (21.662) †
PHILOSOPHY OF THE ARTS (21.671) †
PHILOSOPHY IN LITERATURE (21.672) †
METAPHYSICS (21.682) †
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) †
SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT (21.702)
COSMOLOGY — OLD AND NEW PROBLEMS (21.703) †
BIOLOGICAL BASES OF PERCEPTION AND KNOWLEDGE (21.705) †
PHILOSOPHY OF SCIENCE (21.712)
PHILOSOPHY OF MATHEMATICS (21.714) †
PHILOSOPHY OF MIND (21.716) †
SEMANTICS (21.722) †

FIELD THREE: LITERATURE

LITERARY ANALYSIS (21.11) †‡
or
THE NATURE OF LITERATURE (21.03T) †‡
plus any two of the following:
LITERARY CRITICISM (21.12)
THE EPIC (21.13)

‡ Students who elected 21.03T 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; 21.03T and 21.11 may not both be taken for credit.

THE BIBLE (21.14T)
SHAKESPEARE (21.15T)
CHAUCER (21.16T)
JOYCE (21.17)
MAJOR WRITERS OF THE ENGLISH RENAISSANCE (21.19)
DISSOLUTION OF CLASSICISM (21.21T)
NINETEENTH-CENTURY: THE ROMANTICS (21.22T)
THE BIRTH OF MODERNISM (21.24T)
THE MODERN NOVEL (21.25)
MODERN DRAMA (21.26T)
MODERN POETS: YEATS, ELIOT, STEVENS AND WILLIAMS (21.27T)
MODERN AMERICAN LITERATURE (21.28T)
DOSTOEVSKY, TOLSTOI AND MODERN RUSSIAN LITERATURE (21.29T)
NON-WESTERN LITERATURE (21.30T)
CHINESE LITERATURE (21.302)
NARRATIVE FICTION (21.31T)
THE NATURE OF POETRY (21.32T)
THE DRAMA AS THEATRE (21.33T)
THE SHORT STORY (21.34T)
THEATRE ARTS: ELEMENTARY STAGECRAFT AND PRODUCTION STUDIES (21.35T)
THE NATURE OF THE COMIC (21.36T)
TRAGEDY (21.37T)
MYTH AND SYMBOL IN WESTERN LITERATURE (21.38T)
THE PSYCHOLOGY OF LITERATURE (21.382)
AMERICAN FOLKLORE (21.39)
DANTE I (23.87)
DANTE II (23.88)

FIELD FOUR: MODERN LANGUAGES

Group A — German

INTERMEDIATE GERMAN (23.14)
or
LITERARY ANALYSIS (21.11) †
plus any two of the following:
THE ROMANTIC ERA AND NINETEENTH CENTURY REALISM (23.15) †
NATURALISM, EXPRESSIONISM — ERA OF THE GREAT NOVEL (23.16) †
GOETHE: FAUST (23.18) †
GREAT BOOKS AND AUTHORS IN GERMAN LITERATURE (23.20) †
CONTEMPORARY GERMAN LITERATURE (23.21) †

Group B — French

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

(list continues on page 42)

(list continued from page 41)

Group C — Russian

INTERMEDIATE RUSSIAN (23.94)
or
LITERARY ANALYSIS (21.11) †
plus any two of the following:
ADVANCED RUSSIAN (23.941) †
GREAT BOOKS AND AUTHORS IN RUSSIAN LITERATURE (23.95) †
MODERN RUSSIAN LITERATURE (23.96) †
SOVIET LITERATURE (23.98) †
CHEKHOV AND THE NINETEENTH CENTURY (23.99) †

Group D — Comparative Literature

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

FIELD FIVE: MUSIC

INTRODUCTION TO MUSIC (21.91) †
plus any two of the following:
THEORY OF MUSIC (21.92T)
ANALYSIS OF MUSICAL SOUND (21.926) †
WESTERN MUSIC IN THE MIDDLE AGES AND THE RENAISSANCE (21.93T)
WESTERN MUSIC IN THE BAROQUE ERA (21.94T)
WESTERN MUSIC IN THE CLASSIC ERA (21.95T)
WESTERN MUSIC IN THE ROMANTIC ERA (21.96T)
TWENTIETH-CENTURY MUSIC (21.97)
THE OPERA (21.98)
SEMINAR IN MUSIC (21.991)
SEMINAR IN MUSIC (21.992)

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)
MONETARY AND BANKING POLICY (14.40)
PUBLIC FINANCE (14.43)
INTERNATIONAL TRADE (14.54)

FIELD SEVEN: POLITICAL SCIENCE

Any three of the following subjects:
INTERNATIONAL RELATIONS (14.51) †
PRINCIPLES AND PROBLEMS OF AMERICAN FOREIGN POLICY (14.52)
SEMINAR IN INTERNATIONAL POLITICS (14.53)
PREDICTION OF SOCIAL AND POLITICAL CHANGE (14.55)
CONTEMPORARY IDEAS ON POLITICAL AND ECONOMIC DEVELOPMENT (14.57)
ARMS CONTROL, DISARMAMENT AND FOREIGN POLICY (14.60)
POSTWAR U.S. DEFENSE POLICIES (14.61)
CURRENT U.S. DEFENSE PROBLEMS (14.62)
THE AMERICAN POLITICAL PROCESS (14.91) †
COMPARATIVE POLITICAL SYSTEMS (14.92) †
SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS (14.93)
GOVERNMENT, POLITICS, AND TECHNOLOGY (14.94)
POLITICS, SOCIETY, AND POLICY MAKING (14.95)
POWER, INFLUENCE, AND POLICY DECISIONS (14.96)
ASIAN POLITICAL SYSTEMS (14.97)
STRUCTURE OF URBAN LIFE (14.99)*

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)

FIELD NINE: PSYCHOLOGY

INTRODUCTORY PSYCHOLOGY (9.00) †
and any two of the following subjects:
PHYSIOLOGICAL PSYCHOLOGY (9.01)
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)
THEORIES OF PERSONALITY (9.60)
SOCIAL PSYCHOLOGY (9.70)
BEHAVIOR IN GROUPS (9.80)
DEVELOPMENTAL PSYCHOLOGY (9.89)

FIELD TEN: VISUAL ARTS

Three subjects: selections within both groups required

Group A

VISUAL DESIGN PROBLEMS (4.031) †
VISUAL DESIGN PROJECTS (4.032)
CREATIVE PHOTOGRAPHY (4.033T) †

Group B

INTRODUCTION TO THE VISUAL ARTS I (4.601) †
INTRODUCTION TO THE VISUAL ARTS II (4.602) †
THE CLASSICAL TRADITION IN AMERICA (4.603) †
THE ROMANTIC TRADITION IN AMERICA (4.604) †
MODERN ART FROM POST-IMPRESSIONISM TO CUBISM (4.605) †
SCULPTURE IN THE 20TH CENTURY (4.606) †
ARCHITECTURE IN THE ANCIENT WORLD (4.61) †
ARCHITECTURE IN THE MIDDLE AGES (4.63) †
ARCHITECTURE 1750 TO THE PRESENT (4.64) †
MODERN ARCHITECTURE IN GERMANY FROM 1895 TO THE BAUHAUS (4.641) †

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

(*text continued from page 40*)

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 THE NATURE OF LITERATURE (21.03T) 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 THE MODERN WORLD AND SOCIAL SCIENCE (14.003). 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 sections of the first- and second-year humanities subjects are conducted in French by the Department of Modern Languages.

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

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

The subject offerings are described on the 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 Aeronautics and Astronautics (Course XVI). It may be taken either as the distributional subject or as part of an appropriate three-term concentration.

Military Science, Air Science, and Naval Science

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

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

THE ARMY R.O.T.C. PROGRAM

The Army R.O.T.C. program at M.I.T. has been established to qualify graduates for commissions as reserve or regular officers in the United States Army. The aim is to provide a basic military education, and, in conjunction with other academic disciplines, to develop individual character and attributes essential to an officer. The program is divided into two parts, the Basic Course and the Advanced Course. Texts, reference books, and equipment are furnished to all cadets without charge.

Basic Course

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

Uniforms are issued to the students for wear at drill formations.

Elective Credit

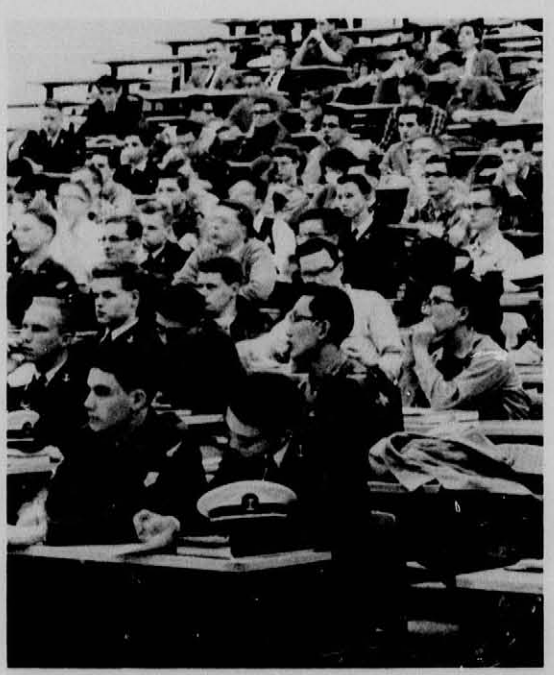
All students completing the Army R.O.T.C. Basic Course will earn twelve units of First-Year Elective credit. Elective credit is not given for the Advanced Course.

Advanced Course

The Advanced Course is a program of study in military subjects common to all of the branches of the Army. Graduates are assigned upon appointment to branches according to their academic training, the needs of the service, and the students' own preferences. Credit for the Basic Course is normally prerequisite for admission into the Advanced Course. Students in the Advanced Course must take at least one junior or senior level academic subject each semester in the areas of effective communication, science comprehension, general psychology, or political development and institutions. The following four subjects are included in the Advanced Course: MS31, MS32, MS41, and MS42. All subjects include one hour of preparation, two hours of recitation and one hour of drill (2–1–1).

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

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



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

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

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

During the first two years the program acquaints students with military and Air Force history, technological advances, and current research and development activities. Leadership training is also begun. During the last two years, emphasis is placed on personal development. Students increase their ability to communicate their thoughts to others both orally and in writing. Subjects in GLOBAL GEOGRAPHY (AS42) and INTERNATIONAL RELATIONS (14.51) deepen the students' understanding of world affairs. Understanding of people and interpersonal relationships are also stressed. Students increase their leadership ability by assuming positions of responsibility in the Cadet Corps at M.I.T. and in the required summer camp. To insure that they will keep abreast of developments in the Air Force, students continue to receive information on technological advances.

While in an undergraduate status, Air Force R.O.T.C. students are furnished, free of charge, all text and reference books, uniforms, and equipment required for Air Science study. Some references and texts, not furnished by A.F.R.O.T.C., will be made available through the Reserve Book Section of the Hayden Library. During the last two years the cadets are paid a subsistence allowance of 90 cents per day; they receive reimbursement for travel to and from summer camp and while there are paid at the rate of $78 per month.

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

Adjustment in the Air Science 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 26 years and 6 months of age for flying training and 28 years of age for all other categories.
4. Planning to pursue work at M.I.T. leading to at least a Bachelor's degree in any Course offered by the Institute.
5. Willing to sign a formal agreement at the beginning of the junior year which obligates him to remain in the R.O.T.C. program for the two final years, to accept a commission, and to serve the required period in the Air Force upon graduation.

The Four-Year Program

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

FIRST YEAR

First Term

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

Second Term

AS 12 FOUNDATIONS OF AIR POWER (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[1]

First Term

AS 31 AEROSPACE SYSTEMS DEVELOPMENT (0–1–0)
(No M.I.T. credit)

Second Term

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

FOURTH YEAR[1]

First Term

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

Second Term

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

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

Application Procedure

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

Selection Procedure

Selection from among eligible applicants will be made by the Professor of Air Science after considering and evaluating such factors as past academic record, leadership displayed in high school activities, personal motivation, and potential officer capabilities.

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, all uniforms and uniform equipment, and in addition is paid a standard ration allowance of 90 cents per day during his third and fourth academic years. Transportation to and from the port of embarkation for the summer cruise is furnished by the Navy, and the student is paid at the current rate of $78 per month while on the cruise. Upon completion of the program and receipt of a Bachelor of Science degree from M.I.T., the student is commissioned as an Ensign (EDO), U.S. Naval Reserve; he is ordered to active duty in an engineering duty billet either afloat or ashore for a period of 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.

Eligibility Requirements

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

1. A male citizen of the United States.
2. Age 17 to 21 by July 1 of his entering year. (This age requirement may be lowered to 16 for outstanding students.)
3. Unmarried, never have been married, and willing to remain unmarried until commissioned.

4. 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), Architecture (IV-A), Cooperative Course in Electrical Engineering (VI-A), Life Sciences (VII), Chemical Engineering Practice (X-B), Economics, Politics, and Engineering or Science (XIV-A and XIV-B), and Cooperative Course in Aeronautics and Astronautics (XVI-B).
6. Willing to sign a contract with the Navy which obligates the student, after completing the requirements for a commission, to fulfill the following additional requirements: to accept a commission, to serve on active duty for a period of 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] 9.00 INTRODUCTORY PSYCHOLOGY (3–0–5) must be taken as a prerequisite for NS42.

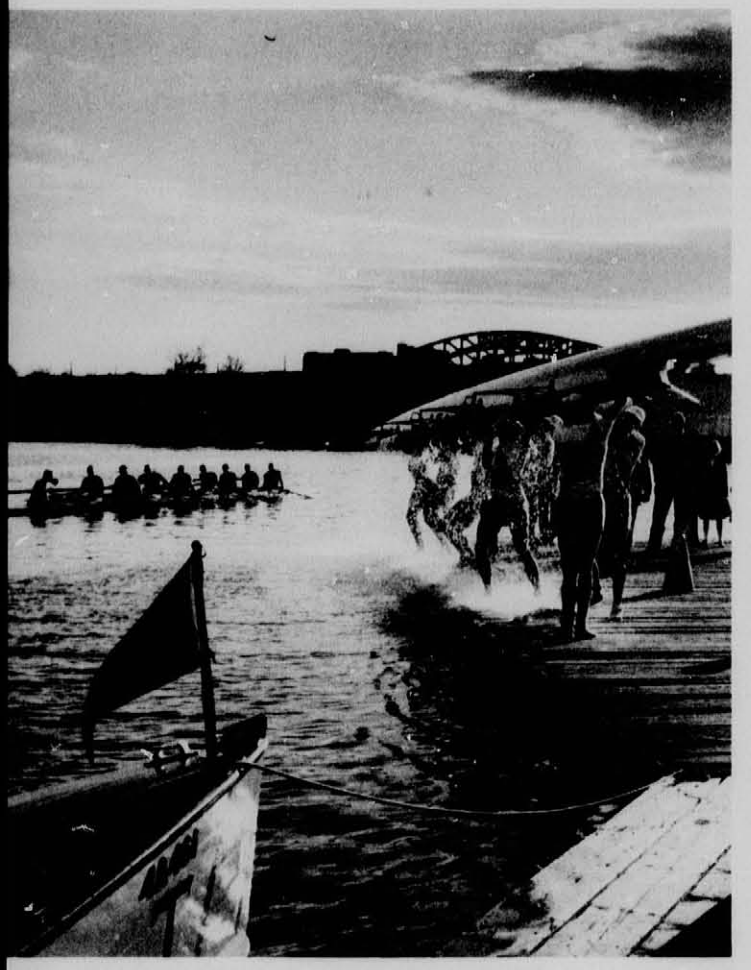
Application Procedure

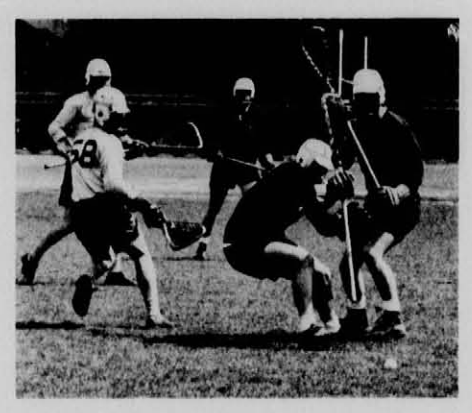
Eligible students should apply for admission to the Naval R.O.T.C. program as soon as they have been notified of their admission to the Institute. Applications should be made directly to the Commanding Officer of the Naval R.O.T.C. Unit, either by mail or by personal visit by Registration Day or as soon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

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

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. 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 3-136, provides similar assistance to graduate students, described in Section 3 of this Catalogue.





Costs

M.I.T. is an independent, endowed institution; the tuition of $1,700 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 an accurate estimate of his expenses, including basic costs, variable personal expenses, and needs for transportation while making his college plans. This estimate should be considered carefully in the light of his available funds 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 1964–65 at M.I.T.:

Tuition	$1,700
Board and room	1,130[1]
Books and materials	150
Medical insurance	70[2]
	$3,050

In addition to these costs, a reasonable allowance (probably at least $300 per academic year) should be made for such expenses as clothes, laundry and personal necessities. This total varies according to individual tastes and requirements.

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

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

SCHOLARSHIPS

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

For Entering Freshmen

For students of limited means who need help in meeting their expenses, the Institute has available a substantial number of scholarship grants ranging up to $2,500, as well as awards from the M.I.T. loan funds, for the freshman year. Approximately one half of the entering class receives some aid from these sources, which include several four-year grants sponsored by corporations, foundations, and industrial organizations; among these are the Alfred P. Sloan, the General Motors, and the Alumni Fund National Scholarships. All awards are based on demonstrated need. (See Appendix A for a complete list of available scholarships.)

For Upperclassmen

Any undergraduate may apply for scholarship aid after one year of residence. Applications are made each January to the Student Financial Aid Committee. Grants are made on an annual basis dependent on academic excellence, achievement in extracurricular and community activities, and demonstrated need.

LOANS

Loans from the Technology Loan Fund and the National Defense Student Loan Fund are available on application to students with satisfactory academic records. Awards from these funds may be in addition to any scholarship grants. Complete details are given in Appendix A.

STUDENT EMPLOYMENT

The Office of Student Personnel is maintained to help students who wish to help themselves meet part of their expenses by earnings in on-the-campus jobs. The requirements of the Institute curriculum are such that only a limited amount of time may be given to employment, and prospective students are advised to have sufficient funds to cover the expenses of the first year at least. The average that can be earned through part-time employment in the freshman year does not usually exceed $200 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

[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.

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.

APPLICATIONS FOR FINANCIAL AID

Consideration for freshman financial aid grants is limited to students who are entering the Institute directly from secondary schools and who make application to the Director of Student Aid before January 15 of the calendar year in which they will enter. Selection for an award is based in general upon the Student Financial Aid Committee's evaluation of the candidate's total record; this includes College Entrance Examination Board test scores, high school or preparatory school records, evidence of need of financial assistance as determined from the Parents' Confidential Statement to the College Scholarship Service, and recommendations from his former teachers, prominent citizens of his community, or Institute alumni. Students wishing to be considered for financial aid should complete and return the financial aid application form which is included with the application for admission. Note the *separate* application procedures for freshman admission and for freshman financial aid.

Application forms for financial aid for upperclassmen are available from the Student Aid Center.

Undergraduate Admission to M. I. T.

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

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

ADMISSION FROM SECONDARY SCHOOLS

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

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

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

Attention is called particularly to the necessity for thorough preparation in English and mathematics. An applicant's training in English should enable him to read with intelligence and sensitivity and to express his ideas clearly in oral and written form. In mathematics, emphasis should be on thorough mastery of fundamental principles, operations, and definitions rather than on covering a wide range of topics.

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

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

English is normally studied through four years, and this is counted as three units. In some states, algebra is completed in 1½ years; this will satisfy the algebra requirement for candidates from those states. The plane geometry requirement may be met either by a course of the traditional type or by a one-year course which is mainly devoted to plane geometry but which includes some work in analytic geometry, solid geometry, or other fields, as suggested by the Commission on Mathematics of the College Entrance Examination Board. 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 6½ additional units, or their equivalent, in secondary school studies; no limitations are imposed in the choice of these elective subjects. In the selection of the entering class the Committee will be guided by the quality of the applicant's work and by his apparent promise on grounds of intellect and character, rather than by his choice of electives.

It is nevertheless recommended 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 W. A. Hokanson, Bursar, 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) Advanced Mathematics *or* 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 Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming, Alberta, British Columbia, Mexico, Australia, Pacific Islands, Japan, and Formosa should apply to the College Entrance Examination Board, Box 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. late in March.

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 3 in 1965. A student interested in his academic standing relative to M.I.T.'s standards should consult the published M.I.T. Freshman Class Statistics, available in the guidance office at his school or through the M.I.T. Admissions Office.

ADVANCED PLACEMENT

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

Qualified juniors and seniors who take college-level subjects offered in their schools in cooperation with the College Entrance Examination Board Advanced Placement Program should take the appropriate three-hour examinations administered by the Board each year in May and instruct the Board to send the scores, test papers, and reports from the school to M.I.T. Credit for M.I.T. subjects, and consequent advanced placement, is given on the basis of a high achievement in the tests. The student is notified before registration of the credit offered so that he may discuss with his Faculty Adviser an optimum schedule.

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

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

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

COLLEGE TRANSFERS

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

Selection of Students

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

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

Advanced Credit

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

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

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

Application Procedure

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

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

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

2. A certified transcript of his college record to date, including a statement of 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 (three for the Bachelor in Architecture).

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

College transfer students are, in general, not eligible for 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 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, 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. The tests will be given on January 16, May 1, and October 2, 1965. It is recommended that applicants take the test on January 16; however, May 1 test results will be accepted. Test registration forms can be secured by writing to the Educational Testing Service at the above address.

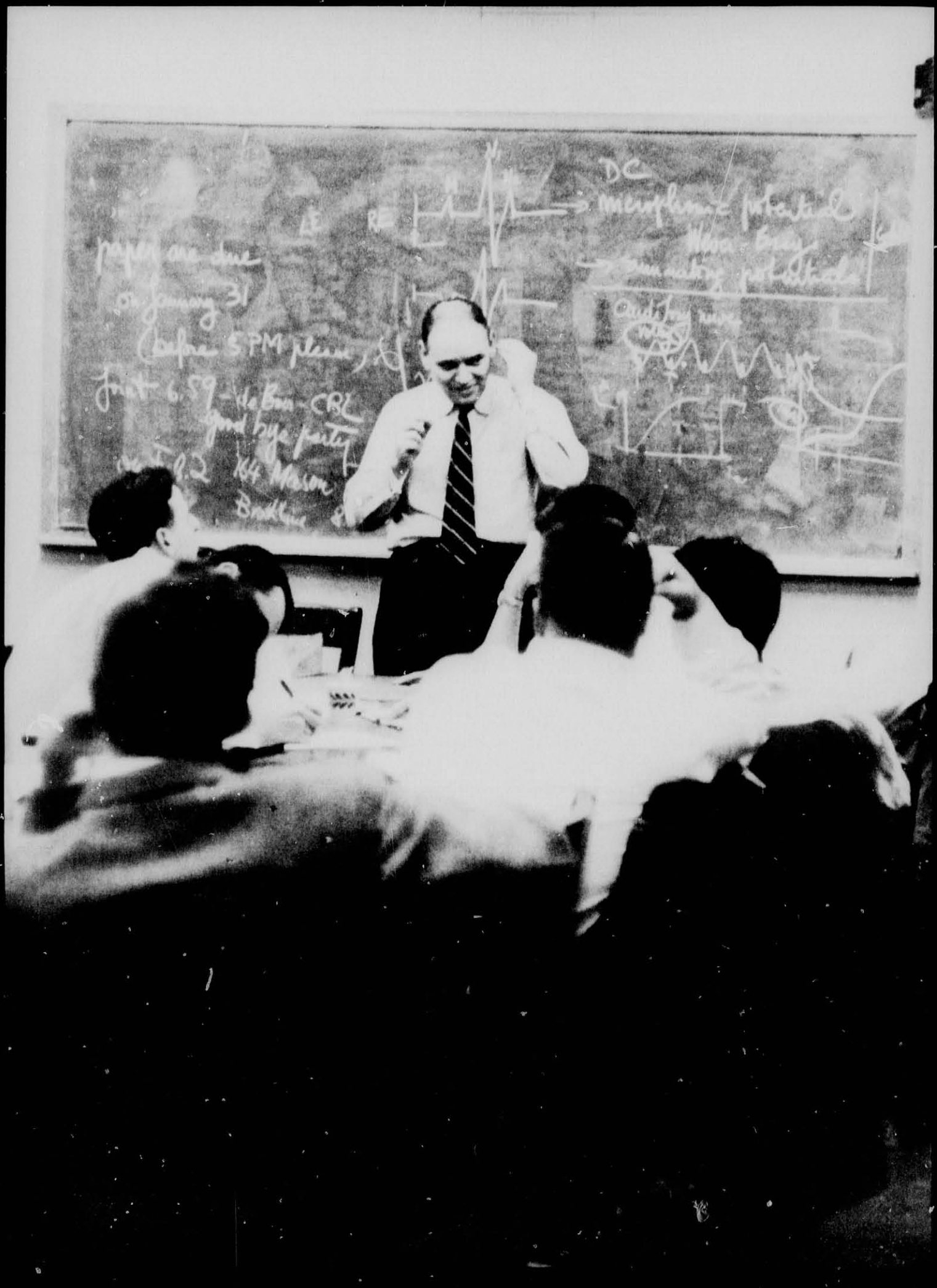
Foreign students should make all arrangements for their financial obligations to M.I.T. and for their entire stay in the United States before leaving their countries.

Foreign students who wish to enter the Institute at the Graduate School level should refer to Section 3 of this Catalogue. Further information about the admission of foreign students is available from the Office of the Adviser to Foreign Students.

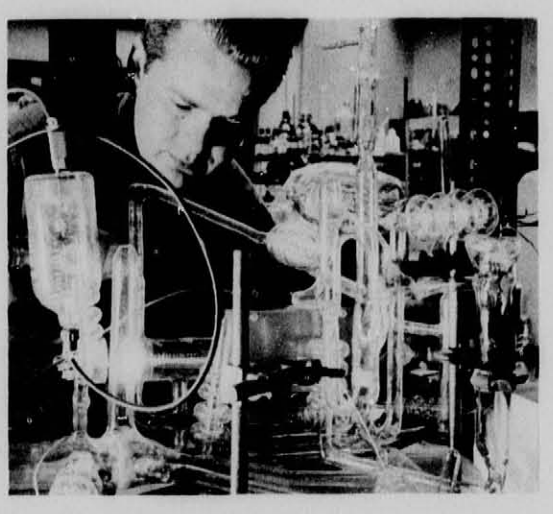
ADMISSION OF SPECIAL STUDENTS

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.



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

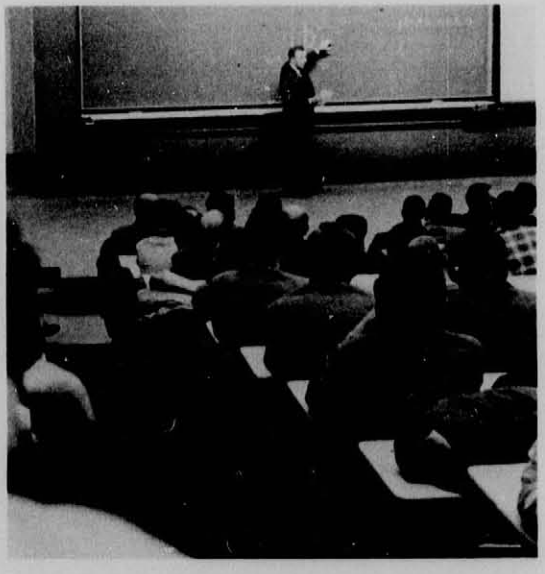
to extending mental horizons, producing new orientations, and developing growth in intellectual courage and in depth of understanding. Achieving mastery of basic principles develops the mind as no mere acquisition of specialized knowledge can; it provides the power to attack unsolved problems with success 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. Therefore graduate students find assignments as teaching assistants rewarding and stimulating as an integral part of their graduate education. These and similar junior staff positions in research also offer the student professional assignments combined with an approach to financial self-sufficiency. At M.I.T., graduate students are in a very real sense junior partners of the faculty in study, in teaching, and in pioneering research. They have the responsibilities of mature students and independent professional workers.

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 2,800. About 1,500 students are admitted to the Graduate School each year, more than 700 of them coming to M.I.T. with baccalaureate degrees from about 175 other American colleges and universities. Some sixty foreign countries and more than 130 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 Insti-



tute'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 eleven 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; with National Science Foundation support they are a national agency for collecting and cataloguing current Communist Chinese publications in science and technology; and 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 pro-

fessional field, M.I.T. encourages breadth of experience as well. Doctoral Minors are occasionally taken in fields entirely unrelated to the Major field. Leaders in many areas of technology 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.

The Graduate House for single men and Westgate apartments for married students, both described in Section 1 of this Catalogue, provide comfortable living accommodations, while the Graduate House also serves as a center for graduate student social life. Professor Francis Bitter of the Department of Geology and Geophysics is Master of the Graduate House; the presence of Professor and Mrs. Bitter in the House contributes greatly to its warmth and friendliness.

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 the Graduate 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.

Graduate House residents have a Graduate 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. Members of the Committee on Graduate School Policy are listed with 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.

FIELDS OF STUDY

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

School of Architecture and Planning

Department of Architecture
ARCHITECTURE, Course IV-A

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

School of Engineering

Department of Aeronautics and Astronautics
AERONAUTICS AND ASTRONAUTICS, Course XVI
Aerodynamics and gas dynamics
Aeroelasticity
Aeronautical and astronautical engineering
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
Computation
Control
Electrical science and engineering
Electronics
Energy processing
Molecular engineering

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

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

Department of Humanities
HUMANITIES, Course XXI
Philosophy

Department of Modern Languages
MODERN LANGUAGES, Course XXIII
Linguistics

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

Alfred P. Sloan School of Management

INDUSTRIAL MANAGEMENT, Course XV

School of Science

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

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

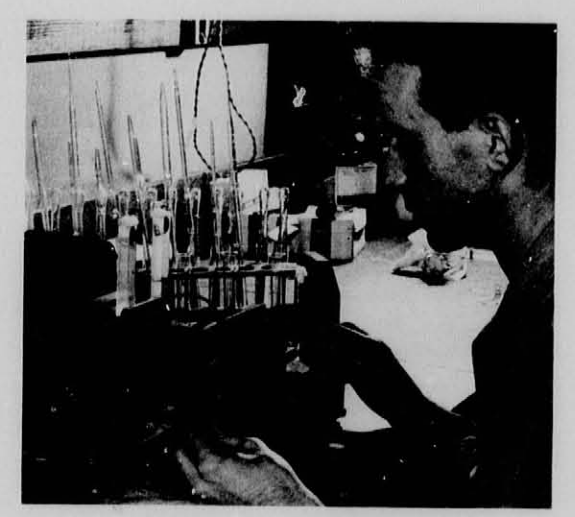
Department of Geology and Geophysics
GEOLOGY AND GEOPHYSICS, Course XII
Geochemistry
Geology (classical geology, theoretical geology)
Geophysics
Oceanography

Department of Mathematics
MATHEMATICS, Course XVIII

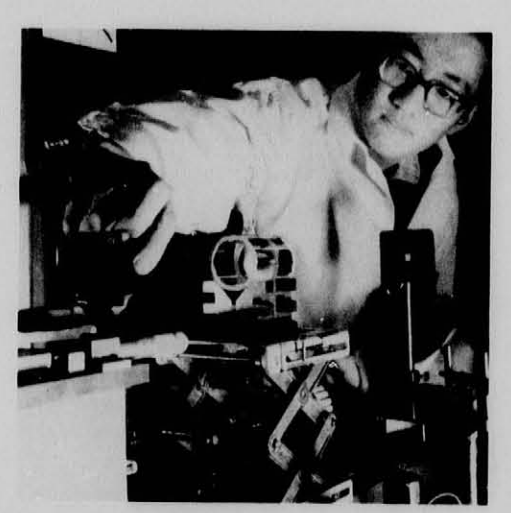
Department of Meteorology
METEOROLOGY, Course XIX
Oceanography

Department of Nutrition 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

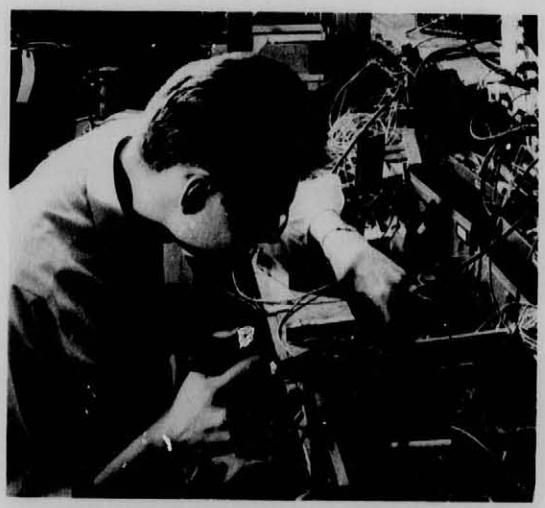
Department of Physics
PHYSICS, Course VIII



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

To be admitted as a Regular Graduate Student, an applicant must have received a Bachelor's degree or its equivalent from a college, university, or technical school of standing acceptable to the Director of Admissions of the Institute. His academic record and other credentials must indicate ability to accomplish satisfactorily an approved program of study and research.

Applicants are 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.

UNDERGRADUATE PREPARATION FOR ADVANCED DEGREES

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

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

Natural Science. Most departments require preparation substantially equivalent to the Institute's first- and second-year physics: PHYSICS I and II (8.01T and 8.02T); ELECTRICITY AND MAGNETISM (8.03); and OPTICS AND ATOMIC PHYSICS (8.04); and the Institute's first-year chemistry: GENERAL CHEMISTRY (5.01, 5.02). Some departments require only one year of physics, and a few only one year of college-level natural science.

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

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

Deficiencies in Preparation

Students with minor deficiencies in preparation may be admitted to the Graduate School; however, deficiencies in prerequisite general or professional subjects must be 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

To be considered for admission to the Graduate School, an applicant must submit a completed application form, which may be obtained from the Director of Admissions, Massachusetts Institute of Technology, Cambridge, 02139, and should be returned to him.

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

A $10 application fee will be required of all citizens of the United States or Canada applying for admission in June, 1965, or in later terms, and of all foreign students studying at United States or Canadian institutions who seek admission in June, 1965, or later. The fee should accompany the application form. Payment should be by check or money order, payable to W. A. Hokanson, Bursar.

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 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 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, whether or not he was a member of the M.I.T. academic staff or the Division of Sponsored Research staff at the time the work was done. His Major department will determine to what extent such subjects are acceptable and whether he will receive residence credit for them.

ADMISSION OF FOREIGN STUDENTS TO THE GRADUATE SCHOOL

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

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

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

Foreign 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.)

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

Further information about the admission of foreign students is available from the Office of the Adviser to Foreign Students, Massachusetts Institute of Technology, Cambridge (02139).

GRADUATE RECORD EXAMINATIONS

Applicants for admission to graduate study in the Schools of Architecture and Planning, Engineering, Humanities and Social Science, and Science are urged to submit results on the aptitude and advanced tests of the Graduate Record Examinations. Normally applicants will be expected to rank not lower than the median in the verbal and quantitative aptitude tests and in 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, 20 Nassau Street, Princeton, New Jersey, 08540. Inquiries from students in western states should be addressed to 1947 Center Street, Berkeley, California, 94704.

Registration

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

Academic Standards

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

Cooperative Arrangement with Harvard University

A graduate student who is engaged full time in study or in a combination of study and academic staff duties equivalent to full time may, by permission, enroll for advanced study (exclusive of research) at Harvard University or Radcliffe College without paying additional tuition, provided that this exchange enrollment does not exceed one-half of his total registration for the term. Included in the above category are 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 to the Dean of the Graduate School at M.I.T. 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 analagous to that described above for Harvard has been made between the M.I.T. Department of Economics and Social 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*.

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 Student Health Program is strongly recommended as a means of avoiding the serious financial burden experienced by a number of students of limited financial resources each year 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, or delay. Every such student, whether or not he anticipates a junior staff appointment as a teaching assistant, research assistant, or instructor, is invited to seek the School's advice and assistance in this matter.

The Graduate School will send 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 will also be sent to the prospective student. All graduate students under Selective Service must fulfill conditions of Operations Bulletin No. 46, as amended August 31, 1960. This requires that a Master's degree shall be completed in not more than two calendar years or a Doctorate in not more than five calendar years beyond the receipt of 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.

GRADUATE HOUSE ACTIVITIES

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

THE MASTER'S DEGREES

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

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

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

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 at least 96 units, of which 72 units, including a thesis of not less than 20 nor more than 40 units, must be "A" subjects. ("A" subjects are those intended primarily for graduate students; they are indicated in the Descriptions of subjects in this Catalogue.)

The choice of field of specialization must be approved by the Committee on Graduate Students of the department in which the student is enrolled. Approval of the entire program must be obtained from this Committee and from the student's Registration Officer. A special interdepartmental committee may be appointed by the Dean of the Graduate School to supervise a program in a field which spans two or more departments.

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

Degrees With and Without Specification

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

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

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

THE ENGINEER DEGREES

The objective of a program leading to an Engineer degree is a more advanced level and a broader range of competence in engineering and science than that required for the Master's degree, but with less emphasis on creative research than that characterizing a doctoral program. In general terms, the Master's degree requires a minimum of one academic year and the Engineer degree 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 comprising at least 192 units of advanced study and research, including a thesis of not less than 20 nor more than 50 units, approved by the appropriate department of the School of Engineering. A department may accept a Master's thesis of superior quality for the Engineer degree.

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

THE DOCTORATES

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

1. Completion of a Major program of advanced study, including a general examination.

2. Completion of a Minor program of study in an area distinct from that of the Major field.

3. Demonstration of proficiency in reading the technical literature of the Major field in modern foreign languages.

4. Completion and oral defense of a thesis on original research.

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

The Major Requirement

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

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

The Minor Requirement

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

The complete Minor program must have full approval before it is begun and the field of the Minor program must be approved by the student's departmental Committee.

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

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

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

The Language Requirement

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

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 one of the approved languages 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. The oral part is arranged individually upon request. Those in reading and translating are held at intervals stated by the Department of Modern Languages.

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

The investigation must be carried out under the supervision of an M.I.T. faculty member. Work already accomplished elsewhere which has not been under the supervision of an Institute faculty member cannot be accepted in partial fulfillment of the thesis requirement, nor can credit be granted for thesis 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.

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.

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

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

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

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

Financial Assistance to Graduate Students

Financial support 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. 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 AND SCHOLARSHIPS

A fellowship 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 (like traineeships given on the same terms), 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 500 students at M.I.T. have fellowships or other grants from national agencies for the academic year 1964–65.

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 15.

(text continues on page 72)

NATIONAL FELLOWSHIPS FOR GRADUATE STUDY

Atomic Energy Commission

Over 250 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 100 fellowships annually to male students graduating from U.S. colleges who seek to become teachers. Tuition plus $1,500 for a single student, $2,000 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

Thirty traineeships (similar to fellowships) granted by N.A.S.A. 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 or expanded programs of study. Tuition plus $2,000 to $2,400 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

Over 1,800 graduate fellowships and about 1,300 cooperative graduate fellowships offered annually to U.S. graduate students for study in the mathematical, physical, medical, biological, and engineering sciences, anthropology, economics (excluding business administration), geography, the history and philosophy of science, psychology (excluding clinical psychology), and sociology (not including social work); political science will be added in 1965–66. Twelve months' tuition plus $2,400 to $2,800 and dependency allowances. Awarded for one or two years; renewable. For graduate fellowships, application in the fall to the National Science Foundation, Washington, D. C., 20550. For cooperative graduate fellowships, application early in the fall on N.S.F. forms to the student's prospective school, from which the forms may be obtained.

A grant of the National Science Foundation provided for 79 traineeships in engineering at M.I.T. in 1964–65 as part of a national traineeship program; the Foundation hopes to expand this program for 1965 so as to provide support for students in engineering, mathematics, and the physical sciences and such related areas as biochemistry and biophysics. 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.

Alfred P. Sloan Foundation

Ten fellowships granted by the Foundation for award by M.I.T. to U.S. male first-year graduate students in engineering who intend to enter the teaching profession. Nine months' tuition plus $2,100 and dependency allowance. 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 71*)

Applications for fellowship aid filed after February 15 are considered 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 about April 1. In accordance with a resolution of the Council of Graduate Schools in the United States, to which over 180 graduate schools have signified their assent, a student has until April 15 to accept or decline an offer. If a student does not reply to an offer shortly after this date it may be cancelled.

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

TEACHING ASSISTANTSHIPS

M.I.T. employs over 350 graduate students each year as part-time 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. (The tuition of teaching assistants, as of other junior academic staff, is set at a level consistent with the time they can give to their studies. Details will be found in Section 1 of this Catalogue under Tuition Fees for Academic Staff Appointees.)

After four years or more of intensive study at the undergraduate level, many students enjoy the new perspectives afforded by a teaching appointment. The departments view 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 may take longer to obtain his degree, but this is not necessarily so.

Appointments to teaching assistantships are made upon recommendation of the head of a department to his academic dean. 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 800 graduate students at M.I.T. each year hold part-time 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 which contribute greatly to its vigor. (It is a policy of the Institute only to accept such projects as will be in keeping with its educational objectives.) Research assistants receive salaries which are intended to be comparable, after payment of income taxes and tuition, with fellowship stipends. The tuition charged to research assistants, as part-time students, is shown in Section 1 of this Catalogue under Tuition Fees for Academic Staff Appointees.

Many students prize the opportunity a research assistantship gives them to participate with others 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 1963–64. 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 because he has no other support or to add to his income from a fellowship or assistantship which is inadequate in his case; 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 will be found in Appendix A under Student Loan Funds. 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 careers as engineering teachers. 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 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.

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, Deposits, and Payments" in Section 1 of this Catalogue.)

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

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

1. 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.

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

Our School does not aim to produce a certain sort of professional man in quantity but rather to make it possible for each student to become an architect or city planner of individual quality. This philosophy of education has been carried out mainly by creating the kind of environment where different minds and talents may find stimulus, motivation, and a sense of direction.

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

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

PIETRO BELLUSCHI

Department of Architecture

LAWRENCE BERNHART ANDERSON, M.ARCH.
Professor of Architecture; Head of the Department
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; Assistant Secretary of the Faculty
PIETRO BELLUSCHI, DOTT.ING., LL.D., SC.D., D.F.A.
Professor of Architecture; Dean of the School of Architecture and Planning
EDUARDO FERNANDO CATALANO, M.ARCH.
Professor of Architecture
HORACIO CAMINOS, ARQ.
Professor of Architecture
ERNEST NAPOLEON GELOTTE, S.B.
Associate Professor of Construction, Emeritus
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
MARVIN EDWARD GOODY, M.ARCH., M.C.P.
Associate Professor of Architecture
WILLIAM JAMES LEMESSURIER, A.B., S.M.
Associate Professor of Structures
GERHARD MICHAEL KALLMANN, A.A.D.P.
Associate Professor of Architecture (Visiting)
WAYNE VESTI ANDERSEN, PH.D.
Associate Professor of the History of Art
HENRY ARMAND MILLON, PH.D.
Associate Professor of the History of Architecture
IMRE HALASZ, DIPL.ARCH.
Assistant Professor of Architecture
JOHN RANDOLPH MYER, B.ARCH.
Assistant Professor of Architecture
MAURICE KEITH SMITH, B.ARCH.
Assistant Professor of Architecture
JOSEPH JAMES SCHIFFER, M.ARCH.
Assistant Professor of Architecture
STANFORD OWEN ANDERSON, M.A.
Assistant Professor of the History of Architecture

Lecturers

CARL KOCH, M.ARCH.
PAUL WEIDLINGER, M.S.

Instructor

PETER LOUIS HORNBECK, M.L.A.

Technical Instructor

NISHAN BICHAJIAN

Professors Emeriti

HENRY LATIMER SEAVER, A.M.
Professor of History, Emeritus
ERNEST NAPOLEON GELOTTE, S.B.
Associate Professor of Construction, Emeritus

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

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

THE UNDERGRADUATE CURRICULUM

Architecture (Course IV-A)

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

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

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

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

The curriculum requirements are as follows:

GENERAL INSTITUTE REQUIREMENTS				*Total units*
8.01T	[1]PHYSICS I	5	0	6
8.02T	[1]PHYSICS II	5	0	6
8.03	[2]PHYSICS	4	1	5
	or			
8.031	[2]PHYSICS	4	1	5
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
21.03T	THE NATURE OF LITERATURE	3	0	5
	or			
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3	0	5
21.05T	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3	0	5
	or			
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	5
	or			
14.003	THE MODERN WORLD AND SOCIAL SCIENCE	3	0	5
	[1]*Freshman electives*		12	
	[3]*Humanities and social science electives*		32	
				136

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

DEPARTMENTAL PROGRAM				
	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			
4.121T	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
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	4
4.31T	STRUCTURES II	2	2	4
4.32T	STRUCTURES III	2	2	4
4.33T	STRUCTURES IV	2	2	2
4.34T	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	CONTEMPORARY ARCHITECTURE	3	0	5	
	THESIS		18		
					316
	Elective Subjects				16
Total units required for the B.Arch. degree					468

[1] Subjects of the first-year program. See pages 36–40.
[2] 8.03 and 8.04 are normally taken. 8.041, if selected in place of 8.04, must be followed by 8.051 (or 8.05).
[3] See pages 40–43 for the humanities and social science program. ECONOMIC PRINCIPLES I (14.01) is required. Subjects in Field Ten (Visual Arts) may not be used in satisfaction of the humanities and social science requirements.

ELECTIVE SUBJECTS

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

4.03 FORM AND COLOR (2–0–4)
4.031 VISUAL DESIGN PROBLEMS (2–6–0)
4.032 VISUAL DESIGN PROJECTS (2–6–0)
4.06 ADVANCED VISUAL DESIGN *
4.35 STRUCTURES SEMINAR (2–0–4)
4.36 STRUCTURES SEMINAR (2–0–4)
4.431 SPECIAL PROBLEMS IN ARCHITECTURAL ACOUSTICS *
4.45 ENVIRONMENTAL CONTROL-LIGHT (2–0–4)
4.47 SITE PLANNING (1–2–5)
4.49 INDUSTRIALIZATION AND DESIGN (2–2–4)
4.53 COMPONENTS OF URBAN ENVIRONMENT (3–0–6)
4.54 CITY PLANNING TECHNIQUES (3–0–6)
4.601 INTRODUCTION TO THE VISUAL ARTS I (3–0–5)
4.602 INTRODUCTION TO THE VISUAL ARTS II (3–0–5)
4.603 THE CLASSICAL TRADITION IN AMERICA (3–0–5)
4.604 THE ROMANTIC TRADITION IN AMERICA (3–0–5)
4.65 THEORIES OF ARCHITECTURE (3–0–5)
4.66 THE CRITICISM OF ARCHITECTURE (3–0–5)
4.67 HISTORY OF URBAN FORM (3–0–5)
4.68 SPECIAL TOPICS IN HISTORY OF ART AND ARCHITECTURE *
4.69 SPECIAL TOPICS IN HISTORY OF ART AND ARCHITECTURE *
4.701 URBAN SOCIAL STRUCTURE AND PROCESS (2–0–6)
4.705 URBAN PLANNING AND SOCIAL POLICY (2–0–6)
4.81 CITY STRUCTURE AND ECONOMIC DEVELOPMENT *
4.85 REAL ESTATE ECONOMICS (2–0–4)

The following subjects in the humanities may be of special interest to students in Architecture:

21.521 HISTORY OF MATERIALS (2–0–6)
21.523 HISTORY OF ENGINEERING (3–0–5)
21.524 HISTORY OF ENGINEERING (3–0–5)
21.525 TECHNOLOGY AND ECONOMIC GROWTH AND SOCIAL CHANGE (3–0–5)
21.526 ENGINEERS IN HISTORY (3–0–5)
21.671 PHILOSOPHY OF THE ARTS (3–0–5)

* Time arranged.

CREDITS FOR TRANSFER STUDENTS HOLDING A PREVIOUS DEGREE

A student admitted into the Course in Architecture who holds a degree from his previous college will be considered to have completed the requirements of two years of the normal architectural curriculum, provided that he has completed the following studies to the satisfaction of the appropriate departments at the Institute.
Two years of subjects in English and history.
One year of mathematics, including differential and integral calculus.
Two years of natural science, including at least one year of physics.
One year of structures or building technology.
One semester of descriptive geometry.
Two years of studio work in drawing and design.
Subjects acceptable as first-year electives.

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

GRADUATE STUDY IN ARCHITECTURE

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

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

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

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

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

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

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

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

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

MASTER IN ARCHITECTURE

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

Department of City and Regional Planning

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

Senior Lecturers

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

Lecturers

PHILIP BARNARD HERR, M.C.P. (*Visiting*)
LAWRENCE A. SULLIVAN, LL.B. (*Visiting*)

Instructor

JOHN DAVIDSON MILLER, M.C.P.

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. Advanced students receive a broad picture of the entire field of planning, supplemented by work in library, workshop, and field. Electives in city planning, land economics, and similar subjects may be chosen by qualified students whose major interests are in related fields.

UNDERGRADUATE PREPARATION FOR CITY AND REGIONAL PLANNING

The Department does not offer an undergraduate degree. However, undergraduates who expect to do graduate work in the Department may, by a careful selection of elective subjects during their last two undergraduate years, reduce the time normally needed to complete the requirements for the graduate degrees.

Suitable undergraduate Courses are Architecture (Course IV-A), Civil Engineering (Course I), Economics, Politics, and Engineering (Course XIV-A), Industrial Management (Course XV), and Humanities and Engineering (Course XXI-A). Students who plan to enter the graduate Course in City Planning should discuss their undergraduate programs with the Department's Registration Officer, preferably during their second year.

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

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

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

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

Mathematics and Physics. 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 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 (4.241)
CITY AND REGIONAL PLANNING (4.261)
SITE PLANNING (4.47)
COMPONENTS OF THE URBAN ENVIRONMENT (4.53)
CITY PLANNING TECHNIQUES (4.54)
URBAN SOCIAL STRUCTURE AND PROCESS (4.701)
METHODS OF RESEARCH IN CITY PLANNING (4.74)
CITY STRUCTURE AND ECONOMIC DEVELOPMENT (4.81)

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 (4.71), PROBLEMS IN CITY PLANNING (4.262), four elective subjects, and an individual thesis of 30 units conducted under the supervision of a member of the staff.

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.

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. These include urban and metropolitan design, housing and urban land problems, mathematical and advanced research techniques, political science and administration, economic analysis, transportation planning, regional planning and development, problems of the developing areas of the world, and city planning methods and techniques. 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).

Following the Institute rules, candidates for the Ph.D. degree will be required to take a minor in a field other than city and regional planning. Candidates will also be required to demonstrate their ability to read professional literature in two modern foreign languages or a substantial competence in speaking and reading one language.

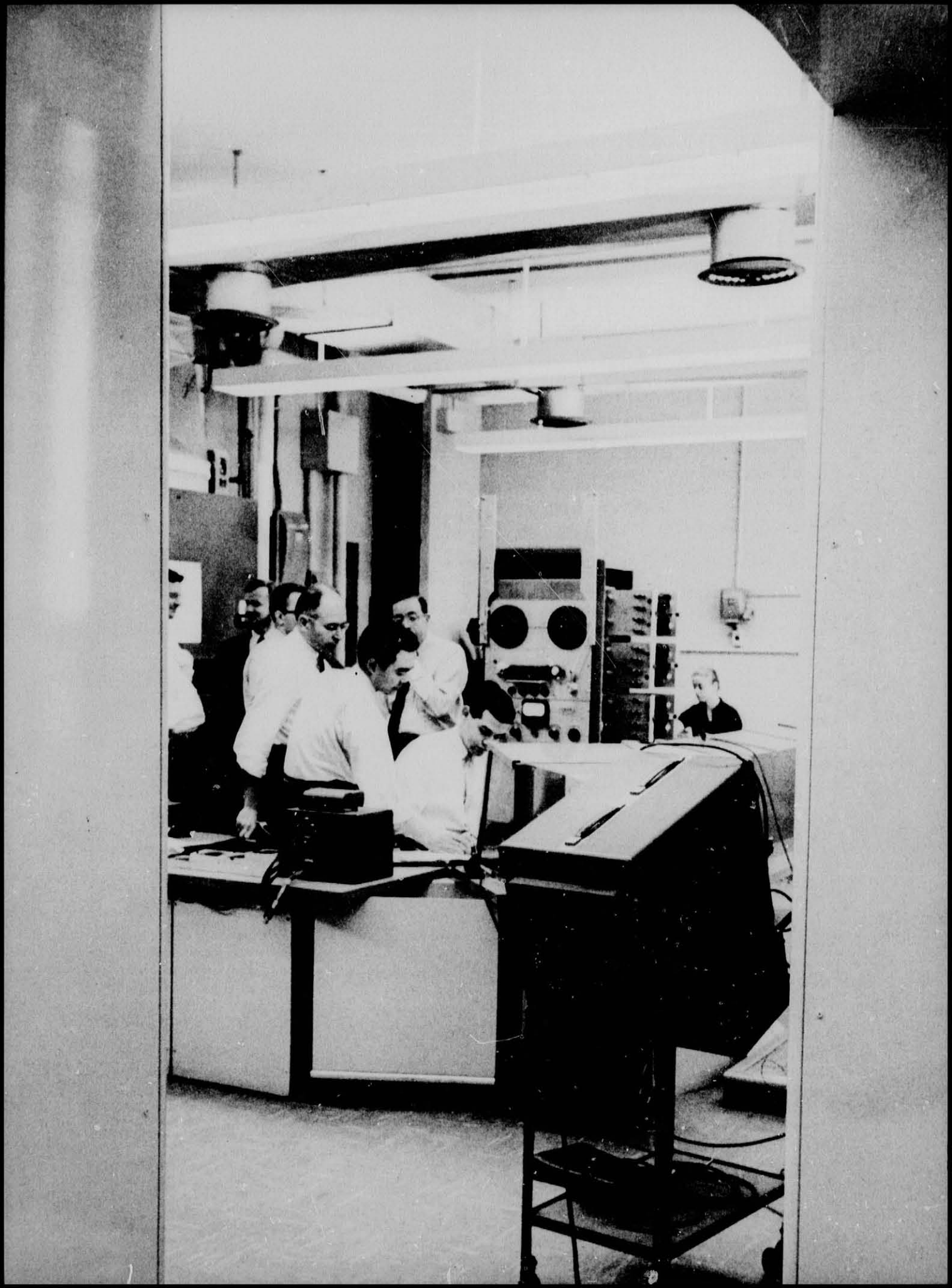
Upon successful completion of examinations, the student is required to prepare a written doctoral thesis evidencing the capacity to do independent research in some approved field of study. Each student is examined orally on his thesis.

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

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

Urban Design

Special workshops and seminars are offered to both master's and doctoral candidates specializing in urban design — the shaping of the visual form of the city, which is distinct from the design of large-scale architectural projects. The urban designer must be a thoroughly trained city planner, and this work is in addition to the basic curriculum. For the master's candidate, an extra term's attendance is required. The urban design program is open to those with a strong background in design and in the liberal arts.



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.

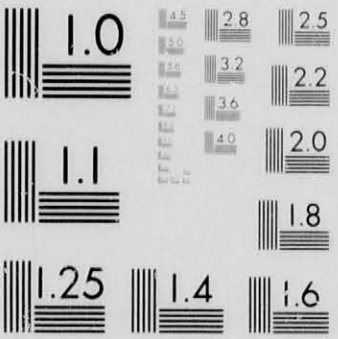
It is the engineer who is bringing about the great revolution in technology. Largely by his efforts we have at last achieved the technical potential for the creation of a society free from want.

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,



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

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

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

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

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

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

GORDON S. BROWN

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

WILLIAM WALTHER SEIFERT, SC.D.
Assistant Dean

ENGINEERING COUNCIL

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

RAYMOND LEWIS BISPLINGHOFF, SC.D. (*Absent*)
Deputy 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.
Head, Department of Electrical Engineering

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

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

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

HERMANN ANTON HAUS, SC.D.
School Representative on the Faculty Committee on Educational Policy

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

EXECUTIVE OFFICERS

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

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

WILLIAM MACGREGOR MURRAY, SC.D.
Department of Mechanical Engineering

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

SCHOOL PROFESSORS

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

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

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. Typical Course Schedules are issued each term by the Registrar with the Class Schedules. Electives within the Departmental Program may include two additional humanities or social science subjects. R.O.T.C. subjects may be used according to the specifications in Section 2.

GENERAL INSTITUTE REQUIREMENTS				*Total Units*
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	PHYSICS	4	1	5
	or			
8.031	PHYSICS	4	1	5
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
21.03T	THE NATURE OF LITERATURE	3	0	5
	or			
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3	0	5
21.05T	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3	0	5
	or			
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	5
	or			
14.003	THE MODERN WORLD AND SOCIAL SCIENCE	3	0	5
	[1]*Freshman electives*		12	
	[3]*Humanities and social science electives*		32	
				176

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

[1] Subjects of the common first-year program. See pages 36–40.

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

[3] See pages 40–44 for the humanities and social science program.

Department of Aeronautics and Astronautics

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

RAYMOND LEWIS BISPLINGHOFF, DR.SCI.TECHN., D.SC. (*Absent*)
Professor of Aeronautics and Astronautics; Deputy Head of the Department

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

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

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

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

JOHN RAYMOND MARKHAM
Professor of Aeronautical Engineering, Emeritus

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

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

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

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

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

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

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.
Professor of Aeronautics and Astronautics

ABRAHAM HYATT, B.S.
Jerome Clarke Hunsaker Professor of Aeronautical Engineering (Visiting)

JAMES WAH MAR, 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

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

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JOHN DUGUNDJI, SC.D.
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JACK LEO KERREBROCK, PH.D.
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WINSTON ROSCOE MARKEY, SC.D.
Associate Professor of Aeronautics and Astronautics

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

EUGENE EDZARDS COVERT, SC.D.
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JAMES ELLIOT McCUNE, PH.D.
Associate Professor of Aeronautics and Astronautics

MYRON ARNOLD HOFFMAN, SC.D.
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Assistant Professor of Aeronautics and Astronautics, Emeritus
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Assistant Professor of Aeronautics and Astronautics
SECOR DELAHAY BROWNE, A.B.
Assistant Professor of Flight Transportation
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.
Assistant Professor of Aeronautics and Astronautics
EARL HUGH DOWELL, SC.D.
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ROBERT WARREN SIMPSON, SC.D.
Assistant Professor of Aeronautics and Astronautics; Postdoctoral Fellow in Engineering
SHEILA EVANS WIDNALL, SC.D.
Assistant Professor of Aeronautics and Astronautics; Postdoctoral Fellow in Engineering

Lecturers
RAMON LUIS ALONSO, PH.D.
RICHARD HORACE BATTIN, PH.D.

Technical Instructors
JOHN BARLEY
ALLAN RALPH SHAW

Professors Emeriti
JEROME CLARKE HUNSAKER, SC.D., ENG.D.
Professor of Aeronautical 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 cause the problems of flight to fall among the most difficult of those that confront mankind.

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 it is possible for students to find assistance in meeting their expenses while acquiring valuable experience in environments of significant achievement.

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 opportunities for 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. It is usual for students who have acquired reasonable levels of skill in the Projects Laboratory to continue their personal development by moving 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 Aeronautics 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. Faculty Counselors approve individual programs, assuring that all students are firmly grounded in science and also have training in engineering subjects that are acceptable as preparation for graduate study. The curriculum requirements for the Bachelor of Science degree are as follows:

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)			176
	PHYSICS 8.03 and 8.04 *or* 8.031 and 8.041[1] must be taken. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.		
DEPARTMENTAL PROGRAM			
	Required subjects		
16.81	FLIGHT VEHICLES	3 0 6	
3.14	ENGINEERING MATERIALS	4 2 4	
16.20	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 4	
16.62	EXPERIMENTAL PROJECTS I	2 4 4	
	THESIS	9	
			79
	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	FLIGHT VEHICLE STRUCTURES I	4 0 6	
	or		
16.202	SOLID MECHANICS II	4 0 6	
16.11	FLIGHT VEHICLE AERODYNAMICS AND DYNAMICS	4 0 5	
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	
			40 to 46
	Unspecified		75 to 69
Total units required for the S.B. degree			370

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

At the beginning of their second year, or as soon thereafter as they begin work toward the Bachelor of Science degree in Aeronautics and Astronautics, students are expected to meet with their Faculty Counselors and complete the tentative selection of subjects for their undergraduate programs. Typical groups of electives are described below, for the purpose of stimulating early consideration and providing guidance rather than placing any limitation on individual choices. Students may review and alter their selections, subject to the Counselors' approval, during the registration period of each term.

In selecting specific subjects, students should be guided by their preferences among the various basic areas of aeronautics and astronautics, maintaining a balance between engineering science and engineering. Individuals planning to continue education in the M.I.T. Graduate School should emphasize electives in mathematics and applied science.

ENGINEERING SCIENCE

The Department allows for personal preferences toward engineering science by suggesting electives in physics, mathematics, gas dynamics and solid mechanics with some concentration on laboratory experience. A typical sequence of elective subjects is given below:

16.03	GASDYNAMICS	4 2 6
16.202	SOLID MECHANICS II	4 0 6
6.44	INTRODUCTION TO ELECTRICAL SCIENCE	4 0 6
16.53	ROCKET PROPULSION	3 0 6
16.63	EXPERIMENTAL PROJECTS II	2 6 4
8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 5
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 6
18.06	ADVANCED CALCULUS FOR ENGINEERS	3 0 6

ENGINEERING

A variety of undergraduate subject sequences are available to provide the elements of engineering education. Sequences of this kind include the Departmental core curriculum and either FLIGHT VEHICLE ENGINEERING (16.71) or SPACE SYSTEMS ENGINEERING (16.73) with ADVANCED CALCULUS FOR ENGINEERS (18.05, 18.06) strongly recommended as electives.

A typical elective sequence for students interested in Flight Systems is:

6.44	INTRODUCTION TO ELECTRICAL SCIENCE	4 0 6
16.02	AERODYNAMICS	4 2 6
16.11	FLIGHT VEHICLE AERODYNAMICS AND DYNAMICS	4 0 5
16.201	FLIGHT VEHICLE STRUCTURES I	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
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6
18.06	ADVANCED CALCULUS FOR ENGINEERS	3	0	6

It is recognized that most students will wish to plan programs that are different from the typical sequences listed and may wish to alter plans as their experience at the Institute develops. Flexibility to allow such changes after consultation with counselors is provided by the wide choice of available electives. For admission to graduate school the particular elective sequence followed is immaterial; the prime criterion is excellence of performance.

The Honors Course

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

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

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

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

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

CURRICULUM IN THE COOPERATIVE COURSE (COURSE XVI-B)

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

16.85	INDUSTRIAL PRACTICE	40 h.p.w.

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 astronau-

tics, in which case there will be less emphasis on engineering applications. Major fields of specialization include vehicle design and operation, aerodynamics or gas dynamics, space mechanics, structures, aeroelasticity, propulsion, instrumentation, and automatic control. For successful graduate work in any of these fields, strong preparation and aptitude in applied mathematics and physics are necessary foundations. Students may elect subjects in other departments which bear a useful relation to their program.

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

Entrance Requirements for Graduate Study

In addition to the general requirements for admission to the Graduate School, all applicants must have 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 (18.04) or its equivalent must be included. This degree is also awarded simultaneously with the Bachelor of Science in Aeronautics and Astronautics upon successful completion of the five-year Honors Course program.

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

ENGINEER IN AERONAUTICS AND ASTRONAUTICS

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

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

DOCTOR OF SCIENCE (OR PHILOSOPHY) IN AERONAUTICS AND ASTRONAUTICS

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

DOCTOR OF SCIENCE WITH SPECIALIZATION IN THE FIELD OF INSTRUMENTATION

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

MATERIALS ENGINEER AND DOCTOR OF SCIENCE IN MATERIALS ENGINEERING

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

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

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

Language Requirement

No language requirement is made for candidates for the Master of Science or Engineer degrees. A candidate for the Doctor of Science or Doctor of Philosophy degree must fulfill the Institute language requirement (page 69). 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.
Professor of Fuel Engineering; Director of the Fuels Research Laboratory

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

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

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

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

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

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

ARTHUR J. MADDEN, JR., PH.D.
Professor of Chemical Engineering (Visiting)

ROBERT CLARK REID, SC.D. *(Absent)*
Associate Professor of Chemical Engineering

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

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

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

KENNETH ALAN SMITH, SC.D. *(Absent)*
Assistant Professor of Chemical Engineering; United Engineers and Constructors, Inc., Preceptor

ADEL FARES SAROFIM, SC.D.
Assistant Professor of Chemical Engineering

WOLF RANDOLPH VIETH, SC.D.
Assistant Professor of Chemical Engineering

JOHN DELANO SHERMAN, B.CH.E.
Assistant Professor of Chemical Engineering

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

CHARLES GRAHAM HILL, JR., SC.D.
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

MAX CURTIS DEIBERT, SC.D.
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

MICHAEL MODELL, SC.D.
Assistant Professor of Chemical Engineering; Director of the Bound Brook Station, School of Chemical Engineering Practice

JON RENE VALBERT, SC.D.
Assistant Professor of Chemical Engineering; Director of the Bayway Station, School of Chemical Engineering Practice

MARTIN EDMUND WEBER, SC.D.
Assistant Professor of Chemical Engineering; Postdoctoral Fellow in Engineering

Technical Instructor

HAROLD HAVNER CARTER

Research Associate

PETER HARROLD DUNDAS, PH.D.

Professors Emeriti

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

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

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

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

STATIONS OF THE SCHOOL OF CHEMICAL ENGINEERING PRACTICE

Directors

JON RENE VALBERT, SC.D., *Bayway*

MICHAEL MODELL, SC.D., *Bound Brook*

Assistant Directors

WALTER FRITZ THEODOR WUERTH, S.M., *Bayway*

SIKIRU ADEBAYO SANNI, S.B., *Bound Brook*

CHEMICAL ENGINEERING

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

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

The 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.

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

In addition to work in science and engineering, students take an integrated sequence of subjects in the humanities and social sciences. The chemical engineer's progress and accomplishments are not determined solely by technological competence; fully as important are his breadth of outlook and understanding of society.

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

Chemical Engineering (Course X)

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

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)					**176**
PHYSICS 8.03 and 8.04 *or* 8.031 and 8.041[1] must be taken.					
DEPARTMENTAL PROGRAM					
Required subjects					
5.43	ORGANIC CHEMISTRY I	4	0	4	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
10.12	CHEMICAL ENGINEERING	3	0	5	
10.15	*THESIS REPORTS	0	4	0	
	THESIS		12		**40**
Elective subjects					
In specified areas:					
	Chemistry	at least 33			
	Chemical engineering	at least 60			
	Professional minor	at least 25			
	Laboratory work (within the above electives or partially in addition thereto)	at least 29			
Unspecified elective subjects as needed to fulfill the total unit requirement of					**144**
Total units required for the S.B. degree					**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).
* 10.15 is a "time-arranged" subject.

Electives in chemistry are normally selected from the following: a second term of organic chemistry (5.42); two further terms in physical chemistry (5.62 and 5.63); a term of analytical

chemistry (5.14); 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 10.91.

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. The requirements are the same as those in the regular program in Chemical Engineering with the following exceptions:

1. The minimum elective requirement in Chemistry is 38 units.

2. The minimum elective requirement in Chemical Engineering is 40 units, to be satisfied with subjects other than 10.61J, 10.64, 10.66, 10.67, 10.68, and 10.69.

3. A minimum of 40 units is to be devoted to an integrated program of subjects relating to materials, offered by the Departments of Physics, Chemistry, Metallurgy, and Mechanical, Civil, Nuclear, Electrical, and Chemical Engineering. Chemistry or Chemical Engineering subjects taken to complete this requirement are not included in the minima specified in (1) and (2).

4. The undergraduate thesis is to be written on a subject relating to the field of materials and approved by the Department. Selection of thesis topics suggested by other departments within the Schools of Engineering or Science is permissible and encouraged.

Chemical Engineering Practice (Course X-B)

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

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

Chemical engineering	45
Professional minor	15
Laboratory work	19

GRADUATE STUDY IN CHEMICAL ENGINEERING

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

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

Entrance Requirements for Graduate Study

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

ORGANIC CHEMISTRY I and II (5.41, 5.42) is normally essential.

Requirements for Advanced Degrees

The general requirements for the various degrees are specified in Section 3.

Fields of Study

The technology of chemical engineering in the process industries falls loosely into two categories: physical and chemical. While both types are encountered in many industrial problems, graduate subjects of instruction and research are logically grouped in the corresponding fields of engineering operations and applied chemistry. Most graduate students take some work in each field, and in the School of Chemical Engineering Practice the problem assignments involve fundamentals in both areas.

ENGINEERING OPERATIONS (PROCESS ENGINEERING)

The variety of graduate offerings provides opportunity for programs in heat transfer, fluid mechanics, and the separation processes based on mass transfer — subjects which are basic in process engineering. The topics include thermodynamics, applied mathematics, molecular transport properties, fluid mechanics and the interrelation of mass, momentum and heat transfer, distillation, mass transfer between phases, combustion, economic balance, and plant design. Opportunities for research of an advanced nature are available.

Relevant subjects offered by the Department include:

ANALYTICAL TREATMENT OF CHEMICAL ENGINEERING PROCESSES (10.33)
CHEMICAL ENGINEERING THERMODYNAMICS (10.40)
DISTILLATION (10.41)
ABSORPTION AND EXTRACTION (10.46)
ION EXCHANGE (10.47)
HEAT TRANSMISSION (10.50)
MECHANICS OF FLUIDS (10.52)
CHEMICAL ENGINEERING DESIGN (10.53)
PRINCIPLES OF COMBUSTION (10.70)

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

APPLIED CHEMISTRY

The Department offers a diversified program in applied chemistry, designed for the student who wants to broaden his competence in the chemical aspects of chemical engineering. This program provides subjects in industrial chemistry and chemical thermodynamics; in chemical kinetics and theory of rate-processes, with emphasis on heterogeneous and catalytic processes; and in the physical chemistry of ion-exchange, adsorption, and chromatography. The subjects listed under Materials Science and Engineering (below) also include several on applied chemistry. Much of the Department's research activity falls into these areas, and unique laboratory facilities are provided.

Relevant subjects offered by the Department include:

INDUSTRIAL CHEMISTRY (10.25)
ION EXCHANGE (10.47)
CATALYSIS (10.60)
SEMINAR IN CATALYSIS (10.601)
ADVANCED THERMODYNAMICS (10.62)
APPLIED CHEMICAL KINETICS (10.65)
CHEMICAL ENGINEERING IN BIOLOGY AND 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 attention is on the applied, as well as the basic, scientific aspects. Specific subjects offered are:

PHYSICS AND CHEMISTRY OF SURFACES (10.61J)
STRUCTURE AND PROPERTIES OF POLYMERS (10.64)
COLLOID CHEMISTRY (10.66)
APPLIED SURFACE CHEMISTRY (10.67)
POLYMER CHEMISTRY (10.68)
HIGH POLYMER TECHNOLOGY (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 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 (10.52)
APPLIED CHEMICAL KINETICS (10.65)
PRINCIPLES OF COMBUSTION (10.70)
SEMINAR IN HIGH TEMPERATURE PHENOMENA (10.72)
RADIATIVE TRANSFER (10.74)

SCHOOL OF CHEMICAL ENGINEERING PRACTICE

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

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

Bachelor's graduates of this Department ordinarily meet the requirements for the S.M. degree in Chemical Engineering Practice (Course X-A) in two terms. Starting in the September following graduation, students are at the field stations in Bayway and Bound Brook (10.85, 10.86 and 10.87, 10.88) until the end of January, and then return to the Institute to complete the program for the Master's degree during the spring term. Practice School experience (10.85, 10.86 or 10.87, 10.88) may be substituted for the S.M. thesis in Course X.

A similar Practice School program at the field stations starts early 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

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Professor of Civil Engineering; Assistant Secretary of the Faculty
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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 composed of structures; these often are large and extensive, requiring materials which perform for extended time periods under complex loads while exposed to the natural actions from the environment. Thus a fundamental understanding of the physics, chemistry, properties, structure, and behavior of materials is basic to civil engineering; new types of materials and structures, coupled with modern analytical and design tools such as computers and models, constitute another dimension in the profession.

The interaction of the many elements essential to the planning, design, construction, operation, and management of civil engineering projects is of controlling significance; these operations may now be formulated in terms of systems which can be engineered for optimum functional modes. Modern developments in mathematical techniques, systems analysis, simulation, operations research, and computer methods make the synthesis of civil engineering systems a challenging new area for study and research.

The research program of the Department is both substantial and comprehensive, supported by extensive experimental facilities. 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

The Department has excellent experimental equipment for study and research by both students and faculty; access to the facilities of other groups within the Institute further extends this capability. Following are descriptions of some 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 include 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, and the erosion of clays 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 fabri-

cate 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* includes a completely equipped digital computer and an information systems laboratory in which the students have direct access to an IBM 1620/1311 Electronic Data Processing System with 60,000 digits of magnetic core memory, magnetic disc storage, card input/output, and an on-line graphical plotting device. Remote console facilities for direct communication with the IBM 7094 in the M.I.T. Computation Center are available in the Department for computer use by students in the time-shared mode of operation. Advanced programming languages and systems which have been specially designed for student use of the computer are available. The information systems laboratory has stereoplotters, scanners, digitizers, and many types of special devices associated with civil engineering data systems; the facilities of the laboratory are being expanded to include additional digital and analog equipment for information acquisition, processing, and display.

THE UNDERGRADUATE PROGRAM

The undergraduate program of the Department offers an unusual educational opportunity to students seeking a strong base for careers in engineering; the program emphasizes fundamental technology, basic to many areas of engineering, as a foundation to assure subsequent professional growth.

The curriculum centers about a core drawn from the physical sciences, including solid and particulate mechanics, fluid dynamics, electromechanics, dynamic systems analysis, materials, and thermodynamics; some of the required subjects are cooperatively presented by the Departments of Civil, Mechanical, and Electrical Engineering and Metallurgy. Because of the importance of computers and of the modern mathematical sciences to engineering, two additional terms of work in this area are specified and four are recommended; for the same reason, the subject in computer methods normally is taken in the first term of the second year to permit the ready use of computational analysis throughout the remainder of the program.

In addition to the study of the physical and mathematical sciences, the undergraduate program includes work in the earth sciences, the social sciences, and engineering; also, through electives and his thesis, each student may develop additional breadth or depth in areas of special interest.

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

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)			176
PHYSICS 8.03 and 8.04 are taken except when plans for further study clearly indicate the need for the subject matter of 8.031 and 8.041.[1] ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.			
DEPARTMENTAL PROGRAM			
Required subjects			
1.01	GEOTECHNICAL SCIENCES	2 0 4	
1.05	FLUID DYNAMICS	3 3 6	
1.06	PARTICULATE MECHANICS	3 2 5	
1.07	ENGINEERING I	3 3 3	
1.08	ENGINEERING II	3 3 3	
1.511	STRUCTURAL ANALYSIS AND DESIGN I	3 2 5	
2.01	MECHANICS OF SOLIDS I	3 0 5	
2.02	DYNAMIC SYSTEMS	3 0 6	
	THESIS	9	
			82
Elective subjects			
In specified areas			
An approved program of one subject in each of the following areas is required: computer methods, electrical engineering, materials, thermodynamics, and probabilistic systems or statistics. The recommended subjects are as follows:			
1.15	COMPUTER APPROACHES TO ENGINEERING PROBLEMS	2 2 2	
6.42	ELECTROMECHANICAL COMPONENTS AND SYSTEMS	3 2 5	
3.14	ENGINEERING MATERIALS	4 2 4	
2.403	THERMODYNAMICS	4 0 8	

6.27J	PROBABILISTIC SYSTEMS ANALYSIS	3	0	6
	or			
18.10	INTRODUCTION TO PROBABILITY AND RANDOM VARIABLES	3	0	6
				47
	Unspecified			55
Total units required for the S.B. degree				360

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

ELECTIVE SUBJECTS

Undergraduate elective subjects offered by the Department include the following:

1.30	SOIL ENGINEERING	3	0	6
1.512	STRUCTURAL ANALYSIS AND DESIGN II	3	2	5
1.60	APPLIED FLUID DYNAMICS	3	0	6
1.92J	BUILDING PROCESS	3	3	4

Undergraduates having the proper prerequisites and high scholastic standing may elect subjects from the graduate program of the Department. The following is a partial list of department graduate subjects available as electives for qualified undergraduates:

1.09	OPERATIONAL SYSTEMS ANALYSIS	3	0	6
1.10	NUMERICAL METHODS OF ENGINEERING ANALYSIS	3	0	6
1.21	FUNDAMENTALS OF TRANSPORTATION SYSTEMS	3	0	6
1.322	SOIL TECHNOLOGY	3	0	5
1.42	STRUCTURAL MATERIALS	3	2	4
1.561	ADVANCED STRUCTURAL MECHANICS	3	0	6
1.71	HYDROLOGY	3	0	6

Students are encouraged to consider appropriate subjects offered by other departments as part of their elective programs. Students planning to continue with graduate work are encouraged to include ADVANCED CALCULUS FOR ENGINEERS (18.05) within 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

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 pursu-

ing 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 various phases of fluid mechanics related to hydraulic engineering, water resources development, sanitary engineering, coastal engineering, and tidal hydraulics. Subjects in hydrodynamics deal with modern developments in turbulence, boundary layers, free surface flow, wave motion, diffusion, and sedimentation. The planning and development of water resources is treated through formal instruction in hydrology, hydraulic engineering, and systems analysis and through studies of the related economic and social factors.

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

A broadly conceived research effort in the Hydrodynamics Laboratory is closely coupled to the educational offerings and at present includes the following areas: computer study of power plant transients, diffusion in stratified flow systems, interaction of waves and floating or submerged bodies, resonant wave motion in coupled basins, wake mechanics and hydroelastic phenomena, turbulence measurements, fluid mechanics of turbo machinery, boundary shear in channels and the geomorphology of streams in erodible beds, and resistance and turbulence phenomena in non-Newtonian fluids.

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, 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 and soil fabric, the effective stress-strength behavior of stabilized soils, the shear strength of clay as influenced by time, temperature, pore fluid, and stress system, the use of computers to solve stress distribution and consolidation problems, the interaction between soil and buried structures, the relationship between wave propagation characteristics and engineering properties of soil, the load-settlement-pore pressure-time behavior of structures on clay deposits using large-scale models, 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, 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

Transportation is a very important area of advanced study and research in the Department. The graduate offerings include subjects in transportation systems, flight transportation, urban highway systems, engineering of location, and theory of traffic flow. Current research includes prediction of transportation demand in urban areas, network flow theory, computer methods of design, economic analysis, and rail transport problems. Over twenty-five staff members are engaged in transportation research. In addition to departmental subjects and research, graduate students interested in transportation have extensive opportunities for related interdisciplinary studies in city and regional planning, social and political sciences, economics, mathematics, management, and engineering in other departments and schools at the Institute. The Joint Center for Urban Studies and the Center for International Studies also have interests and activities in the field of 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 Sloan School of Management.

Research Assistants

The research of the Department is an integral part of the study program, and approximately eighty 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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DONALD EUGENE TROXEL, PH.D.
Assistant Professor of Electrical Engineering

BRUCE DANIELS WEDLOCK, SC.D.
Assistant Professor of Electrical Engineering

VIDAL RAPHAEL ALGAZI, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

ROGER WARE BROCKETT, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

ROBERT SHANKLIN COOPER, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

CHARLES KIMBALL CRAWFORD, SC.D.
Assistant Professor of Electrical Engineering

JOSEPH LINDLEY HALL, II, PH.D. (*Absent*)
Assistant Professor of Electrical Engineering

THOMAS SHI-TAO HUANG, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

ROBERT SPAYDE KENNEDY, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

CHUNG LAUNG LIU, SC.D.
Assistant Professor of Electrical Engineering

RUSSELL RAYMOND PFEIFFER, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

JOHN WILLIAM PODUSKA, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

IRVIN GALE STIGLITZ, PH.D.
Assistant Professor of Electrical Engineering (at Lincoln Laboratory)

OLEH JOHN TRETIAK, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

THOMAS FISCHER WEISS, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

DAVID JEROME KUCK, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

MICHAEL ATHANS, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

JAMES DONALD BRUCE, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

MICHAEL LEONIDAS DERTOUZOS, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

JAMES FRANCIS JANAK, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

ARTHUR THOMAS LEWIS, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

ALAN VICTOR OPPENHEIM, SC.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

DANIEL GUREASKO BOBROW, S.M.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

ELIJAH POLAK, PH.D.
Assistant Professor of Electrical Engineering (Visiting)

STEVEN EMANUEL SCHWARZ, PH.D.
Assistant Professor of Electrical Engineering; Postdoctoral Fellow in Engineering

PHILIP EDWARD SECKER, PH.D.
Assistant Professor of Electrical Engineering (Visiting)

RICHARD DALE SMALLWOOD, SC.D.
Assistant Professor of Electrical Engineering

Administrative Officer

JOHN AVERY TUCKER, M.ENG.

Lecturers

JORDAN JAY BARUCH, SC.D.
LEO LEROY BERANEK, SC.D.
GODFREY THOMAS COATE, M.S.
ALEXANDER KUSKO, SC.D.
WALTER HARRY PITTS
BARNEY REIFFEN, PH.D.
ROBERT HARVEY RINES, S.B., LL.B.
DOUGLAS TAYLOR ROSS, S.M.
JOHN ERWIN WARD, S.M.

Instructors

RALPH ALTER, S.M.
THOMAS HERNE CRYSTAL, S.M.
THOMAS GARDINER KINCAID, S.M.
GERALD BURT KLIMAN, S.M.
EMANUEL LANDSMAN, S.M.
JOHN SPENCER MacDONALD, S.M.
JONNY ANDERSEN, S.M.
RUDD HOOVER CANADAY, S.M.
WILLIAM GAMBRILL MAY, S.M.
ROBERT BRUCE PARENTE, E.E.
PIERRE ROLLAND BÉLANGER, E.E.
PETER RUSSELL GRAY, S.M.
PETER GEZA KATONA, S.M.
FREDERICK DAVID KETTERER, M.S.E.E.
RONALD RICHARD PARKER, S.M.
JEROME HOWARD SALTZER, S.M.
PAUL JOHN SHAVER, S.M.
RICHARD NELSON SPANN, S.M.
WILLIAM BENJAMIN LENOIR, S.M.
MURRAY BRUCE SACHS, S.M.
RONALD WILLIAM SCHAFER, S.M.
HERMAN MARTIN SCHNEIDER, S.M.
ROBERT E. KAHN, PH.D.
Postdoctoral Fellow in Engineering

Administrative Assistants

FREDERIC HENRY FAIRCHILD, B.S.
DOROTHY YOUNG

Non-Resident Instructors

RICHARD W. AHRONS, PH.D.
CHESTER M. DAY, JR., S.M.
LEO HELLERMAN, B.E.E., M.A.
RALPH W. KLOPFENSTEIN, PH.D.
PHILIP M. LEWIS, SC.D.
CABELL NICHOLAS PRYOR, JR., S.M.
JOHN FRANCIS TAYLOR, A.B.
GEORGE NORMAN TRYTTEN, PH.D.
STEPHEN J. URBAN, M.S.

Research Associates

MANUEL BLUM, PH.D.
MANUEL VALDIVIA CERRILLO, PH.D.
NATHANIEL I. DURLACH, M.A.
EDWARD LEWIS GLASER, B.A.
PAUL A. KOLERS, PH.D.
JEROME YSRAEL LETTVIN, M.D.
ARTHUR LINZ, PH.D.
DEAN ARNOLD POWERS, E.E.
ELWOOD WORRAL SCHAFER, S.B.
VICTOR HUSE YNGVE, PH.D.

Professors Emeriti

HERBERT BRISTOL DWIGHT, D.SC.
Professor of Electrical Machinery, Emeritus
RALPH GORTON HUDSON, S.B.
Professor of Electrical Engineering, Emeritus
CARLTON EVERETT TUCKER, 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
ARTHUR ROBERT VON HIPPEL, PH.D.
Institute Professor, Emeritus;
Professor of Electrophysics, Emeritus
KARL LELAND WILDES, S.M.
Professor of Electrical Engineering, Emeritus
RICHARD DUDLEY FAY, A.B., S.B.
Associate Professor of Electrical Communications, 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. Today its products and services influence the daily living of most of the world's population, and the tempo of growth and change continues. Because new concepts and developments are steadily appearing in the field, professional study and training must give more than a competence to handle the problems of the present. Students should not merely seek to acquire specific skills and methods; they must search for deep understanding of their work and direct it toward the future.

Electrical engineering at M.I.T. supports, in the main, two impelling desires of man. The first is his desire to establish communication — between man and man, between man and machine, and between machine and machine. Radar, radio and wire telephony, measurement, electronics, computation, and control — which are broadly referred to as *processing and transmitting information* — are the fields in which this communication takes place. The second is man's desire to substitute machines for human muscle — the giant motors, machines, and power systems that control the wheels of industry and also give us heat and light. Here the issue is to exploit energy for energy's sake, and we refer to these activities as *processing, transmitting, and controlling energy.*

A vital element in the virility of the environment is the influence of research on the evolution of the academic program. The Department supports large-scale research laboratories in a number of important fields, each with its own shops and supporting staff. These activities greatly enrich the whole academic environment, undergraduate and graduate.

THE UNDERGRADUATE CURRICULA

The Department offers two undergraduate degree programs: Electrical Engineering, a four-year program leading to the Bachelor of Science degree; and Electrical Science and Engineering, which emphasizes a broad and deep mastery of the engineering sciences. For either program cooperative work may be taken (Course VI-A) which interweaves industrial or research experience with education. Course VI-A and Course VI, Program 2, may extend over four or five years depending upon whether the student completes the requirements for the Bachelor of Science degree or goes on for the Master of Science degree.

The common objective of all these programs is to enable the student to develop an enduring basis upon which he can establish a career — not merely a job — in the multitude of professional, industrial, or business areas which depend upon electrical technology. In preparation for his career, the electrical engineering student must develop a working mastery of the basic sciences of mathematics, physics, and chemistry, with emphasis on mechanics, electricity and magnetism, and thermodynamics. On these are built his professional study of the principles of electrical engineering and their applications.

A major feature of the professional programs of the last three years is the group core of seven classroom subjects, embracing the areas of circuit theory, electronic devices, circuits and signals, field theory, energy processing, and materials, which are required for all students in the Department. In the classroom, emphasis is placed first on basic principles and methods of analysis and then on their integration and application to a broad range of specific electrical processes and equipment. The student becomes aware that these principles and applications form a closely integrated core of electrical science. By applying basic principles in elective subjects and in his thesis research in the fourth year, each student achieves a still deeper understanding of the significance of the sciences for his field.

The laboratory subjects are used to teach experimental technique and not to illustrate the classroom material. Illustration is provided by classroom demonstrations. The laboratory objectives go beyond the mastery of related experimental facts, methods, and techniques. The work includes a large proportion of project activity, in which students acquire the art of providing an experimental model of a physical situation and using it to achieve the objectives of an engineering investigation. Here each student encounters the need for engineering judgment, team work, and careful planning. He sharpens his ability to observe, gains confidence in making decisions from independent, creative thought, and assumes a progressively increased responsibility for the planning and execution of his laboratory work.

Many features of the programs contribute strongly to the development of initiative, judgment, resourcefulness, and responsibility. Indi-

vidual study, under staff guidance, is encouraged. Close association among staff and students in small class sections serves to encourage vigorous and healthy discussions among students and staff who have similar interests.

Electrical Engineering (Course VI)

THE ELECTRICAL ENGINEERING PROGRAM

The Course leads to the degree of Bachelor of Science in Electrical Engineering. This four-year program is designed for the student who wishes to defer the decision on his future work or on graduate study until toward the end of his program. In addition to the humanities electives, about one-half of the senior-year program is elective. The student's selection of subjects, made in consultation with his Faculty Counselor, will depend on whether he expects to undertake graduate study in electrical engineering or some other field, at M.I.T. or elsewhere, or expects to enter industry for work or further study in an industrial training program; a total of 16 units of additional humanities may be elected.

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

1. ELECTRICAL ENGINEERING PROGRAM CURRICULUM

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)			**176**
	PHYSICS 8.031 and 8.041[1] 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	
6.06	FIELDS, FORCES, AND MOTION	3 0 6	
6.07	ENERGY TRANSMISSION AND RADIATION	3 0 6	
6.08	MOLECULAR ENGINEERING	3 0 6	
6.70	EXPERIMENTAL ELECTRONICS	1 4 1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1 4 1	
6.72	ELECTROMAGNETIC LABORATORY	1 4 1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1 4 1	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 5	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 6	
	THESIS	9	
			126
	Elective subjects		
	Unspecified		**58**
Total units required for the S.B. degree			**360**

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

[2] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

THE ELECTRICAL SCIENCE AND ENGINEERING PROGRAM

This program is offered for a selected group of students who feel relatively confident at the sophomore level that they will want to go on to graduate study and therefore wish an early opportunity to build a basic background in the engineering sciences. There is abundant evidence pointing to the need for graduate study to equip a young engineer with first-rate technical competence and breadth in the world of today and tomorrow. This program is distinguished from Program 1 by the extent to which its curriculum includes higher mathematics and physics and emphasizes the electrical science aspects of the core curriculum subjects.

Students normally apply for admission to Program 2 at the beginning of the sophomore year. Transfer students or others who are well prepared in mathematics and who have completed the work of the sophomore Program 1 curriculum may be admitted at the beginning of the junior year. It is expected that students who elect Program 2 will maintain high academic records and that many will wish to continue their education to the level of the doctorate. The Department urges all students in the program to spend at least one and preferably two summers gaining practical experience in some industrial activity before graduation. Faculty Counselors will assist them with this.

Program 2 may lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year, if the student is admitted to the Graduate School. The curriculum requirements for the Bachelor of Science degree are given below.

2. ELECTRICAL SCIENCE AND ENGINEERING PROGRAM CURRICULUM

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)			**176**
	PHYSICS 8.031 and 8.041[1] 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 ELECTRIC CIRCUIT THEORY	4 0 8	
6.023	ELECTRONIC DEVICES AND CIRCUITS	4 0 8	
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4 0 8	
6.053	CIRCUITS, SIGNALS AND SYSTEMS	4 0 8	
6.063	FIELDS, FORCES, AND MOTION	3 0 6	
6.073	ENERGY TRANSMISSION AND RADIATION	3 0 6	
6.083	MOLECULAR ENGINEERING	3 0 6	

6.11	[2]PROJECT SEMINAR	2	0	4	
6.12	[2]PROJECT SEMINAR	2	0	4	
6.13	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	3	0	6	
6.70	EXPERIMENTAL ELECTRONICS	1	4	1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
6.72	ELECTROMAGNETIC LABORATORY	1	4	1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
18.18	PROBABILITY	3	0	6	
					147
	Elective subjects				
	Unspecified				37
Total units required for the S.B. degree					360

[1] 8.041 must be followed by 8.051 (or 8.05).
[2] 6.11 and 6.12 PROJECT SEMINAR satisfy the S.B. thesis requirement.

Electrical Engineering (Cooperative Course) (Course VI-A)

This program combines academic study with industrial practice correlating the scientific and engineering principles of the classroom and laboratory with from thirty to sixty weeks of practical experience in the plants of a particular industry. This educational plan makes it possible for students to do some "undergraduate" work in industry interwoven with their undergraduate studies at the Institute. The first four years of the required studies are identical in academic content with those of Course VI. The fifth year includes a complete academic year of graduate work, subject to the provisions of the Graduate School.

Candidates for admission to the Course are selected from the second-year class at the Institute and from transfer students who have completed substantially the equivalent of the first two years of Course VI. The fifth year necessitates admission to the Graduate School, for which acceptance is based on each student's scholastic record and upon personal qualifications, as exhibited in his cooperative work experience.

Taken together, the fields of work and the application of the cooperating companies cover substantially the entire spectrum of electrical technology and the electrical industry. While a student is normally associated only with one company for his plant work, his plant assignments are arranged to provide broad experience with the affairs and operating procedures of industry and with the kinds of work in which engineers are engaged. The level of technical sophistication and responsibility at the plants is kept in step with each student's growing technical competence as he advances in his academic program.

The industrial companies — such as the AVCO Corporation, General Electric Company, General Radio Company, International Business Machines Corporation, Philco Corporation, Radio Corporation of America, and Raytheon Company — provide experience in testing, design, development, and research in various areas of the 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 government laboratories, such as the Air Force Cambridge Research Laboratories and the Naval Ordnance Laboratory, provide opportunities to experience, with progressively increased responsibility, the many skills and technical disciplines which are brought together in a large laboratory that is concerned with basic and applied research and creative engineering covering a wide range of electrical technologies.

While at the plants, students are subject to the usual company regulations. They receive regular compensation for their work. During the practice periods, classes in prescribed academic subjects are held two evenings a week. At the conclusion of the work, students are not obligated to accept employment with the company, nor is the company obligated to offer employment.

The Course leads to the degree of Bachelor of Science in Electrical Engineering for four years of study; and may lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously[1] at the end of the graduate year, if the student is admitted to the Graduate School. The curriculum requirements for the Bachelor of Science degree are given below.

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

CURRICULUM BASED ON ELECTRICAL ENGINEERING (COURSE VI, PROGRAM 1)

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)				**176**
	PHYSICS 8.031 and 8.041[1] 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
6.06	FIELDS, FORCES, AND MOTION	3	0	6
6.07	ENERGY TRANSMISSION AND RADIATION	3	0	6
6.08	MOLECULAR ENGINEERING	3	0	6
6.70	EXPERIMENTAL ELECTRONICS	1	4	1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1
6.72	ELECTROMAGNETIC LABORATORY	1	4	1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6
	THESIS[2]		9	
				126
	Elective subjects			
	Unspecified[2,3]			**58**
Total units required for the S.B. degree				**360**

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

[2] Students who go on for the S.M. degree and receive the S.B. and S.M. degrees simultaneously may substitute 9 units of additional elective for the S.B. thesis.

[3] Industrial practice subjects must be taken by students in this Course VI-A curriculum; elective credit for these subjects is limited to a maximum of 27 units and a minimum of 18 units.

CURRICULUM BASED ON ELECTRICAL SCIENCE AND ENGINEERING (COURSE VI, PROGRAM 2)

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)				**176**
	PHYSICS 8.031 and 8.041[1] 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 ELECTRIC CIRCUIT THEORY	4	0	8
6.023	ELECTRONIC DEVICES AND CIRCUITS	4	0	8
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
6.053	CIRCUITS, SIGNALS AND SYSTEMS	4	0	8
6.063	FIELDS, FORCES, AND MOTION	3	0	6
6.073	ENERGY TRANSMISSION AND RADIATION	3	0	6
6.083	MOLECULAR ENGINEERING	3	0	6
6.13	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	3	0	6
6.70	EXPERIMENTAL ELECTRONICS	1	4	1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1
6.72	ELECTROMAGNETIC LABORATORY	1	4	1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	1	4	1
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6
18.18	PROBABILITY	3	0	6
	[2]*Industrial project subject*		9	
				144
	Elective subjects			
	[2]*Unspecified*			**40**
Total units required for the S.B. degree				**360**

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

[2] Industrial practice and industrial project subjects must be taken by students in this Course VI-A curriculum; credit for these subjects is limited to a maximum of 27 units and a minimum of 18 units.

GRADUATE STUDY IN ELECTRICAL ENGINEERING

Graduate work in the Department of Electrical Engineering is in the fullest sense a partnership with an eminent professional faculty. Its objective is to aid each graduate student to develop a deeper grasp of fundamental principles and to achieve skill in their creative application to new and unsolved problems. The work is built around the close interrelations among mathematics, physics, advanced electrical engineering, and an extensive and diversified group of research and teaching activities.

Three kinds of advanced degree programs are offered. The program for the degree of Master of Science in Electrical Engineering provides one year of graduate work in which scientific and engineering principles are strengthened and applied in a limited area of electrical engineering. The programs for the degree of Electrical Engineer or for the degree of Materials Engineer require a much broader two-year graduate program for students preparing for engineering practice. The nominal three-year program for the degree of Doctor of Science or Doctor of Philosophy includes about one year or more of intensive research and leads toward careers in teaching or research. These one-, two-, and three-year periods are full-time minima for qualified Bachelors in Electrical Engineering.

There are no fixed programs of study for these degrees. Particular effort is made with each student to develop his program of graduate study along the lines of his individual special interest. Such a procedure provides him with a strong incentive for a high level of accomplishment and gives him a specialized ability that is immediately useful. This specialized ability, however, is deemed a less significant result of graduate study than is the clearer insight into and better integration of fundamental principles so generally gained by the graduate stu-

dent. Soundly conceived advanced work rarely fails to send the student back to deepen his understanding of elementary but basic principles. These ideas are evidenced by the methods of approach used in graduate engineering subjects and by the fact that students usually include in their programs further formal study of mathematics and physics.

Graduate work usually centers about a number of especially vital areas in electrical engineering. Each of these areas is characterized by an active research program coordinated with the graduate class and laboratory programs. Representative fields in which there are graduate subjects appropriate for advanced degree work in electrical engineering include:

Active circuits, instrumentation, and systems
Automata theory and switching circuits
Communications in man-made and natural 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; work is also available in business and industrial management, economics, and social science.

Research laboratories of extraordinary range and strength are sponsored by the Department. The principle of close integration between regular graduate studies and these research laboratories has proven very effective, yielding educational values beyond those of formal study alone. Most of the research work is free from security restrictions, and graduate student participation is a significant element of many projects. The Department regards active research as a dominant influence in its graduate program, and each project is conceived and administered so that graduate students can and do have full opportunity to associate with it while retaining their scientific individuality and initiative. Some of the research projects are mentioned in the following paragraphs.

In the *Electronic Systems Laboratory*, a large research and development program is closely coupled with extended graduate study covering numerous and varied phases of this subject. Close integration of control, digital and analog computation, and instrumentation, involving solid-state devices, electronic and electric circuits, and electromechanical, hydraulic, and mechanical elements in varied dynamical systems and processes, provides excellent educational breadth and depth in a currently active field.

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 radio physics, plasma dynamics, and communication sciences. The research in radio 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 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.

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

A group in *high voltage research* is concerned with the techniques of producing high-energy particles and radiation, and with their application to the needs of science, medicine, and industry.

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 Energy Conversion and Semiconductor Group* is concerned with problems which range from the fundamental physics of semiconductors to the engineering problems encountered in semiconductor device development and analysis. *The Microwave*

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 devices. Research carried out by the *Quantum Electronics Group* centers on a variety of problems involving masers and lasers, including the development of new materials, the production, modulation and detection of laser beams, and the application of these beams to problems in both solid state science and communication. New and unconventional semiconductors are being studied by a group concerned with *Photoconductive Semiconductors and Devices.* The development of new instrumentation important for solid state research is being undertaken by the *Mass Spectrometry Group. 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 Growing 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-, electron-, and neutron-diffraction techniques are used in studying crystal properties.

A facility differing in kind from these laboratories but equally essential in the educational program is the Vail Library, one of the great electrical libraries in the world, which now comprises approximately 50,000 volumes.

From the emphasis given to the graduate student's association with active projects, it is evident that his graduate study is conceived as a coordinated whole, culminating in thesis research, which allows him to develop his ability to reason constructively and to contribute to the advancement of engineering.

Studies toward an advanced degree can be pursued either as a full-time student or in combination with a graduate assistantship, of which about sixty are offered each year beginning in the summer or in the fall. These assistantships provide the opportunity for participation in one of the sponsored research laboratories associated with the Electrical Engineering Department, or participation in the teaching program of the Department, or both. All teaching assistantships in the Department of Electrical Engineering are full time and permit carrying about 50 per cent of a full-time graduate study program. Thus, a degree requires about twice the minimum time, but holders of the appointments find the additional educational experience associated with them quite as valuable as the formal study. Part-time research assistantships are available. These reduce the time requirement for a degree to about one and one-half times the normal total, or less. For the doctorate especially, candidates often desire both teaching and research experience. The financial assistance given by these appointments is frequently an important additional consideration.

A brochure on *Graduate Study in Electrical Engineering*, describing research and teaching opportunities in detail, may be obtained from the Department.

Entrance Requirements for Graduate Study

The general requirements are as set forth in Section 3 of this Catalogue, without exception.

The Graduate Record Examination, described 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:

INTRODUCTION TO QUANTUM PHYSICS (8.051)
INTRODUCTORY CIRCUIT THEORY (6.01, 6.02)
ELECTROMAGNETIC FIELDS AND ENERGY (6.03)
CIRCUITS, SIGNALS, AND SYSTEMS (6.05)
FIELDS, FORCES, AND MOTION (6.06)
ENERGY TRANSMISSION AND RADIATION (6.07)
ADVANCED CALCULUS FOR ENGINEERS (18.05)
MOLECULAR ENGINEERING (6.08)

Credit is not usually allowed for undergraduate subjects in which the applicant's grades are low. Superior achievement in undergraduate mathematics and physics is considered particularly important.

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

The Graduate Degrees

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

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

Students working for the Master's degree are expected to devote themselves to a few subjects, not more than four each term, in addition to their research. The subjects are wholly elective and are not restricted to those given by the Electrical Engineering Department; however, the program of study must be well balanced, emphasizing one or more of the mathematical, economic, or experimental aspects of electrical engineering.

The Cooperative Course in Electrical Engineering (Course VI-A) and Electrical Science and Engineering (Course VI, Program 2), which are described above, may both lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year.

ENGINEER DEGREES

Able students who wish to prepare for creative application of engineering and scientific principles in engineering practice and who desire more extensive training than is possible within the 96 units required for the Master's degree, yet who are not interested in acquiring the training in research afforded by doctoral study, are encouraged to study for the Electrical Engineer or Materials Engineer degrees. Programs for these degrees are elective except for the thesis and ordinarily require at least four terms of graduate study beyond the Bachelor's degree level.

The general requirements for the Engineer degrees are given in Section 3.

DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY

Only students who have shown promise of performing truly creative work in either engineering or engineering science are encouraged to study for the Doctor's degree. Students entering on graduate work who do not have records that show strong evidence of this ability are usually advised to qualify first for the Master's degree. The thesis research for the doctorate is expected to make a substantial and noteworthy contribution in electrical engineering or a related field.

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

The General Examination is divided into two parts, of which the first is both written and oral. The written part is designed to determine whether the candidate is qualified, in terms of command of the basic sciences and practices of electrical engineering, to take advanced study and research of doctoral caliber. It should be taken at or before the end of the first calendar year of graduate study. The second part of the General Examination is normally taken early in the third academic year of graduate study when the preparatory program of specialized graduate study has been completed.

Each applicant for the doctorate in electrical engineering is required to satisfy the language requirements as stated on page 69 of this Catalogue. Modern languages should be selected from German, Russian, and French.

The field of the Minor is not prescribed by the Department, but usually mathematics or physics is chosen.

Department of Mechanical Engineering

HORTON GUYFORD STEVER, PH.D., SC.D.
Professor and Head of the Department

WILLIAM MacGREGOR MURRAY, SC.D.
Professor of Mechanical Engineering; Executive Officer

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

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

JOSEPH HENRY KEENAN, S.B.
Professor of Mechanical Engineering

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

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

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

EGON OROWAN, D.ENG.
Professor of Mechanical Engineering

ASCHER HERMAN SHAPIRO, SC.D.
Ford Professor of Engineering;
Chairman of the Faculty

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

STEPHEN HARRY CRANDALL, PH.D. (*Absent*)
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.
Professor of Mechanical Engineering

HENRY MARTYN PAYNTER, 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

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

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

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

STEVEN ANSON COONS
Associate Professor of Mechanical Engineering

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

GEORGE ARTHUR BROWN, SC.D.
Associate Professor of Mechanical Engineering

GEORGE SHERIDAN REICHENBACH, SC.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

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

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

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

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

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

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

JEROME CATZ, SC.D.
Assistant Professor of Mechanical Engineering

STEVEN IRWIN FREEDMAN, PH.D.
Assistant Professor of Mechanical Engineering
DEAN CHARLES KARNOPP, PH.D.
Assistant Professor of Mechanical Engineering
EDWARD FULTON KURTZ, JR., PH.D.
Assistant Professor of Mechanical Engineering
WILLIAM CRAIG MOFFATT, SC.D.
Assistant Professor of Mechanical Engineering
JOHN MITCHELL REYNOLDS, III, SC.D.
Assistant Professor of Mechanical Engineering
ROBERT ERWIN STICKNEY, PH.D.
Assistant Professor of Mechanical Engineering
FORBES TAYLOR BROWN, SC.D.
Assistant Professor of Mechanical Engineering
WILLIAM HENRY HEISER, PH.D.
Assistant Professor of Mechanical Engineering
CHARLES ADOLPH BERG, SC.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering
DAVID EDWARD NEWLAND, SC.D. (*Absent*)
Assistant Professor of Mechanical Engineering
GEORGE STEPHEN SPRINGER, PH.D.
Assistant Professor of Mechanical Engineering
MIKIO SUO, SC.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering
ARTHUR EDWARD BERGLES, PH.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering
AIDAN BENEDICT MCNAMARA, PH.D.
Assistant Professor of Mechanical Engineering (Visiting)
HAL LYNWOOD MOSES, PH.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering
RAYMOND GORDON COOK, PH.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering
IGOR PAUL, SC.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering
ARTHUR SHAVIT, PH.D.
Assistant Professor of Mechanical Engineering
CHAU-HSING SU, PH.D.
Assistant Professor of Mechanical Engineering; Postdoctoral Fellow in Engineering

Administrative Officer
JAMES HARRISON EACKER, S.M.

Senior Lecturer
GEORGE NICHOLAS HATSOPOULOS, SC.D.

Lecturer
HENRY MERRIAM MORGAN, SC.D.

Instructors
LEON ROBERT GLICKSMAN, S.M.
WILLIAM RUSSELL FERRELL, B.A., MECH.E.
RICHARD JOSEPH GURSKI, MECH.E.
JON RONALD KELLY, S.M.
DAVID NEAL WORMLEY, S.B.

Technical Instructors
RALPH JOHN BOWLEY
CLARENCE WILLIAM CHRISTIANSEN
FREDERICK HAROLD ANDERSON
JOHN LEACH

Professors Emeriti
CHARLES EDWARD FULLER, S.B.
Professor of Theoretical and Applied Mechanics, Emeritus
CHARLES WILLIAM BERRY, S.B.
Professor of Heat Engineering, Emeritus
JOSEPH CAINS RILEY, S.B.
Professor of Heat Engineering, Emeritus
CHARLES FAYETTE TAYLOR, PH.B., M.E.
Professor of Automotive Engineering, Emeritus
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
JAMES HOLT, S.B.
Professor of Mechanical Engineering, 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
IRVING HENRY COWDREY, S.B.
Associate Professor of Testing Materials, 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 science subjects as the dynamics of solids and fluids, the physics and mechanics of solids, thermodynamics, electrical circuit theory, and electromagnetic field theory.

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

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

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

THE UNDERGRADUATE PROGRAMS

Mechanical Engineering (Course II)

The work in the first two years of the undergraduate curriculum lays a thorough foundation in mathematics, physics, and chemistry. In the succeeding two years each student has a wide area of choice and may follow his natural interest, restrained only by the necessity of a balanced and logical program, which must have the approval of his Faculty Counselor. While the Faculty Counselor will consider any program a student may propose, the Department has worked out two basic programs, one centered around engineering and the other centered around engineering science. The Course leads to the degree of Bachelor of Science in Mechanical Engineering.

THE ENGINEERING PROGRAM

Building on a base of the pure sciences and the engineering sciences, a student in the Engineering Program has the opportunity to choose a coherent set of subjects in some particular technological area. The object is not specialization but rather a development of skill in joining the scientific with the creative aspects of engineering for useful ends. Examples of such areas are as follows:

Power and Propulsion. Power may be produced by gasoline engines, steam cycles, gas turbines, jets, or as-yet-undeveloped devices like the hydrogen-fusion power plant. The subjects available for this power and propulsion program give each student experience in the scientific approach to the problems which arise in power-producing machines. Since power machinery involves a great many branches of technology, basic analytical methods must be drawn from a variety of disciplines — including thermodynamics, combustion, fluid mechanics, strength of materials, and design — and applied to the analysis and design of engines and power plants.

Design, Manufacturing, and Controls. Design and manufacturing are at the very core of most engineering projects, and many graduate mechanical engineers are engaged in these activities.

The engineering design process starts with a statement of something desired. The engineer creates a concept which tentatively satisfies the requirements of function, environment, and economy. This concept, or a suitable simplification or model of it, is then subjected to critical analysis in which science, tempered by engineering judgment, is applied at whatever level of sophistication may be justified by the nature of the problem. Since the culmination of the process is a tangible device, the problems of manufacturing must influence the process of design.

The manufacture of missiles, rocket engines, nuclear reactors, and other new mechanical devices requires unusual materials which present many challenging problems of fabrication. New tool materials such as ceramics and newly developed machining processes such as spark machining, ultrasonic grinding, and chemical and electrolytic removal processes provide students with interesting research problems that are in the vanguard of engineering progress.

Materials (Including Textiles). Many advances in engineering design and technology are limited by the performance of the materials available for any particular application. To make the most of materials requires a basic understanding of why materials behave mechanically in the way they do and of the measures that may be employed to take advantage of, or to improve upon, their properties for particular applications. In its broadest sense, this task requires a background ranging from the basic sciences of physics, chemistry, and mathematics to the engineering sciences of thermodynamics, mechanics of materials, physical structure of solids, elasticity, and plasticity.

Students may prepare for any of several activities in the general area of materials engineering by an appropriate selection of electives. These activities may range from the engineering aspects of advanced technological developments to the manufacturing, processing, and development of new materials.

Textile technology is a branch of the subject of materials which is growing in importance. It has received special attention within the Mechanical Engineering Department.

A program in industrial design can be arranged.

The curriculum for the first year is described on pages 36–40; since graphical competence is essential to effectiveness in mechanical engineering, GRAPHICAL CONCEPTS (2.721) or ENGINEERING GEOMETRY (2.711) are recommended as elective subjects. The undergraduate curriculum is given below. All undergraduate students in mechanical engineering are urged to devote one or two summers to practical experience in some industrial activity of their own choice before graduation.

1. ENGINEERING PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)		**176**
	PHYSICS 8.03 and 8.04 *or* 8.031 and 8.041[1] must be taken.	

DEPARTMENTAL PROGRAM

	Required subjects				
2.01	MECHANICS OF SOLIDS I	3	0	5	
2.02	DYNAMIC SYSTEMS	3	0	6	
2.03	DYNAMICS	3	0	6	
2.201	FLUID MECHANICS	4	0	8	
2.403	THERMODYNAMICS	4	0	8	
3.14	ENGINEERING MATERIALS	4	2	4	
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4	
2.731	ENGINEERING DESIGN	3	3	6	
2.671	EXPERIMENTAL ENGINEERING	2	4	2	
2.672	ENGINEERING PROJECTS	2	0	4	
	THESIS		15		
					113
	Elective subjects				
	In specified areas:				
	Thermodynamics				
2.404	STATISTICAL MECHANICS AND KINETIC THEORY	3	0	6	
	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				
6.42	ELECTROMECHANICAL COMPONENTS AND SYSTEMS	3	2	5	
	Materials				
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
	or				
2.301	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
					30 or 28
	Unspecified				**41 or 43**
Total units required for the S.B. degree					**360**

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

THE ENGINEERING SCIENCE PROGRAM

Revolutionary advances in science have opened new areas of knowledge whose practical exploitation has only begun. At the same time the pace of technological change has greatly accelerated, so that a man wishing to work at the frontier of engineering development must be prepared both to learn continuously and to make marked shifts in direction several times during his career. All this has created the need for men with a broad training deeply rooted in the sciences.

The program in engineering science prepares students for such careers by study covering two general fields. In the first are physics chemistry, and mathematics. In the second are the engineering sciences: the dynamics of rigid and elastic bodies, the mechanics of elastic and plastic solids, fluid dynamics, thermodynamics, the dynamics of systems, materials, and electrical science. This program differs from others in the Department because it incorporates more study in mathematics and physics and because the subjects in engineering science are at a level

which builds on the additional mathematics and physics.

Experience in research is an essential part of the Engineering Science Program. Design projects offer experience in the art of engineering. These parts of the program are adjusted to the interests, needs, and capacities of the individual student.

Although it is expected that most students in engineering science will proceed into graduate study, the undergraduate program is designed as a terminal program. It is intended as a basis for a career of versatility in research and development.

The curriculum for the first year is described on pages 36–40; since graphical competence is essential to effectiveness in mechanical engineering, GRAPHICAL CONCEPTS (2.721) or ENGINEERING GEOMETRY (2.711) are recommended as elective subjects. The undergraduate curriculum is given below. All undergraduate students in mechanical engineering are urged to devote one or two summers to practical experience in some industrial activity of their own choice before graduation.

2. ENGINEERING SCIENCE PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)					**176**
PHYSICS 8.031 and 8.041[1] are prescribed.					
DEPARTMENTAL PROGRAM					
Required subjects					
2.01	MECHANICS OF SOLIDS I	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	
2.403	THERMODYNAMICS	4	0	8	
2.404	STATISTICAL MECHANICS AND KINETIC THEORY	3	0	6	
3.14	ENGINEERING MATERIALS	4	2	4	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4	
2.671	EXPERIMENTAL ENGINEERING	2	4	2	
2.672	ENGINEERING PROJECTS	2	0	4	
	THESIS		15		
					134
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				
6.42	ELECTROMECHANICAL COMPONENTS AND SYSTEMS	3	2	5	
	Materials				
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
	or				
2.301	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
					19 or 21
	Unspecified				**36**
Total units required for the S.B. degree					**365 or 367**

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

The Advanced Undergraduate Program

In the conviction that a gifted mind can be developed to its full potential when suitably challenged, the Department makes special provision for the education of its exceptional students. Selection of students for the Advanced Undergraduate Program is made at the end of the sophomore year. During their third and fourth years, these men undertake special programs of study designed on an individual basis, with many graduate subjects included. Students in this program have, at the end of the fourth year, an intellectual maturity and a technical knowledge surpassing that of most Master's candidates and are in a unique position to pursue further graduate work. While the emphasis of the program is on the conscious pursuit of excellence rather than on degrees, it is sometimes possible for students in the Advanced Undergraduate Program to acquire the Master's degree before the end of the fifth year.

Students in this program will normally be invited to become members of the Honors Course, described below.

The Undergraduate Honors Course

Towards the end of the junior year an opportunity is offered to a limited additional number 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, including the time allotted to the Bachelor's thesis, with the exception that a single thesis of not less than 30 units is required.

Mechanical Engineering (Cooperative Course) (Course II-B)

The Cooperative Course in Mechanical Engineering gives students the opportunity to acquire

a background of industrial experience prior to the professional work of the fourth year. It 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.
2.952T	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 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, empha-

sizing one or more of the analytical, economic, design, or experimental aspects of mechanical engineering.

MASTER OF SCIENCE IN TEXTILE TECHNOLOGY

Candidates for the Master of Science in Textile Technology should have the training offered by the Institute (or equivalent training from another institution) in the fields of either chemical engineering, chemistry, mechanical engineering, business and engineering administration, or industrial physics. The program for the degree lasts from one to two years, depending upon preparation. Students who have graduated with high standing from technical or textile schools which offer less extensive preparation in science and engineering may be accepted for study, but should expect to spend a minimum of two years to fulfill the degree requirements.

MECHANICAL ENGINEER

In recent years there has developed a need for leaders possessing knowledge in depth in a number of areas associated with mechanical engineering. For those who desire to prepare themselves for engineering practice at a high professional level, the degree of Mechanical Engineer is awarded for a program of study which is more advanced than that for the degree of Master of Science. The requirements for the degree include an additional year of class work beyond the Master's degree together with satisfactory performance in a comprehensive examination. If the Master's degree was not taken at M.I.T., a thesis of 20 to 50 units must be a part of the program. The general requirements for the degree are given in Section 3 of this Catalogue.

MATERIALS ENGINEER

Candidates interested in studying materials engineering in the Mechanical Engineering Department should in general have training equivalent to that offered by the Institute in its undergraduate programs in any of several departments of engineering or science. The graduate program encompasses study in the areas of mathematics, physics, chemistry, electrical materials, continuum and dislocation mechanics, metallurgy, ceramics, elastomers, and plastics, as well as research. In general, two years are required for completion of the degree of Materials Engineer. General requirements for the degree of Materials Engineer include a qualifying examination, as described for the Mechanical Engineer Degree.

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

Admission to the doctoral program is granted only after the candidate has passed a qualifying examination; this should be taken as soon as possible after completing the Master's degree program. The requirements for the Doctor's degree include a Major program, a Minor program, a thesis, and qualification in two foreign languages with French, German, and Russian recommended.

The Major program, consisting of advanced study and research, may be selected in any field of science or engineering approved by the Department Committee on Graduate Studies. While no fixed number of units is prescribed, the usual program includes a substantial number of subjects in the student's area of principal interest, in addition to those taken to satisfy the requirements for the Master's degree; these, with the Minor program, usually require an additional two terms of work beyond the Master's degree.

The Minor program must be approved by the student's doctoral committee as well as by the department in which the minor is taken. It must conform to the provisions for the Graduate School in general, given in Section 3 of this Catalogue.

The qualifying examination must be completed before any program of research is undertaken. The language requirements should be fulfilled as early as possible in the program, so that the student will be capable of reading the foreign scientific literature on his proposed thesis subject before starting the actual research.

For his thesis, each candidate undertakes a program of research which will contribute significantly to his major field of interest. The Major program and the thesis are under the supervision of a doctoral committee selected by the student and his thesis supervisor. The doctoral committee makes an annual evaluation of the candidate's progress and conducts a final examination based on the thesis. While no fixed number of units is prescribed, the research usually requires at least one year of registration.

Candidates entering this doctoral program following award of the Master's degree in textile technology must meet the foregoing requirements but with a thesis in the field of fibrous materials.

Department of Metallurgy

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
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 Metallurgy;
Head of the Solid State Division, Lincoln Laboratory
CLYDE MELVIN ADAMS, JR., SC.D.
American Brake Shoe Company Professor of Metallurgy
WALTER ALAN BACKOFEN, SC.D.
Professor of Metallurgy
JOHN WERNER CAHN, PH.D.
Professor of Metallurgy
ROBERT EDWARD OGILVIE, SC.D.
Associate Professor of Metallurgy
MERTON CORSON FLEMINGS, SC.D.
Associate Professor of Metallurgy
ROBERT LOUIS COBLE, SC.D.
Associate Professor of Ceramics
ALFRED ROBERT COOPER, JR., SC.D. (*Absent*)
Associate Professor of Ceramics
ROBERT MICHAEL ROSE, SC.D.
Assistant Professor of Metallurgy
ROY KAPLOW, SC.D.
Assistant Professor of Metallurgy
THOMAS RAYMOND MEADOWCROFT, PH.D.
Assistant 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;
Postdoctoral Fellow in Engineering
RONALD ALAN BROWN, PH.D.
Assistant Professor of Metallurgy;
Postdoctoral Fellow in Engineering
JAMES HENRY HEASLEY, M.S.
Assistant Professor of Ceramics
KENNETH CALVIN RUSSELL, PH.D.
Assistant Professor of Metallurgy;
Postdoctoral Fellow in Engineering
BERNHARDT JOHN WUENSCH, PH.D.
Assistant Professor of Ceramics;
Postdoctoral Fellow in Engineering

Administrative Officer
DOUGLAS CRAIG JOHNSTON, S.B.

Instructors
ROBERT STEPHEN MROCZKOWSKI, S.B.
JOHN LAWRENCE BOMBACK, S.M.
DAVID KALISH, S.B.
HAROLD RICHARD LARSON, B.S.

Technical Instructors
PAUL FREDERICK HUGHES
ARTHUR JEREMIAH GREGOR
PHILIP RENE LAFRANCE

Research Associates
DONALD HILLS AVERY, SC.D.
BILL CORMANN GIESSEN, SC.D.
SHINJI KAWAJI, D.SC.
KENNETH MICHAEL RALLS, SC.D.
PETER MATHER ROBINSON, PH.D.

Professors Emeriti
JOHN CHIPMAN, PH.D., SC.D.
Professor of Metallurgy, Emeritus
CARLE REED HAYWARD, S.B.
Professor of Process Metallurgy, 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

Metallurgy is the engineering science which deals with the production, structure and properties, and utilization of metallic materials. While it is strongly based on the physical sciences, metallurgy is closely related to several branches of engineering. It is a field of great importance to science and industry, since metals in pure and alloyed form and in composite structures are man's most widely used materials with the most useful combination of properties. About three-quarters of the elements are metals, and fortunately they are found in the earth's crust in quantity and in suitable chemical combination so that they may be recovered at reasonable cost.

Metals have remarkable mechanical, electrical, and thermal properties which can be modified in many ingenious ways. New alloys and processing techniques are constantly being developed to tailor-make properties to specific applications. Metallic materials may indeed be regarded as the working substance of modern engineering; the operation of propulsion units such as gas turbines and rocket motors, of energy-producers such as nuclear reactors, and of electrical and mechanical machines and devices is critically dependent on the availability of very pure metals or complex alloys.

Metallurgists are in constant demand for service in industry, research, and government. The giant metal-producing industry employs metallurgists in all capacities from management of plant operations to development and research. The consumer industries, which make products ranging from automobiles to snap fasteners, also insure that the demand for metallurgists constantly exceeds the supply. Modern technology puts increasingly severe demands on the uses of metals, and metallurgists are prominent in research on the nature and properties of metals and alloys and in the development of new processing and production techniques. Metallurgy is particularly a field of interest to the physical scientist who is not content with the acquisition of knowledge but wishes to see the fruits of his endeavors realized in practice.

The basic training of a metallurgist with the Bachelor's degree is suitable for active participation in a great many engineering fields, but graduate study is increasingly necessary for careers in research.

Materials science is the study of the structure, properties, and behavior of materials of all kinds, but especially of those engineering materials which are used in structures, machines, and devices. It is a very broad field, and the Department concentrates on metals and ceramics, due attention being given to the properties of high polymers and composite materials. Considerable emphasis is given to the atomic, crystal, and gross structure of materials. Controlled manipulation of the structure is one of the principal areas of research and development in materials science, since properties can be profoundly affected thereby. Structure-property relations are emphasized in materials science on a broad front, whereas in metallurgy it is possible to concentrate on one class of materials and give more attention to the chemical properties.

Materials science requires enlightened application of the physics and chemistry of solids to real substances, complete with structural imperfections. Although it appears to be a relatively new field, it is one of the fundamental branches of engineering, brought into focus by the increasingly severe demands of modern technology. The methods of materials science have contributed largely to the development of electronic materials, including the transistor and other solid-state devices, superconducting materials, dispersion-hardened high-temperature alloys, ductile forms of many materials once thought to be completely brittle, new ceramic materials with remarkable properties, and novel methods for utilizing the new polymers. Development of new and better materials is one of the most urgent requirements of the national efforts in space exploration and energy conversion. The Department offers a wide range of subjects on the preparation, structure, properties, and processing of materials, on both undergraduate and graduate levels.

THE UNDERGRADUATE CURRICULA

The undergraduate curricula in Metallurgy and Materials Science seek to develop understanding of metals and materials from a foundation of basic physical and engineering science. They are purposely flexible, so that from a common core of subjects on thermodynamics, transport properties, and materials science a student can emphasize fields such as physical metallurgy, processing of materials, or ceramics. The elective programs, which constitute more than 20 per cent of the student's time, are chosen, with the help of an adviser, to give depth to such fields. Many graduate subjects are also open to undergraduates who have the necessary preparation. A booklet which describes possible groups of elective subjects is available from the Depart-

ment, and students are advised to obtain this before talking with faculty counsellors.

Participation in laboratory work by undergraduates is encouraged in the Department, and many different facilities are available. Some laboratories are associated with specific subjects, but each student can find separate facilities for thesis research. Among the teaching laboratories are extensive materials science and physical metallurgy facilities. The equipment includes microscopic, x-ray, and electron diffraction units, electron microscopes, and test apparatus for the study of mechanical, thermal, electrical, and magnetic properties. In the ceramics laboratories most types of ceramics, refractory and electrical, can be prepared and their properties studied. The chemical metallurgy laboratories contain equipment for the study of heat and mass flow, for the measurement of thermodynamic properties, and for kinetic studies. The materials processing laboratories are equipped for the study of deformation processing, solidification of materials, joining by welding and brazing, and the deposition of materials. The mineral engineering laboratories have facilities for the study of materials separation and surface chemistry as applied to flotation processes.

The Course in Metallurgy and the Course in Materials Science lead to the degree of Bachelor of Science in Metallurgy; the curriculum requirements are given below.

Metallurgy (Course III-A)

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)					176
PHYSICS 8.03 and 8.04[1] are preferred.					
DEPARTMENTAL PROGRAM					
Required subjects					
3.00	THERMODYNAMICS I	4	0	6	
3.01	HEAT AND FLUID FLOW	4	3	6	
3.02	CHEMICAL METALLURGY	4	3	5	
3.20	THERMODYNAMICS II	4	0	4	
3.31	MATERIALS SCIENCE I	4	3	5	
3.50	X-RAY METALLURGY	2	2	4	
3.81	PRINCIPLES OF MATERIALS SEPARATION	4	3	5	
2.01	MECHANICS OF SOLIDS I	3	0	5	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
	THESIS		12		
					103
Elective subjects					
Unspecified (except that total THESIS units may not exceed 18)					84
Total units required for the S.B. degree					363

[1] 8.041, if selected in place of 8.04, must be followed by 8.051 (or 8.05).

Materials Science (Course III-B)

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)					176
PHYSICS 8.031 and 8.041[1] are preferred.					
DEPARTMENTAL PROGRAM					
Required subjects					
3.00	THERMODYNAMICS I	4	0	6	
3.01	HEAT AND FLUID FLOW	4	3	6	
3.12	MATERIALS PROCESSING	3	3	6	
3.20	THERMODYNAMICS II	4	0	4	
3.31	MATERIALS SCIENCE I	4	3	5	
3.51	MATERIALS SCIENCE II	4	3	5	
2.01	MECHANICS OF SOLIDS I	3	0	5	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
6.14	ELECTRONIC NETWORKS AND DEVICES	4	2	6	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5	
	THESIS		12		
					116
Elective subjects					
Unspecified (except that total THESIS units may not exceed 18)					71
Total units required for the S.B. degree					363

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

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.

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 and plastic instability.

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 experimental foundry 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.

The Department maintains an analytical laboratory, machine and instrument-making shops, and a student machine shop.

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:

HEAT AND FLUID FLOW (3.01)
MATERIALS SCIENCE I (3.31)
THERMODYNAMICS II (3.20)
PHYSICAL CHEMISTRY II (5.62)
or
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)

Graduate students who wish to specialize in Mineral Engineering are, in addition, expected to have studied the equivalent of

PRINCIPLES OF MATERIALS SEPARATION (3.81)

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 (3.70) 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.

MATERIALS SCIENCE (3.31)
THERMODYNAMICS II (3.20)

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 including major, minor, and language 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. 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 on a full- or half-time basis 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

HORTON GUYFORD STEVER, PH.D., SC.D.
Professor and Head of the Department
JOHN HARVEY EVANS, B.ENG.
Professor of Naval Architecture; Executive Officer
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus
JACOB PIETER DEN HARTOG, PH.D., D.ENG.
Professor of Mechanical Engineering
MARTIN AARON ABKOWITZ, PH.D.
Professor of Naval Architecture
WILLIAM MAC NICHOLSON, S.M.
Captain, U. S. Navy
Professor of Naval Construction
PHILIP MANDEL, B.S.
Professor of Naval Architecture
SHANNON CURTIS POWELL, DOTT.ING.
Associate Professor of Marine Engineering
WILLIAM ROBERT PORTER, PH.D.
Commander, U. S. Navy
Associate Professor of Naval 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.
Assistant Professor of Marine Engineering
NEAL ALVIN BROWN, PH.D.
Assistant Professor of Naval Architecture

Lecturer
WILLIAM AVERY BAKER, S.B.

Professors Emeriti
LAWRENCE BOYLSTON CHAPMAN, S.B.
Professor of Marine Transportation and Marine Engineering, Emeritus
HENRY EASTIN ROSSELL, S.M.
Professor of Naval Construction, Emeritus
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus
GEORGE CHARLES MANNING, SC.D.
Professor of Naval Architecture, Emeritus
LAURENS TROOST, IR.
Professor of Naval Architecture, 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 operating below and just above the sea surface, as well as on it. Its interests range from the application of the most advanced engineering science disciplines to the unusual, and sometimes specialized, problems encountered in such vehicles; through the synthesis of all the systems, components, and structures of which they are comprised; to their construction; and to the management of shipping enterprises. These activities have the common purpose of creating new or better ships of all types by applying the latest developments in science. In keeping with this purpose, the Department of Naval Architecture and Marine Engineering emphasizes both the application of scientific knowledge and the development of each student's ability to interpret and apply future knowledge in all disciplines which are, or may become, pertinent.

The educational program of the Department leads to a broad engineering competence, with a core content which includes application of fundamental principles to problems in naval architecture and marine engineering. It is based on a wide-ranging foundation of fundamental science and is an excellent background for almost any later special activities based on the physical sciences. A flexible curriculum, a departmental faculty with wide and continuing industrial experience, and unusually close faculty-student contact all contribute to a sound and effective 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. 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 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, can be made up of subjects of general or specialized interest within or outside the department; or it may be chosen to satisfy well-defined objectives in special fields, such as hydrodynamics, structures, oceanography, noise and vibration, and hydroelasticity. Throughout the curriculum the emphasis is on developing logic and originality, so that graduates may make an orderly attack on any engineering problem.

The undergraduate curriculum is given below. Substitution for departmentally prescribed subjects is encouraged when appropriate to a student's educational objective and particularly when more effective sequencing of subjects can result, provided that the same broad coverage is maintained. Within departmental subjects, the time spent in design emphasizes the underlying engineering basis of design, rather than the mere presentation of results. Further, since both naval architecture and marine engineering are based in the general field of mechanical engineering, students spend much of their class time in the Department of Mechanical Engineering.

This four-year Course leads to the degree of Bachelor of Science in Naval Architecture and Marine Engineering. The curriculum requirements for this degree are given below:

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 85*)		**176**
	PHYSICS 8.03 and 8.04 or 8.031 and 8.041[1] must be taken.	
DEPARTMENTAL PROGRAM		
	Required subjects	
13.00	PRINCIPLES OF NAVAL ARCHITECTURE 4 1 7	
13.10	SHIP STRUCTURAL ANALYSIS AND DESIGN 3 3 6	
13.20	ENERGY CONVERSION SYSTEMS AND COMPONENTS 4 1 7	
13.30	MECHANICAL VIBRATION 3 0 5	
13.40	INTRODUCTORY SHIP DESIGN 1 6 2	
2.01	MECHANICS OF SOLIDS I 3 0 5	
2.02	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 6	
	THESIS 9	**130**
	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.	**54[2]**
Total units required for the S.B. degree		**360**

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

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 M.I.T.'s Department of Economics and Social Science and Alfred P. Sloan School of Management. They also broaden their experience by electing advanced subjects offered by other departments at the Institute.

The coordinated program of undergraduate electives and graduate study for Course XIII-B will be approved after consultation with and concurrence of the Department of Economics and Social Science and the 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 during that year with this end in view because interdepartmental requirements of graduate subjects in Economics and Industrial Management make early use of elective time for prerequisites highly desirable. Completion of the prescribed program within the minimum unit requirements specified

below 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.

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 67 units of graduate study and 29 units of THESIS, a total of 96 units. Up to a total of 11 units of additional THESIS may be taken with a corresponding reduction of the units of graduate study.

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 96 credit units, which is usually completed in one academic year if based on an undergraduate curriculum equivalent in scope to that offered by this Department, leads to the degree of Master of Science in Naval Architecture and Marine Engineering; a two-year program leads to the degree of Naval Architect or Marine Mechanical Engineer. Students with a less broad undergraduate background usually require more time; or they may follow a program leading to a Master of Science without specification, which requires equally high standards of academic performance.

To obtain the degree of Doctor of Science in Naval Architecture and Marine Engineering usually requires a minimum of three years of graduate work.

Subjects in this Department which are appropriate to the programs of civilian graduate students include the following areas:

HYDROMECHANICS (13.02, 13.03, 13.04)
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 will not generally be accepted by 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. 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. A reading knowledge of technical material in two foreign languages, or a reading and speaking knowledge in one, is required for the Doctor of Science degree. The particular languages chosen must be acceptable to the Department on the basis of the importance of their professional literature.

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 part-time assistantships in connection with teaching and research duties are available each year. In addition to M.I.T. fellowships and scholarships, and National Science Foundation grants awarded on recommendation of the department, 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. Simultaneously, at the end of the program, the Master of Science degree is awarded upon recommendation 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 addi-

tion 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 and Social Science, 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 subjects in statistics, probability theory, economics, management, accounting, and basic operations research required for 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 Study in 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
GORDON LEE BROWNELL, PH.D.
Associate Professor of Nuclear Engineering
ELIAS PANAYIOTIS GYFTOPOULOS, SC.D.
Associate Professor of Nuclear Engineering
NORMAN CARL RASMUSSEN, PH.D.
Associate Professor of Nuclear Engineering
HENRI FENECH, SC.D.
Associate Professor of Nuclear Engineering
DAVID DAYTON LANNING, PH.D.
Associate Professor of Nuclear Engineering; Assistant Director of the M.I.T. Reactor
KENT FORREST HANSEN, SC.D.
Assistant Professor of Nuclear Engineering
THOMAS HENDERSON DUPREE, PH.D.
Assistant Professor of Nuclear Engineering
LAWRENCE MARK LIDSKY, PH.D.
Assistant Professor of Nuclear Engineering
ARMANDO TRAVELLI, PH.D.
Assistant Professor of Nuclear Engineering; Postdoctoral Fellow in Engineering
FRANKLYN MILES CLIKEMAN, PH.D.
Assistant Professor of Nuclear Engineering; Postdoctoral Fellow in Engineering
THOMAS OWENS ZIEBOLD, PH.D.
Assistant Professor of Nuclear Materials

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

Research Associates
EDWARD JAMES BARNETT
WILLIAM NORMAN BLEY, S.B.
LINCOLN CLARK, JR., A.B., S.M.
PHILLIP EDMONDS, PH.D.
LYALL ROBERT ENSTICE, JR., B.S.
JAMES WATERBURY GOSNELL, M.S.
ERNEST THOMPSON, B.SC.
WILLIAM MACLAREN TRENHOLME, B.E.E., M.A.

NUCLEAR ENGINEERING

Nuclear engineering deals with the practical application of scientific knowledge of nuclear reactions and radiations. Today, fission is the nuclear reaction of greatest practical importance. Much of present-day nuclear engineering is concerned with use of the fission reaction for production of heat and power, transmutation of elements, and production of neutrons, gamma radiation, and radioisotopes. In the years ahead, the fission of nuclear fuels is expected to supplement and in many areas to replace the combustion of chemical fuels for producing power.

In the long-term evolution of nuclear engineering, thermonuclear reactions (fusion) may well play at least as important a role as fission does now. Development of a practical and economic means of producing power from the controlled fusion of deuterium would provide the world with an inexhaustible store of energy. Thus it is also important for the nuclear engineer to be familiar with the principles of fusion technology.

Recognizing that fission reactions and fusion reactions are both important areas of nuclear engineering, the Department offers optional graduate curricula either in fission technology or in thermonuclear and related plasma processes.

Nuclear engineering makes use of a synthesis of many skills. Important contributions to the solution of problems in the field are being made by men trained in physics, chemistry, and metallurgy and in chemical, civil, electrical, and mechanical engineering. The program in nuclear engineering at M.I.T. is open to men with undergraduate training in these and related fields. It aims to teach the basic principles of nuclear reactors and process technology and to show the student how his field of undergraduate specialization may be applied to nuclear engineering problems. The program should interest graduate students who wish to specialize in nuclear engineering as well as graduate students or advanced undergraduates in other departments who wish to obtain some familiarity with nuclear technology.

The Department offers the degrees of Master of Science and Doctor of Science in Nuclear Engineering and of Nuclear Engineer. No undergraduate degree is offered.

Registration in the Department and in all subjects of instruction is open to all students with the requisite prior training.

RESEARCH FACILITIES

The Department's educational program is supported by a number of outstanding experimental facilities for advanced basic research in nuclear engineering.

THE M.I.T. RESEARCH REACTOR

The M.I.T. Research Reactor is a 2000 kw. reactor fueled with U-235 and cooled and moderated by heavy water. Completed late in the spring of 1958, it is one of the finest university research reactors in the world. It provides first-hand experience in the design, performance, and operation of nuclear reactors and serves as a source of radiations for use in laboratory instruction on radiation detection and measurement methods. A variety of research projects make use of the intense sources of neutrons and gamma rays produced by the reactor. Areas of research in which the reactor is being used include: neutron physics, cross-section measurements, reactor physics, solid-state studies based on neutron diffraction, radiochemistry of the fission products, physics of neutron-capture processes, activation analysis, research with short-lived radioisotopes, radiation-catalyzed chemical reactions, radiation-induced biological effects, radiation therapy, and radiation-damage studies of materials.

OTHER RESEARCH FACILITIES

The Department has a well-equipped nuclear instrumentation laboratory, a 3.5 mev pulsed Van de Graaff accelerator, a pulsed neutron source, and two subcritical natural-uranium reactors, one moderated by water and the other by graphite. Laboratory space and shop facilities are available for research in all areas of nuclear engineering. M.I.T.'s IBM Type 7094 electronic computer is used extensively in research and graduate instruction.

Research on plasmas and controlled fusion is done in close cooperation with several other groups in the Institute's Research Laboratory of Electronics. This laboratory is an association of faculty and graduate students which is active in all aspects of plasmas. Typical research projects of Nuclear Engineering Department members have been: large, highly ionized steady-state plasmas, super-conducting magnetic systems, controlled fusion energy injection and extraction systems, thermionic diodes and plasma propulsion.

UNDERGRADUATE PREPARATION FOR NUCLEAR ENGINEERING

An undergraduate degree in physics, chemistry, or metallurgy, or in chemical, civil, mechanical, or electrical engineering offers suitable preparation for graduate study in nuclear engineering, provided the following M.I.T. undergraduate subjects or their equivalent have been included.

Physics: Three years, including atomic and nuclear physics.

Mathematics: Three years, including ADVANCED CALCULUS FOR ENGINEERS (18.05, 18.06).

Thermodynamics: 2.403, 3.20, or 10.13.

Heat Transfer: 2.50.

Electromagnetic Theory: 8.041 for all students intending to proceed to the Doctorate, and 6.07 or 8.72 for those students concentrating in the thermonuclear area.

Prospective graduate students should make every effort to take these subjects before starting graduate study. Students deficient in one or more of them may make up their deficiencies after admission to graduate study, but they will need more time to complete the graduate program.

Students who expect to apply for admission to the graduate Course in Nuclear Engineering should discuss their undergraduate programs with the Department's Registration Officer, preferably before the end of their junior year.

GRADUATE STUDY IN NUCLEAR ENGINEERING (COURSE XXII)

Details of the requirements for graduate degrees are given in the following paragraphs.

MASTER OF SCIENCE IN NUCLEAR ENGINEERING

The general requirements for this degree are listed in Section 3 of this Catalogue. Subjects 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 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:

BIOLOGICAL EFFECTS OF NUCLEAR RADIATION (22.20)
NUCLEAR REACTOR PHYSICS II (22.22)
NUCLEAR REACTOR ENGINEERING (22.231)
NUCLEAR PLANT DYNAMICS (22.242)
NUCLEAR REACTOR DESIGN (22.26)
NUCLEAR ENGINEERING FOR SPACE APPLICATION (22.232)
NUCLEAR CHEMICAL ENGINEERING (22.31)
NUCLEAR REACTOR LABORATORY (22.42)
RADIATION SHIELDING (22.54)
PLASMAS AND CONTROLLED FUSION (22.61)
MATERIALS FOR NUCLEAR REACTORS (22.71)
RADIATION AND RADIOISOTOPE APPLICATIONS (22.81)

Subjects recommended for candidates electing the thermonuclear process option are:

NUCLEAR REACTOR PHYSICS I (22.21)
PLASMAS AND CONTROLLED FUSION (22.61)

THERMONUCLEAR PROCESSES (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, although occasionally a fall and spring term are sufficient.

NUCLEAR ENGINEER

The program of study leading to the Nuclear Engineer degree is intended to provide a broader knowledge of nuclear engineering than is possible in the Master's program and to develop competence in engineering application or design. The general requirements for the Engineer degree are given in Section 3 of this Catalogue.

The program of 192 units required must be approved by the department and should provide a broad education for creative work in the field of nuclear engineering.

This program must include the completion of a substantial engineering design project of approximately 40 credit units, which may be represented by the Master's and/or Engineer theses. In any case, one thesis of at least 20 credit units is necessary.

DOCTOR OF SCIENCE IN NUCLEAR ENGINEERING

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

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

NUCLEAR REACTOR PHYSICS I (22.21)
NUCLEAR PHYSICS FOR ENGINEERS (8.531, 8.532)
PLASMAS AND CONTROLLED FUSION (22.61)

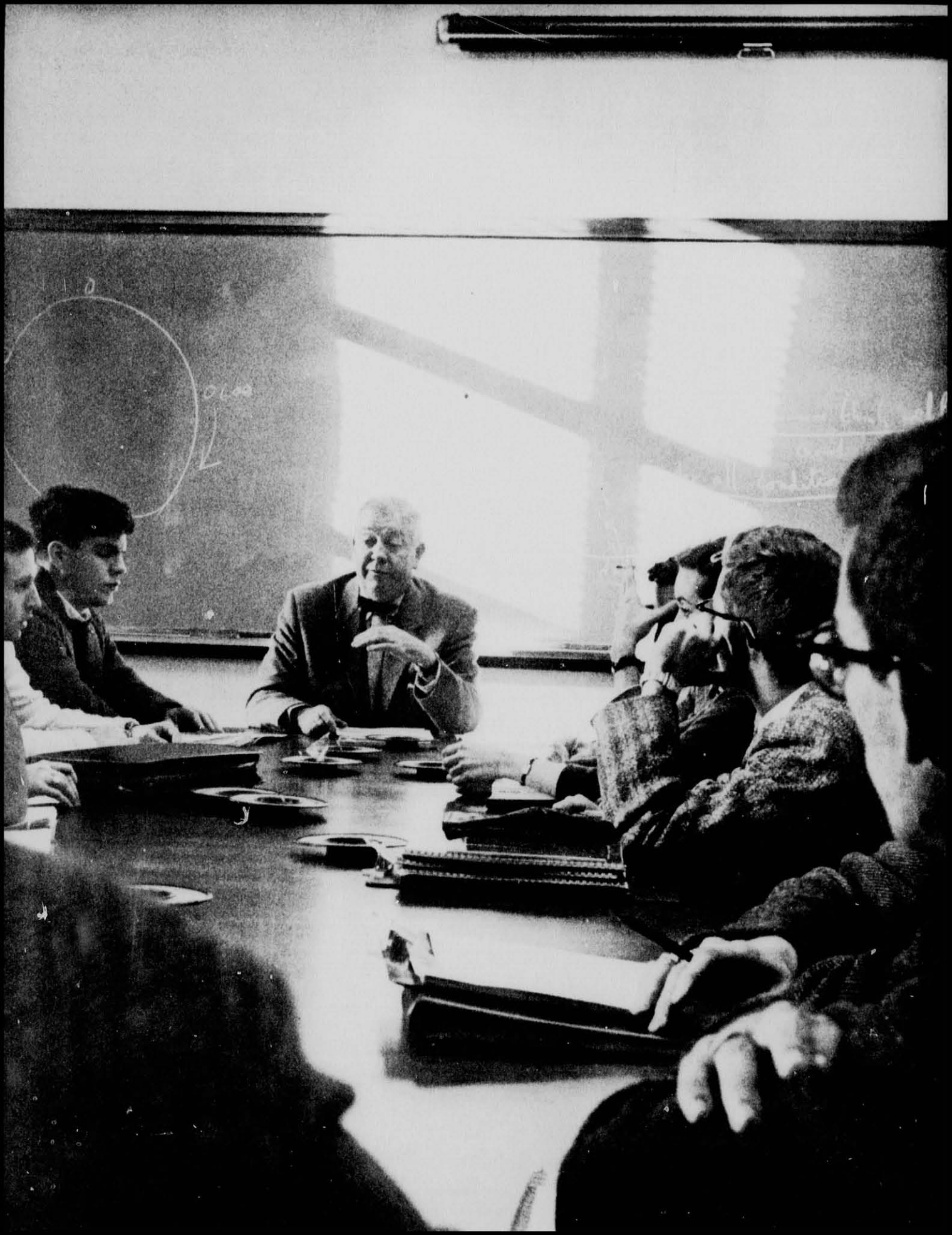
Candidates for the doctorate who elect the fission option must also be familiar with the content of:

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)
THERMONUCLEAR PROCESSES (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, superconducting solenoids, charged particle transport theory, plasma propulsion, and plasma production and confinement.



SCHOOL OF HUMANITIES AND SOCIAL SCIENCE 6.

The Acting Dean of the School of Humanities and Social Science describes its many activities in serving M.I.T. Courses and granting M.I.T. degrees.

The School of Humanities and Social Science embraces the work of a faculty organized in four departments and embracing an appreciably larger number of distinct disciplines. The Department of Economics and Social Science includes the faculty interested in economics, political science, labor relations, and sociology; the Department of Humanities includes the faculty concerned with history, literature, music, and philosophy; the Department of Modern Languages numbers those whose interest is in modern languages, literature in foreign languages, comparative literature, and linguistics. Most recently organized as a separate unit is the Department of Psychology.

This faculty has three complementary missions. The School is in the first place responsible for much of the general education required of every undergraduate at M.I.T., regardless of his area of specialization. In this role members of the faculty, drawn mostly from the Department of Humanities, guide every student through a uniform freshman year in the humanities and a selected pair of rather broadly disciplinary subjects in the sophomore year; later, all of the faculties of the School meet their share of juniors or seniors, as these upperclassmen are required to elect four additional semesters in the humanities and social sciences, including typically three semesters in a single field. The curriculum for the first two years and the fields for subsequent study are described in Section 2 of this Catalogue.

A second mission of the School involves offerings leading to the degree of Bachelor of Science. There are currently four such programs, two in the Department of Economics and two in the Department of Humanities. These four degree programs all require a second major either in some branch of science or in a branch of engineering. In this respect they differ in form from curricula in similar fields at other institutions.

There are other differences of perhaps greater import. M.I.T., as an institution polarized around science and engineering, accepts the view that science and engineering are important elements in all modern life, that they are to be embraced rather than to be feared. Thus these degree offerings in the School of Humanities and Social Science require the same rigor in science and engineering — though not the depth of accomplishment — that is required of scientists and engineers; the programs include these subjects as a fundamental part of contemporary culture. Far from regarding the scientific study as antithetical to the humanistic, they recognize the essential unity of serious study in any area. Thus these programs may be particularly well fitted to prepare the right kind of young man or woman for living in the modern world.

The student whose formal education is completed with his four-year degree is likely to find that the preparation for

modern life afforded by these Courses in economics, political science, or humanities is unique and effective; if he intends to continue to higher degrees, he will find that he is well prepared for study in a law school, medical school, or graduate business school; he will also find it possible to continue at once in graduate work in either of the two majors he has carried as an undergraduate. Thus the curriculum is an unusually flexible and open-ended one.

The School of Humanities and Social Science accepts a third part of its mission — to enlarge the frontiers of knowledge — with enthusiasm, and indeed would regard the achievement of the other two parts as much less probable were it not for research and graduate work. Few members of the faculty of this School are not engaged in research and publication, ranging from individual efforts to the large group engagement of the Center for International Studies, which is also a part of the School. Doctorates can be earned in economics, political science, 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, a pair which makes 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 groupings of subjects which combine work in one field of engineering or science with a concentration in one of the humanities or social science disciplines (the Departmental Programs). The General Institute Requirements are given below. The Departmental Programs are given by each department on the following pages.

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

GENERAL INSTITUTE REQUIREMENTS				*Total units*
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	PHYSICS	4	1	5
	or			
8.031	PHYSICS	4	1	5
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
21.03T	THE NATURE OF LITERATURE	3	0	5
	or			
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3	0	5
21.05T	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3	0	5
	or			
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	5
	or			
14.003	THE MODERN WORLD AND SOCIAL SCIENCE	3	0	5
	[1]*Freshman electives*		12	
	[3]*Humanities and social science electives*		32	
				176

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

[1] Subjects of the common first-year program. See pages 36–40.
[2] 8.041, if selected, must be followed by 8.051 (or 8.05).
[3] See pages 40–43 for the humanities and social science program.

Department of Economics and Social Science

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

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

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

PAUL ANTHONY SAMUELSON, PH.D.
Professor of Economics

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

HAROLD ADOLPH FREEMAN, S.B.
Professor of Statistics

CHARLES POOR KINDLEBERGER, PH.D.
Professor of Economics

MAX FRANKLIN MILLIKAN, PH.D.
Professor of Economics

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

EVERETT EINAR HAGEN, PH.D. (*Absent*)
Professor of Economics

WALT WHITMAN ROSTOW, PH.D. (*Absent*)
Professor of Economic History

EVSEY DAVID DOMAR, PH.D.
Professor of Economics

DANIEL LERNER, PH.D. (*Absent*)
Professor of Sociology

EDGAR CARY BROWN, PH.D.
Professor of Economics

ITHIEL DE SOLA POOL, PH.D.
Professor of Political Science

ROBERT MERTON SOLOW, PH.D.
Professor of Economics

MORRIS ALBERT ADELMAN, PH.D.
Professor of Economics

PAUL PIGORS, PH.D.
Professor of Industrial Relations

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

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

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

EDWIN KUH, PH.D.
Professor of Economics

ROBERT COLDWELL WOOD, PH.D.
Professor of Political Science

LINCOLN PALMER BLOOMFIELD, PH.D. (*Absent*)
Professor of Political Science

GEORGE HERBERT HILDEBRAND
Professor of Industrial Relations (Visiting)

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

LOUIS LEFEBER, PH.D. (*Absent*)
Associate Professor of Economics

MYRON WEINER, PH.D.
Associate Professor of Political Science

RICHARD SAMUEL ECKAUS, PH.D.
Associate Professor of Economics

FRANKLIN MARVIN FISHER, PH.D.
Associate Professor of Economics

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

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

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

ELSPETH DAVIES ROSTOW, A.M. (*Absent*)
Assistant Professor of Political Science

ROBERT EVANS, JR., PH.D.
Assistant Professor of Industrial Relations

DONALD LAWRENCE MORTON BLACKMER, A.M.
Assistant Professor of Political Science

LEONARD J. FEIN, PH.D.
Assistant Professor of Political Science

JOHN SELIM SALOMA, III, PH.D.
Assistant Professor of Political Science

WALTER CARL CLEMENS, JR., PH.D.
Assistant Professor of Political Science
PAUL WEBSTER MACAVOY, PH.D.
Assistant Professor of Economics
MORTON GORDEN, PH.D.
Assistant Professor of Political Science
WILLARD RAYMOND JOHNSON, PH.D.
Assistant Professor of Political Science
PAUL KAY, PH.D.
Assistant Professor of Political Science
STEPHEN ALAN MARGLIN, PH.D.
Assistant Professor of Economics
KARL SHELL, PH.D.
Assistant Professor of Economics

Administrative Officer
IDELLA LYMAN TAPLEY, A.B.

Lecturers
WILLIAM EDGAR GRIFFITH, PH.D.
HAROLD ROBERT ISAACS, A.B.
ALEXANDER GREGORY KOROL, M.A.
THOMAS ANDREW LEHRER, A.M.
EUGENE BERTRAM SKOLNIKOFF, M.A., S.M.

Instructors
ARTHUR CLARKE HERRINGTON, SC.D.
GEORGE ERIC HANSEN, 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

ECONOMICS AND SOCIAL SCIENCE

This Department is concerned with the scientific study of people both as individuals and as members of society. Such study has a place at M.I.T. not only because engineers go into business and participate in the government of the country, but also because the activities of engineers and scientists have profound effects on economic and political activity. M.I.T. believes that its students, by learning something about themselves and about the social environment in which they live and work, will have greater satisfaction in life and become more valuable members of their professions.

Economics has long been a part of M.I.T. education. In addition, sections in Industrial Relations and Political Science have now been developed within the Department. These different approaches to the study of human behavior complement each other and afford a number of programs from which students may choose. An examination of the curricula listed below will reveal considerable flexibility within each program.

THE UNDERGRADUATE CURRICULA

Economics, Politics, and Engineering (Course XIV-A)

Economics, Politics, and Science (Course XIV-B)

The Courses in Economics, Politics, and Engineering and in Economics, Politics, and Science combine basic training in either engineering or science with the social sciences. This combination emphasizes the relationships among scientific, engineering, economic, political, and human relations problems, thus giving insight into both the technical and nontechnical aspects of an industrial society. Students may prepare for a wide range of careers, particularly in the research, engineering, economics, personnel, sales, production, planning, and international departments of business and in governmental and labor organizations.

Students concentrating in political science will be equipped with knowledge and skills for dealing with the increasing range of problems which arise between business and government and which involve the activities of governmental agencies and political groups in matters of direct concern to scientists and engineers. The Courses also provide a broad undergraduate preparation for graduate work in such fields as economics, engineering, science, business administration, law, and medicine.

Students in Course XIV-A elect an area of engineering concentration which corresponds to one of the established engineering fields at M.I.T. Each student works out an individual program of studies which includes the core subjects required of those majoring in that engineering field, as recommended by the particular engineering department. Social science subjects are substituted for the more specialized subjects offered in the engineering Courses.

Similarly, students in Course XIV-B choose an area of science concentration. The same principle applies here, with the appropriate science subjects recommended by the science department concerned.

Course XIV-A leads to the degree of Bachelor of Science in Economics, Politics, and Engineering, and Course XIV-B leads to the degree of Bachelor of Science in Economics, Politics, and Science.

ECONOMICS

The objectives of the economics program are threefold: (1) to develop the ability to analyze, both theoretically and quantitatively, economic problems of the firm, the industry, and the economy as a whole; (2) to provide knowledge and understanding of economic and social institutions; and (3) to promote skill in examining broad questions of social and economic policy. The required subjects, while emphasizing the analytic side, provide a general background in the other two areas. The extent to which these various objectives are emphasized is then determined primarily by the student's selection of electives.

The elementary subjects, ECONOMIC PRINCIPLES I and II (14.01 and 14.02), are an introduction to the whole field of economics. The intermediate subjects, PRICES AND PRODUCTION (14.03) and ECONOMIC FLUCTUATIONS AND GROWTH (14.05), deepen this knowledge: the first in industry analysis and price formation, and the second in the study of economic fluctuations and growth. Preparation for the quantitative side of economics is offered in STATISTICAL THEORY (14.371).

With this general background the student may go farther in particular fields by his choice of junior and senior electives. The program specifies that a minimum of five subjects (40 units) are to be elected in economics, with at least four of these subjects in one of three areas: (1) the general problems of an economy; (2) the particular problems of different industries and of labor relations; or (3) the more technical field of quantitative analysis, with further study in mathematics, statistics, and econometrics. If a student wishes, he also may elect up to four additional subjects in economics, two of which may be considered as electives in his humanities and social science elective program.

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

The curriculum requirements for the Bachelor's degree under the Economics Program are given below.

1. ECONOMICS PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 139*)		**176**
	PHYSICS 8.03 and 8.04 are normally taken. If work in nuclear and atomic physics is to form part of a student's program in a science or engineering field, 8.031 and 8.041[1] are taken. Sixteen of the 32 units of humanities and social science electives must fall outside the field of a student's social science specialization. The remainder may form part of the concentration in economics.	
DEPARTMENTAL PROGRAM		
	Required subjects	
14.01	ECONOMIC PRINCIPLES I — 3 0 5	
14.02	ECONOMIC PRINCIPLES II — 3 0 5	
14.03[2]	PRICES AND PRODUCTION — 3 0 5	
14.05[2]	ECONOMIC FLUCTUATIONS AND GROWTH — 3 0 5	
14.371	STATISTICAL THEORY — 3 0 6	
14.39	ECONOMIC RESEARCH SEMINAR — 2 0 6	
	THESIS — 9	
		58
	Elective subjects	
	Specified	
	Subjects in a particular field of engineering or science — 63	
	Economics elective subjects, with stipulation of a minimum of 32 units in one of the following areas: general economics, industrial and labor economics, or quantitative economics and method — 39	
	Unspecified — 24	
		126
Total units required for the S.B. degree		**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).
[2] With special permission, 14.121 and 14.122 may be substituted for 14.03, and 14.451 and 14.452 may be substituted for 14.05.

POLITICAL SCIENCE

The political science programs give special attention to the growing interrelationship between government on the one hand and science and engineering on the other. The objectives

are: (1) to provide an understanding of the nature of political behavior and the political process; (2) to examine government's role in science and technology, both in America and abroad, and its role in international relations; (3) to develop familiarity with the techniques of policy formulation and decision-making on issues of public policy.

There is no rigid program of subjects of instruction in the political science curriculum. Programs are worked out with the aid of an adviser. A student normally takes three or four subjects in some field that interests him particularly and one or two subjects in several other fields. One field, for example, is international relations, in which the introductory subject, INTERNATIONAL RELATIONS (14.51), is followed by a subject in PRINCIPLES AND PROBLEMS OF AMERICAN FOREIGN POLICY (14.52) and a SEMINAR IN INTERNATIONAL POLITICS (14.53). A comparative government field includes, among other subjects, THE AMERICAN POLITICAL PROCESS (14.91), COMPARATIVE POLITICAL SYSTEMS (14.92), and a SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS (14.93). In the field of public policy, subjects include POLITICS, SOCIETY, AND POLICY MAKING (14.95); GOVERNMENT, POLITICS, AND TECHNOLOGY (14.94); and a triple subject, STRUCTURE OF URBAN LIFE (14.99). Another field covers political philosophy. Some of the subjects in this field are offered under the Department of Humanities but are fully accepted as political science subjects. Political philosophy subjects include CONTEMPORARY IDEAS ON POLITICAL AND ECONOMIC DEVELOPMENT (14.57).

As a student progresses into his senior year and desires a higher degree of specialization than is offered in the available undergraduate subjects, he typically takes, in addition to his thesis work, some reading seminars and some graduate subjects from the political science offering.

The curriculum requirements for the Bachelor's degree under the Political Science Program are given below.

2. POLITICAL SCIENCE PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 139*)		**176**
PHYSICS 8.03 and 8.04 are normally taken. If work in nuclear and atomic physics is to form part of a student's program in a science or engineering field, 8.031 and 8.041[1] are taken. Sixteen of the 32 units of humanities and social science electives must fall outside the field of a student's social science specialization. The remainder may form part of the concentration in politics.		
DEPARTMENTAL PROGRAM		
Required subjects		
THESIS	9	
		9
Elective subjects		
Specified		
Elective subjects in a particular field of engineering or science	63	
Political science elective subjects	88	
Unspecified	24	
		175
Total units required for the S.B. degree		**360**

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

GRADUATE STUDY IN ECONOMICS AND POLITICAL SCIENCE

The Department of Economics and Social Science offers work leading to the degrees of Master of Science in Economics and Engineering, Master of Science in Economics and Science, Doctor of Philosophy in Industrial Economics and Doctor of Philosophy in Political Science.

The following subjects are given by the Department primarily for graduate students in economics:

Economic theory:
14.121, 14.122, 14.123, 14.132, 14.151, 14.451, 14.452.

Economic history:
14.161, 14.162.

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

Economic development:
14.171, 14.172, 14.182, 14.282

Industrial organization and policy:
14.271, 14.272.

Statistics:
14.372, 14.374, 14.383, 14.384.

International economics:
14.581, 14.582, 14.584, 14.586.

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

Personnel administration:
14.681, 14.682, 14.693,15.312.

Special subjects:
14.101 (for students with little or no college mathematics).
14.381 (for students with little or no previous statistics).

Special reading subjects:
Students may arrange with individual instructors to take special reading subjects in fields of their particular interest which are not otherwise covered.

The following subjects are given by the Political Science Section primarily for graduate students in political science and related fields:

International relations and foreign policy:
14.531, 14.532, 14.534, 14.535.

Political communications:
14.951, 14.953, 14.954, 14.956, 14.957, 14.958, 14.961, 14.962.

Defense policy:
14.521, 14.523, 14.524, 14.526.
Public policy and science:
14.941T, 14.942T, 14.943, 14,944.
Political and economic development:
4.84, 14.161, 14.162, 14.585, 14.921, 14.924, 14.925.
Political theory and comparative politics:
14.57, 14.58, 14.901, 14.902, 14.922.
Special reading subjects:
Students may arrange with individual instructors to take special reading subjects in fields of their particular interest which are not otherwise covered.

MASTER OF SCIENCE IN ECONOMICS AND ENGINEERING OR IN ECONOMICS AND SCIENCE

Undergraduate preparation for the Master's degrees should include the equivalent of the Institute's economics subjects required for the Bachelor's degree. The other admission requirements are those given in Section 3 of this Catalogue, with the following exceptions:

Mathematics. DIFFERENTIAL EQUATIONS (18.04) is not a prerequisite.

Physics. A complete college course in physics of at least *one* year is required.

Science and Engineering Subjects. A substantial number of science or engineering units is required, comparable to the number required in the undergraduate Course XIV. The Master's degree is available only to students who have taken a substantial amount of undergraduate work in engineering or science.

Students who have deficiencies in prerequisites for admission may take these prerequisites along with their graduate work.

Graduates of Course XIV-A or XIV-B or of similar undergraduate programs elsewhere ordinarily complete the requirements for the Master's degree in one year. Candidates with an undergraduate major in engineering or science elect a two-year program. The first year of study is devoted to satisfying economics prerequisites, and the second year is given completely to graduate work, in accordance with the general requirements for the Master's degree.

Doctoral Studies in Economics or Political Science

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites for graduate study leading to the Doctor of Philosophy in Industrial Economics or in Political Science.

Mathematics. One full year of college mathematics, including at least one term of calculus.

Science. One full year of college work in science.

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

Professional Subjects. See the separate requirements for economics and political science below.

Economics students may remove a deficiency in mathematics by completing a special one-semester subject, MATHEMATICS FOR ECONOMISTS (14.101). Political science students may remove a deficiency in mathematics by completing a special one-semester subject, INTRODUCTION TO MATHEMATICAL MODELS IN THE SOCIAL SCIENCES (14.903), and one other semester of mathematics in such subjects as MATHEMATICS FOR ECONOMISTS (14.101 or 14.102) or STATISTICAL METHOD (14.381). A deficiency in science may be removed by completing any suitable one-semester subject in science at the Institute. A student whose deficiencies are of minor extent will be permitted graduate registration while taking appropriate subjects to remove them.

DOCTOR OF PHILOSOPHY IN INDUSTRIAL ECONOMICS

Ordinarily, an undergraduate major in economics is required for doctoral studies in industrial economics. However, qualified students who have majored in a related field may be admitted if their programs have included an appreciable amount of economics.

A candidate for the doctorate must prepare himself in five fields, four of which are covered by the General Examination. Economic theory, including both micro- and macroeconomics, is required as a primary field for all students. One other field, also designated as primary, requires more intensive preparation than the remaining three, which are designated as secondary. Elective fields include advanced economic theory, monetary economics, fiscal economics, industrial organization and policy, international economics, economic development, labor economics and labor relations, personnel administration, 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.

Following the Institute rules, candidates for the doctorate are required to take a Minor in a field other than economics. Possibilities include political science and international relations, industrial management, mathematics, history, other humanities or social sciences, and particular fields of science or engineering.

DOCTOR OF PHILOSOPHY IN POLITICAL SCIENCE

A candidate for the doctorate in political science must prepare himself for a General Examination covering four approved fields. In studying for this examination, he must satisfy a basic requirement in two subjects: CONCEPT FORMATION AND RESEARCH TECHNIQUE IN POLITICAL BEHAVIOR (14.901) and THEORY OF POLITICAL PROCESSES (14.902). Possible fields include: international relations and foreign policy, political communications, defense policy, public policy and science, political and economic development, and political theory and comparative politics; or approved combinations of some of these together with economics, industrial management, sociology, social psychology, or science and engineering fields may be acceptable.

Programs of study logically combining advanced work in some scientific or engineering fields with political science will be welcomed. A candidate's qualifications must indicate promise of ability to develop fruitful new lines of inquiry on problems touching the relationship of government, human behavior, science, technology, and the political process.

Following the Institute rules, candidates for the doctorate will be required to take a Minor in a field other than political science. Possibilities include economics, industrial relations, industrial management, mathematics, history, philosophy, sociology, social psychology, or relevant fields in science or engineering.

General Requirements for Doctoral Candidates

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

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

Candidates are required to 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; Secretary of the Faculty

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

CARVEL COLLINS, PH.D.
Professor of English

KLAUS LIEPMANN
Professor of Music; Director of Music

ROY LAMSON, PH.D.
Professor of English

HUSTON CUMMINGS SMITH, PH.D. (*Absent*)
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

HILARY PUTNAM, PH.D.
Professor of the Philosophy of Science

JAMES FREDERICK THOMSON, M.A.
Professor of Philosophy

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

SIDNEY WILFRED MINTZ, PH.D.
Professor of Anthropology (Visiting)

GREGORY TUCKER
Professor of Music

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

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

EDWARD NEAL HARTLEY, A.M. (*Absent*)
Associate Professor of History

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

IRVING SINGER, PH.D.
Associate Professor of Philosophy

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

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

BRUCE MAZLISH, PH.D.
Associate Professor of History

NORMAN NORWOOD HOLLAND, PH.D.
Associate Professor of English

THOMAS PARKE HUGHES, PH.D.
Associate Professor of the History of Technology

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

ABNER ELIEZER SHIMONY, PH.D
Associate Professor of the Philosophy of Science

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

GORDON MAURICE JENSEN, PH.D.
Assistant Professor of History

EMMET JOSEPH LARKIN, PH.D. (*Absent*)
Assistant Professor of History

LOUIS KAMPF, B.A.
Assistant Professor of English

VICTOR HENRY MATTFELD, PH.D.
Assistant Professor of Music; Organist

FREDERIC LAWRENCE HOLMES, PH.D. (*Absent*)
Assistant Professor of the History of Science

BARRY BERNARD SPACKS, M.A.
Assistant Professor of English

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

HUBERT LEDERER DREYFUS, PH.D. (*Absent*)
Assistant Professor of Philosophy

JERRY ALAN FODOR, PH.D. (*Absent*)
Assistant Professor of Philosophy

IRA ALBERT GLAZIER, PH.D.
Assistant Professor of History

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

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

JERROLD JACOB KATZ, PH.D. (*Absent*)
Assistant Professor of Philosophy

SAMUEL JUDAH TODES, PH.D.
Assistant Professor of Philosophy
WILLIAM BRAASCH WATSON, PH.D.
Assistant Professor of History
ROBERT ADOLPH, PH.D.
Assistant Professor of English
ARTHUR DANIEL KALEDIN, M.A.
Assistant Professor of History
WARREN JORDAN MACISSAC, PH.D.
Assistant Professor of English
TRAVIS RHODES MERRITT, A.M.
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
ARNULF ZWEIG, PH.D.
Assistant Professor of Philosophy (Visiting)

Lecturers
ERCOLINO FERRETTI, B.MUS.
HAROLD CLARK KIRKER, PH.D.
JUDITH JARVIS THOMSON, PH.D.

Instructors
HENRY ROBISON WEST, B.D., M.A.
MICHAEL LAY, M.M.
PAUL ALBERT LEE, PH.D.
MARY KATHARINE WAKEMAN, M.A.
STEVEN NEIL GILBORN, A.B.
JOHN C. GRAVES, A.M.
MARK LEVENSKY, M.A.
DUNCAN MORSE NELSON, PH.D.
NATHAN SIVIN, M.A.

Professor Emeritus
JOHN ELY BURCHARD, L.H.D., D.ARCH.
Professor of Humanities, Emeritus; Dean of the School of Humanities and Social Science, Emeritus

HUMANITIES

M.I.T., in its determination to achieve a well-balanced education for all its undergraduates, provides through this Department required and elective subjects in history, literature, philosophy, history and philosophy of science, music, and drama.

In addition, the Department of Humanities administers two Courses. These combine the basic subjects in science or engineering with a concentrated program in the humanities, in equal proportions. They are known as Humanities and Engineering (Course XXI-A) and Humanities and Science (Course XXI-B).

THE UNDERGRADUATE CURRICULA

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

The Courses in Humanities and Engineering and in Humanities and Science offer a balanced education from which students may go on to graduate study in science, engineering, or humanities, or into teaching, law, medicine, business, and a variety of other fields. Graduates of Course XXI have found interesting careers in teaching, research, medicine, and industry.

Course XXI has been called "a double major." Because of a flexible program of elective subjects, 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 these fields.

Both Courses lead to a Bachelor's degree after four years; a student may study a fifth year to earn a second Bachelor's degree in the particular field of science or engineering he has been exploring; in some cases this fifth year may lead to a Master's degree.

On a base which is essentially the Institute's well-rounded program of introductory mathematics, physics, chemistry, and humanities, each of these Courses provides a balanced educational experience. One part of each program is the undergraduate curriculum of one of the professional departments, shortened through omission of some of the more specialized or technical subjects. The other is a sequence of advanced work in humanities, concentrating in one particular humanities discipline of the student's choice: literature, history, philosophy, the history and philosophy of science, or music.

To assist students in integrating their studies and in bringing into focus the insights and techniques developed in both professional and

humanistic studies, the Department makes two requirements: the senior HUMANITIES SENIOR SEMINAR (21.07); and the writing of a thesis.

Course XXI-A leads to the degree of Bachelor of Science in Humanities and Engineering, and Course XXI-B leads to the degree of Bachelor of Science in Humanities and Science. The curriculum for the first year is shown on pages 36–40; the curriculum requirements for the degrees in both Courses are summarized below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 139*)					**176**
	PHYSICS 8.03 and 8.04 or 8.031 and 8.041[1] are taken according to the science or engineering curriculum being pursued in conjunction with humanities.				
DEPARTMENTAL PROGRAM					
	Required subjects				
21.07	HUMANITIES SENIOR SEMINAR	2	0	6	
21.08T	THESIS PREPARATION AND REPORTS	1	2	3	
	THESIS		12		
					26
	Elective subjects				
	Specified				
	Selection from a series of subjects in the humanities discipline chosen for concentration			16	
	Elective subjects restricted to one of the science or engineering curricula			52[2]	
	Elective subjects restricted to one of the humanities disciplines: e.g., literature, philosophy, etc.			32	
	Unspecified			58	
					158
Total units required for the S.B. degree					**360**

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

[2] The student who intends to obtain a second S.B. degree in one of the science or engineering Courses by continuing his studies at M.I.T. in a fifth year and the student who plans to enter upon graduate study in science or engineering should carry at least 88 units. The additional units will be drawn from the 58 units of unrestricted elective subjects.

Science and Mathematics Teaching Program

Students who wish to register for the Science and Mathematics Teaching Program conducted in cooperation with the Harvard University Graduate School of Education should consult the Head of the Department of Humanities.

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.

In accord with Institute regulations, candidates for the doctorate are required 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

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.
Professor of Modern Languages
MORRIS HALLE, PH.D.
Professor of Modern Languages
JERZY KURYŁOWICZ, PH.D.
Professor of Linguistics (Visiting)
GEORGE HUBERT MATTHEWS, PH.D.
Associate Professor of Modern Languages
KRYSTYNA POMORSKA, PH.D.
Associate Professor of Russian
RICHARD FELIX KOCH, A.M.
Assistant Professor of Modern Languages, Emeritus
SECOR DELAHAY BROWNE, A.B.
Assistant Professor of Russian
EDWARD STEPHAN KLIMA, M.A.
Assistant Professor of Modern Languages
ALEXANDER LOUIS LIPSON, A.M.
Assistant Professor of Russian
CARL JOHN BLACK, JR., M.A.
Assistant Professor of French and Humanities
PAUL MARTIN POSTAL, PH.D.
Assistant Professor of Modern Languages
CLAUDE JANE-MARIE CAREY, M.A.
Assistant Professor of Modern Languages and Humanities
PETER COLACLIDES, PH.D.
Assistant Professor of Linguistics (Visiting)

Lecturers

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

Instructors

RENATA HOFMAN BRIGGS (*Absent*)
DAVID MICHAEL PERLMUTTER, A.B.
MAGDA BUKA, B.A.
ILONA RICARDO KINZER
RENATA BERG PAN, M.A.
URSULA BRIGITTE MCCUNE

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 Modern Language Department offers subjects for undergraduate and graduate students in several languages and 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 entirely in the foreign language and include discussions of the form and content of the literature of each country. A specially equipped language laboratory provides facilities for hearing and speaking languages at all levels.

Undergraduate subjects in linguistics are offered to explore the structural and semantic relationships of language and to examine problems in linguistics and search for possible solutions. There is an active program of research, in which tools and concepts of science and engineering are applied to the study of language.

Special sections of the freshman and sophomore humanities subjects provide reading and lectures in French, allowing students to use and improve their knowledge of the language while simultaneously satisfying the humanities requirement. These sections are open to graduates of American high and secondary schools with three or more years of unusually good achievement in French.

A two-semester sequence on Dante provides both language study and literary analysis.

The Department's subjects are open as electives to all qualified students throughout the Institute and are acceptable as freshman electives. There is, however, no undergraduate degree program in modern languages or linguistics at M.I.T.

In choosing language subjects, students should assume that one year of secondary school study is roughly equivalent to one Institute term. Credit towards graduation will not be given for repeating work offered for admission.

GRADUATE SUBJECTS

One-semester subjects in French, German, and Russian, *open to graduate students only*, are designed to help each student develop rapidly the ability to read technical and scientific material in his own field whether or not he has any previous acquaintance with the language. These subjects carry no credit.

The Doctoral Program in Modern Languages (Course XXIII)

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

DOCTOR OF PHILOSOPHY IN LINGUISTICS

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

Mathematics. One full year of college mathematics.

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 (23.731)
LINGUISTIC STRUCTURE (23.752)
PROBLEMS OF PHONOLOGY (23.762)
SURVEY OF GENERAL LINGUISTICS (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 Institute policies concerning the Minor program, examinations, and the thesis are given in Section 3 of this Catalogue.

Department of Psychology

HANS-LUKAS TEUBER, PH.D.
Professor of Psychology; Head of the Department
RICHARD MARX HELD, PH.D.
Professor of Experimental Psychology
JOSEPH ALTMAN, PH.D.
Associate Professor of Psychology
STEPHAN LEWIS CHOROVER, PH.D.
Assistant Professor of Psychology
HERBERT DAVID SALTZSTEIN, PH.D.
Assistant Professor of Psychology
WAYNE ALLEN WICKELGREN, PH.D.
Assistant Professor of Psychology
CHARLES GORDON GROSS, PH.D.
Assistant Professor of Psychology
ALAN HEIN, PH.D.
Assistant Professor of Psychology
PETER HARKAI SCHILLER, PH.D.
Assistant Professor of Psychology

Administrative Assistants

ROBERT I. MCELROY, B.A.
LOUISE ANNA PFEIFFER, B.A.

Research Associates

THOMAS G. BEVER, B.A.
GOPAL DWARKA DAS, M.A.
HELEN STEPHANIE MAHUT, PH.D.
RITA GILLIS RUDEL, 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 the PSYCHOLOGY PROSEMINAR (9.001 and 9.002) during his first year in residence. Training beyond the Proseminar is provided in the form of an array of optional graduate seminars and of supervised research and reading subjects. 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.

In keeping with general Institute rules, all students are required to take a Minor in some field of study other than psychology. Possible areas for a Minor include mathematics, electrical engineering, physics, chemistry, biology, communication sciences, philosophy, history, sociology, economics, industrial relations, industrial management, political science, and linguistics.

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 renaming in 1964 of the School of Industrial Management as the Alfred P. Sloan School of Management at once honored America's most distinguished industrial executive and emphasized M.I.T.'s strong interest in research and teaching in the broad fields of management.

The year just past also marked the twelfth in the School's lively operation at M.I.T. The Institute's concern with management began, however, long before the founding of the School, and, in that sense, neither 1952 nor 1964 marks the beginning. Sixty years earlier, President Francis A. Walker had pressed for the teaching of business management to engineering students and had organized a small faculty for that purpose. Then, beginning in 1914, Course XV became the regular vehicle for providing education in engineering and business 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 M.I.T. has occurred since then. In the past ten years, over two thirds of our Master's degrees in industrial management have been awarded; 80 per cent of our Sloan Fellows have had their remarkable year of study at M.I.T.; all of the Senior Executives have come through; and our first Ph.D. candidates have received their degrees. More important than these numbers, however, the School has produced a style that now makes its own imprint on M.I.T. and its community. Increasingly, the concern for developing imaginative, analytical managers has become a part of M.I.T.'s own thrust in the world. The new designation of the School as the Sloan School of Management is a fitting way of identifying M.I.T.'s concentration on more effective management.

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. This

task of educating men for management is our first purpose; but 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.

HOWARD W. JOHNSON

HOWARD WESLEY JOHNSON, M.A.
Professor of Industrial Management; Dean
JOHN MACDONALD WYNNE, A.B., S.M. (*Absent*)
Associate Dean; Senior Lecturer
DOUGLASS VINCENT BROWN, PH.D.
Alfred P. Sloan Professor of Industrial Management; Acting Associate Dean
JOHN ELY BURCHARD, L.H.D., D.ARCH.
Professor of Humanities, Emeritus; Dean of the School of Humanities and Social Science, Emeritus
DOUGLAS MURRAY McGREGOR, PH.D., LL.D.
Sloan Fellows Professor of Industrial Management
CHARLES ANDREW MYERS, PH.D.
Professor of Industrial Relations
EDWARD PENNELL BROOKS, D.S.C.
Professor of Industrial Management, Emeritus; Dean Emeritus
ELTING ELMORE MORISON, A.M.
Professor of Industrial History
BILLY EARL GOETZ, PH.D.
Professor of Industrial Management
SIDNEY STUART ALEXANDER, PH.D.
Professor of Industrial Management
JAY WRIGHT FORRESTER, D.ENG.
Professor of Industrial Management
DAVID DURAND, PH.D.
Professor of Industrial Management
DONALD GEORGE MARQUIS, PH.D.
Professor of Industrial Management
CARROLL LOUIS WILSON, SC.D.
Professor of Industrial Management
DANIEL MARK HOLLAND, PH.D.
Professor of Finance
EDWIN KUH, PH.D.
Professor of Finance
FRANCO MODIGLIANI, D.JUR., D.SOC.SCI.
Professor of Finance
WARREN G. BENNIS, PH.D.
Professor of Industrial Management
THOMAS MASON HILL, A.B., M.B.A.
Professor of Industrial Management
EDWARD HARRY BOWMAN, PH.D.
Professor of Industrial Management
EDGAR HENRY SCHEIN, PH.D.
Professor of Industrial Management

ABRAHAM J. SIEGEL, PH.D. (*Absent*)
Professor of Industrial Relations
RAVI JOHN MATTHAI, M.A.
Professor of Management (Visiting)
EMANUEL PARZEN, PH.D.
Professor of Statistics (Visiting)
LEO BENJAMIN MOORE, S.M.
Associate Professor of Industrial Management
WILLIAM LOUIS LETWIN, PH.D.
Associate Professor of Industrial History
MARTIN GREENBERGER, PH.D.
Associate Professor of Industrial Management
ZENON SOTERIOU ZANNETOS, PH.D. (*Absent*)
Associate Professor of Industrial Management
PAUL HAROLD COOTNER, PH.D.
Associate Professor of Finance
WILLIAM MARTIN EVAN, PH.D.
Associate Professor of Sociology and Industrial Management
HERBERT FRANKLIN GOODWIN, S.B.
Associate Professor of Industrial Management
RONALD ARTHUR HOWARD, SC.D.
Associate Professor of Industrial Management; Associate Director of the Operations Research Center
JOHN DUTTON CONANT LITTLE, PH.D.
Associate Professor of Industrial Management
HANS MARTIN WEINGARTNER, PH.D.
Associate Professor of Finance
PETER SAVOIS KING, B.S., M.B.A.
Associate Professor of Marketing
WILLIAM FRANK POUNDS, PH.D.
Associate Professor of Industrial Management
BARNARD ELLIOT SMITH, PH.D.
Associate Professor of Industrial Management
ANDREW CHARLES STEDRY, PH.D. (*Absent*)
Associate Professor of Industrial Management
WILLIAM PENFIELD TRAVIS, PH.D.
Associate Professor of Industrial History
JAMES CARLETON EMERY, S.M.
Assistant Professor of Industrial Management
DONALD CARY CARROLL, S.M.
Assistant Professor of Industrial Management
GEOFFREY P. E. CLARKSON, PH.D.
Assistant Professor of Industrial Management
HENRY JOHN CLAYCAMP, PH.D.
Assistant Professor of Industrial Management
EDWARD BAER ROBERTS, PH.D.
Assistant Professor of Industrial Management
PEER OLAV SOELBERG, M.S.
Assistant Professor of Industrial Management
ARNOLD EVERETT AMSTUTZ, S.B.
Assistant Professor of Industrial Management
DAVID ELMER BERLEW, PH.D.
Assistant Professor of Industrial Management
JAMES SUREN HEKIMIAN, D.B.A.
Assistant Professor of Industrial Management
GORDON MAYER KAUFMAN, D.B.A.
Assistant Professor of Industrial Management
JOHN DANIEL NYHART, A.B., LL.B.
Assistant Professor of Industrial Management
DONALD EUGENE FARRAR, PH.D.
Assistant Professor of Finance
JAMES JOHN LINN, PH.D.
Assistant Professor of Industrial Management
WILLIAM LEO WHITE, S.B.
Assistant Professor of Finance
MICHAEL JAMES BROWER, B.S., M.A.
Assistant Professor of Industrial Management
WILLARD RUSSELL FEY, S.M.
Assistant Professor of Industrial Management
WILLIAM HARRIS GRUBER, B.S.
Assistant Professor of Industrial Management
OTTO HERBERT POENSGEN, S.M.
Assistant Professor of Industrial Management
DAVID PETER TAYLOR, M.B.A.
Assistant Professor of Industrial Relations
LEON SELIGSBERGER WHITE, PH.D.
Assistant Professor of Industrial Management
GEORGE EDWARD DELEHANTY, PH.D.
Assistant Professor of Industrial Relations (Visiting)

Senior Lecturers

DAVID FERGUESON AUSTIN, LL.D.
RICHARD BECKHARD, A.B.
ROBERT CROZER CASSELMAN, B.S.
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.
BERNARD J. MULLER-THYM, PH.D., LL.D.
RICHARD DUNLOP ROBINSON, PH.D.
HAROLD JAMES ZOLD, B.A.
GERALD BRUCE TALLMAN, PH.D.

Lecturers
ROBERT LEON BRANDFON, PH.D.
RICHARD THOMAS MURPHY, JR., A.B., B.S., LL.B.

Instructor
DILEEP RAMANLAL MEHTA, S.M.

Executive Development Programs
PETER PAUL GIL, PH.D.
Director; Senior Lecturer
PRISCILLA ANN KARB, A.B.
Assistant Director

International Programs
CONSTANTINE B. SIMONIDES, A.B., M.B.A.
Assistant Director; Assistant to the Dean

Sloan Faculty Fellows
HENRY B. EYRING, D.B.A.
DAVID T. KLEINMAN, PH.D.

Research Associates
THOMAS JOHN ALLEN, JR., S.M.
GUY BLACK, PH.D.
BRUCE ALDEN BLOMSTROM, S.M.
CARROLL WORCESTER BREWSTER, LL.B.
TOM JOEL FARER, LL.B.
STEPHEN FISKE HALL, S.M.
WARREN J. KEEGAN, M.S., M.B.A.
JONATHAN MALLAMUD, LL.B.
ALEXANDER LE FEVRE PUGH, III, E.E.
JOHN FRALICK ROCKART, M.B.A.
MICHAEL ROEMER, S.M.
DOUGLAS A. SCOTT, M.B.A.
GILBERT PAUL VERBIT, LL.B.
CHARLES CHIA-HUNG YING, PH.D.

Administrative Assistants
GERTRUDE ELIZABETH BURNS
ESTHER MERRILL, B.S.
MIRIAM SHERBURNE, A.B.

Professors Emeriti
ERWIN HASKELL SCHELL, S.B.
Professor of Industrial Management, Emeritus
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

Industrial Management (Course XV)

The undergraduate Course in Industrial Management is designed for students who combine an aptitude for science and engineering with the qualities necessary for effective administration. Successful management of industrial enterprises in the future will demand the ability to deal with technological issues of increasing complexity, a broad comprehension of business problems, and a deep understanding of human behavior. Fundamental training in science and engineering has proved to be an excellent base for the study of management, and the Institute is uniquely qualified to provide a curriculum which combines science and technology with administration and the humanities.

The undergraduate program in Industrial Management rests upon the underlying disciplines of the social sciences, especially economics. Students who plan to study management should therefore anticipate their future work by taking a basic subject in economics during their sophomore year. In all of the prescribed subjects, emphasis is on the application of the social sciences to the analysis of business problems and the understanding of managerial principles.

Much of the work in management is quantitative, and several of the required subjects offer immediate introduction to the many rapidly developing mathematical and statistical techniques for solving industrial problems.

The management curriculum provides for flexibility by allowing five or six unspecified electives, about half of which would ordinarily be taken in management or related fields.

An important part of the fourth-year program is the thesis, which affords the dual opportunity of exploring in depth a problem of the student's own choice and of carrying out a limited research program on his own initiative.

The science and engineering programs in the Course in Industrial Management emphasize matter of a fundamental nature rather than the details of its application. The School believes that within the limits of a four-year program, of which the main objective is a sound professional education for administration, students should have a solid foundation in science and engineering — primarily as preparation for effective management and secondarily, as preparation for further progress in professional engineering.

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

The curriculum leading to the degree of Bachelor of Science in Industrial Management consists of a program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements) plus a group of subjects combining work in a field of engineering or science with the study of industrial management (the Departmental Program). The curriculum requirements for this degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS					
5.01	[1]GENERAL CHEMISTRY	4	2	5	
5.02	[1]GENERAL CHEMISTRY	4	2	5	
8.01T	[1]PHYSICS I	5	0	6	
8.02T	[1]PHYSICS II	5	0	6	
8.03	[2]PHYSICS	4	1	5	
	or				
8.031	[2]PHYSICS	4	1	5	
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	
21.03T	THE NATURE OF LITERATURE	3	0	5	
	or				
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3	0	5	
21.05T	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3	0	5	
	or				
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	5	
	or				
14.003	THE MODERN WORLD AND SOCIAL SCIENCE	3	0	5	
	[1]*Freshman electives*		12		
	[3]*Humanities and social science electives*		32		
					176

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

DEPARTMENTAL PROGRAM

	Required subjects				
15.01	INDUSTRIAL MANAGEMENT I	3	0	6	
15.02	INDUSTRIAL STATISTICS	3	0	6	
15.30	PERSONNEL ADMINISTRATION	3	0	6	
15.41	FINANCIAL MANAGEMENT	3	0	6	

(*continued*)

Required subjects (*continued*)

15.50T	MANAGERIAL INFORMATION AND CONTROL	3	0	6	
15.71	PRODUCTION MANAGEMENT	3	0	6	
15.81	MARKETING	3	0	6	
	THESIS		12		
					75
	Elective subjects				
	Specified				
	Subjects in science or engineering making up a program minimally totaling		72		
	Unspecified		48		
					120
	Total units required for the S.B. degree				[4]371

[1] Subjects of the common first-year program. See pages 36–40.

[2] PHYSICS 8.03 and 8.04 are taken except when plans for further work clearly indicate the need for the subject matter of 8.031 and 8.041; 8.041, if selected, must be followed by 8.051 (or 8.05).

[3] See pages 40–43 for the humanities and social science program. ECONOMIC PRINCIPLES I (14.01) is required. Subjects in Field Six (Economics) and Field Eight (Labor Relations) may not be used in satisfaction of the humanities and social science sequence requirement.

[4] In exceptional cases this total may be reduced by the School within the General Institute Requirements.

MANAGEMENT MINOR FOR ENGINEERS

In addition to the above, the School offers upperclass undergraduates majoring in any field of engineering or science a program known as the Management Minor. This program consists of four basic core subjects plus two optional subjects. It is described in a brochure available through departmental Faculty Counselors or at the office of the Undergraduate Program in Industrial Management, Room 52-480.

GRADUATE STUDY IN INDUSTRIAL MANAGEMENT

The Alfred P. Sloan School of Management offers graduate study leading to the degrees of Master of Science and Doctor of Philosophy in Industrial Management.

MASTER OF SCIENCE

The Master's program is designed to prepare the science or engineering graduate for executive responsibilities — to develop men whose intelligence, motivation, and character promise executive ability and whose training and experience combine an understanding of natural science and engineering with an appreciation of the social, political, and economic implications of industry. Outstanding applicants whose undergraduate work has been in the humanities or social sciences will be considered for admission if the minimum prerequisites listed below have been met or can be satisfied after admission.

Although the primary aim is not that of training staff specialists, proposals for specialized programs will be considered when the desired course of study is particularly appropriate to the facilities available at M.I.T. Possible special programs include a concentration in subjects in industrial operations research and in business applications of electronic data-processing equipment.

The typical Master's degree program in industrial management requires two years of study at M.I.T. Credit for subjects completed elsewhere may permit some students to meet the requirements for the degree in three semesters or in one year. The required curriculum for those who have done no previous work in this field includes the following subjects:

STATISTICAL METHOD (15.025)
MATHEMATICS FOR INDUSTRIAL MANAGEMENT (15.091, 15.092)
PROBLEMS IN AMERICAN POLITICAL ECONOMY (15.201)
PSYCHOLOGY AND HUMAN ORGANIZATION (15.331)
MANAGERIAL INFORMATION AND CONTROL (15.501)
ECONOMICS OF THE FIRM (15.012)
ECONOMICS AND INDUSTRIAL MANAGEMENT (14.117)
MANAGERIAL MODELS (15.702)
LABOR-MANAGEMENT RELATIONS (15.312)
FINANCIAL MANAGEMENT (15.412) (A)
OPERATIONS MANAGEMENT (15.712) (A)
MARKETING (15.812T) (A)

The second year is given wholly to advanced work, in accordance with the general requirements for the Master's degree. The typical program includes five elective subjects in addition to the three (A) subjects listed above and a thesis, the latter representing an individual research project conducted under the supervision of a separate staff committee for each student. Subject offerings are described elsewhere in this Catalogue. Selection is not limited to offerings in the 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 IBM 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 substantial stipends and affording opportunity for direct participation in faculty research are available.

DOCTOR OF PHILOSOPHY

The doctoral program in industrial management is designed primarily for students interested in teaching and research in industrial management and business administration or in the conduct of specialized managerial functions in business or other organizations. The program is largely an integration of the several fields which can advance the study and practice of management. It accordingly requires familiarity with a broad range of basic management subjects, reflected in a distribution requirement. It also requires specialization in at least one area of managerial application together with one or more of the underlying disciplines.

The doctoral program normally requires two years' work beyond the requirement for a Master's degree in the Alfred P. Sloan School of Management, about one year of course work and another year for the doctoral thesis. A Master's degree is normally taken by Doctor's degree candidates. Each student's program, to be worked out with a specially designated faculty committee, is subject to four principal requirements: distribution, specialization, general examination, and thesis. In addition, students must fulfill the minor field and language requirements given in Section 3.

Distribution

A student must present evidence of his grasp of the subject areas required in M.I.T.'s program for the Master's degree in Industrial 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 committee, an area of specialization consisting of one applied area of management in combination with one or more primary disciplines, normally selected from the following list. The list is not exhaustive, however, and proposals for the inclusion of other studies in a doctoral program are considered.

Primary disciplines	*Areas of application*
Economics	Production
Psychology	Marketing
Quantitative analysis	Business finance
Statistics	Controllership and accounting
Operations research	Managerial organization
Mathematics	Labor relations — personnel
Industrial dynamics	International management
Political science	
Other social sciences	

General Examination

Upon prospective completion of the program of course work arranged with his committee, the student takes a general examination in four fields: his field of functional specialization, two fields in his primary discipline, and a fourth field selected with the approval of his committee as meaningfully related to his program.

Doctoral Thesis and Special Examination

The doctoral candidate's thesis, written in residence, normally represents a year's research. It must give evidence of the candidate's ability to design and carry out significant scholarly research in his area of specialization. The thesis is defended in an oral examination, which also covers the subject matter of his advanced work as a whole.

Entrance Requirements for Graduate Study

The general admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions.

Undergraduate preparation for this program should include: mathematics through college algebra and one year of differential calculus; at least one year of an experimental science at the college level; and a course in principles of economics. An undergraduate course in elementary psychology is desirable. In some cases, deficiencies in preparation may be remedied by summer study prior to enrollment or even by special work during the first year of graduate study. The Graduate Committee is willing to consider the particular needs of any applicant who is strongly motivated to study in the School and who has demonstrated high intellectual capacity.

ADMISSION TEST FOR GRADUATE STUDY IN BUSINESS

All candidates for admission to graduate study in the 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 INDUSTRIAL MANAGEMENT

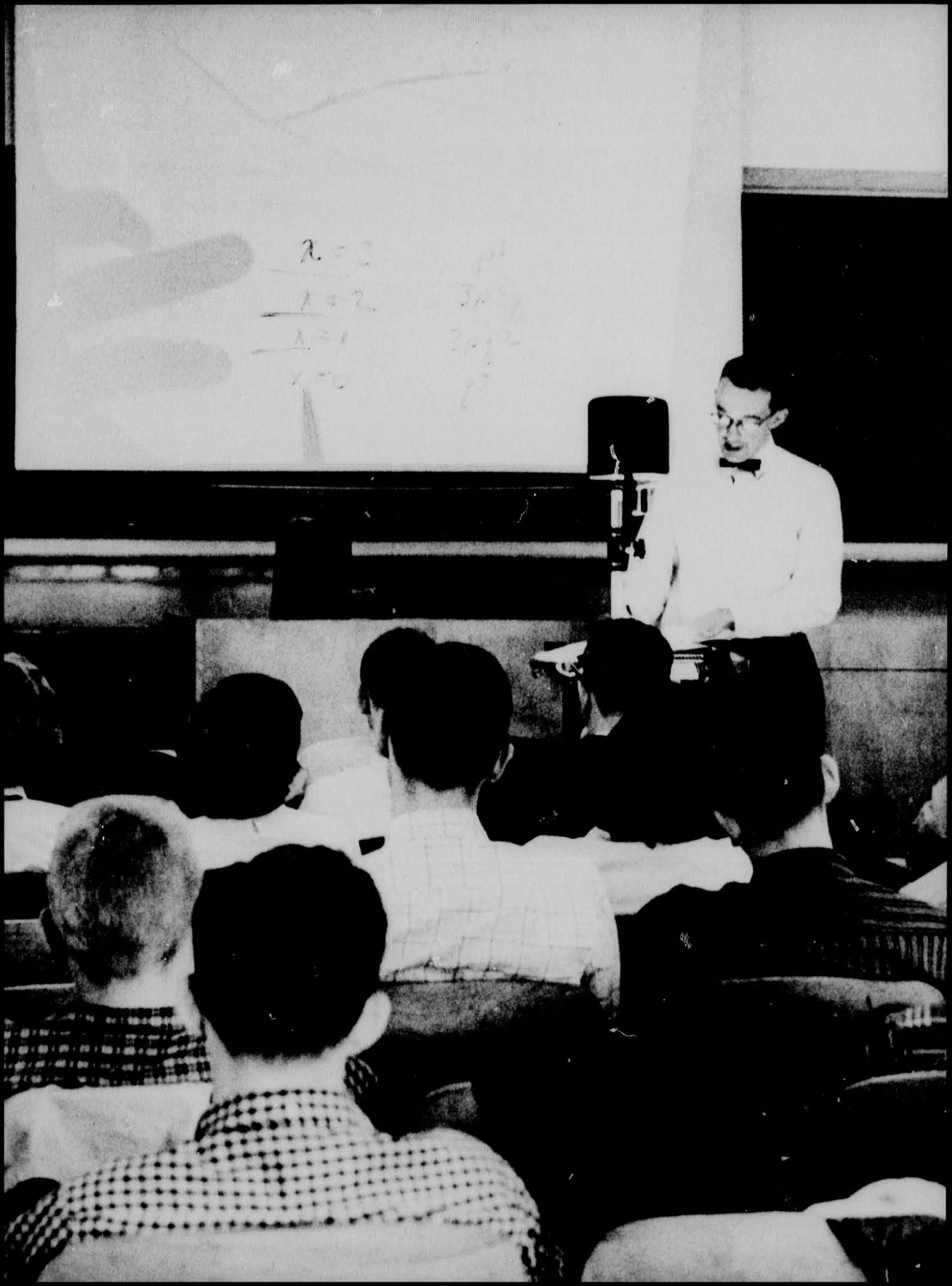
The Alfred P. Sloan School of Management provides two programs for business executives who wish to extend their knowledge of the fundamentals underlying effective management. Applicants for these programs are nominated by their companies.

The *Sloan Fellowships in Executive Development*, available under special grants of the Alfred P. Sloan Foundation, are awarded to exceptionally able young executives (30 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 Industrial Management. Only 40 to 45 men are admitted each year, and they are divided into three groups for most of their course work.

The *Program for Senior Executives* is an intensive ten-week course of study designed for the mature executive already in or preparing for a position of major managerial responsibility. Enrollment is limited to 24 qualified executives in each of the two ten-week sessions held in the spring and fall each year.

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 a great variety of possibilities open to him. As an individual research worker, he can pursue knowledge at the frontiers of science. As a teacher he is needed at all levels of education and often combines this activity with an active research program. Industry and government offer ever-increasing opportunities for the scientist, either as an individual worker or as a member of a large team engaged in research or development activity. And finally, the scientist with management interests is also in demand as an administrator in a broad range of activities involving scientific and engineering workers.

The School of Science at M.I.T. offers a broad educational program which prepares students for 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 this lightest of the particles can be used; the structures of atoms and molecules and of the electric and magnetic interaction of their various parts; the structures of liquids and solids, metals, insulators, and semiconductors; and the analysis and building up of molecular assemblages of increasing complexity.

The life sciences cover a very broad field. The most fundamental division is concerned with molecular biology and the chemistry of the molecules found in living cells. These molecules occur in a wide variety of forms, from the simplest inorganic and organic types up to the most complex known, the protein mole-

cules. 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 with the chemical, physical, and microbiological reactions and interactions which cause flavor, odor, toxicological or nutritional changes during and after processing.

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 — these 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, as well as the continuing close contact of our staff with a wide variety of scientific problems encountered by industry and by state and national governments provide a most stimulating atmosphere for study.

JEROME B. WIESNER

JEROME BERT WIESNER, PH.D.
Dean

SCIENCE COUNCIL

IRWIN WHITING SIZER, PH.D.
Head, Department of Biology
ARTHUR CLAY COPE, PH.D., SC.D.
Head, Department of Chemistry
ROBERT RAKES SHROCK, PH.D.
Head, Department of Geology and Geophysics
WILLIAM TED MARTIN, PH.D.
Head, Department of Mathematics
HENRY GARRETT HOUGHTON, SC.D.
Head, Department of Meteorology
NEVIN STEWART SCRIMSHAW, PH.D., M.D., 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

PATRICK DAVID WALL, M.D.
Department of Biology
GLENN ALLEN BERCHTOLD, PH.D.
Department of Chemistry
WILLIAM HENRY DENNEN, PH.D.
Department of Geology and Geophysics
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 the advice and consent of a Faculty Counselor. Typical Course schedules are issued each term by the Registrar with the Class Schedules. Electives within the Departmental Program may include two additional humanities or social science subjects. R.O.T.C. subjects may be used according to the specifications in Section 2.

GENERAL INSTITUTE REQUIREMENTS

				Total units
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	PHYSICS	4	1	5
	or			
8.031	PHYSICS	4	1	5
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
21.03T	THE NATURE OF LITERATURE	3	0	5
	or			
21.04T	PHILOSOPHY: CLASSIC AND CONTEMPORARY	3	0	5
21.05T	THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM"	3	0	5
	or			
21.06T	THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS	3	0	5
	or			
14.003	THE MODERN WORLD AND SOCIAL SCIENCE	3	0	5
	[1]*Freshman electives*		12	
	[3]*Humanities and social science electives*		32	
				176

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

[1] Subjects of the common first-year program. See pages 36–40.

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

[3] See pages 40–43 for the humanities and social science program.

Department of Biology

IRWIN WHITING SIZER, PH.D.
Professor of Biochemistry; Head of the Department
PATRICK DAVID WALL, M.D.
Professor of Physiology; Executive Officer
FRANCIS OTTO SCHMITT, PH.D., SC.D.
Institute Professor; Professor of Biology
JOHN MACHLIN BUCHANAN, PH.D., D.SC. (*Absent*)
Professor of Biochemistry; in charge of the Division of Biochemistry
DAVID FLOYD WAUGH, PH.D.
Professor of Biophysics
CYRUS LEVINTHAL, PH.D.
Professor of Biophysics
SALVADOR EDWARD LURIA, M.D.
Professor of Microbiology
BORIS MAGASANIK, PH.D.
Professor of Microbiology
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
BERNARD SIDNEY GOULD, PH.D.
Associate Professor of Biochemistry
KURT SIEGFRIED LION, DR.ING.
Associate Professor of Applied Biophysics
EUGENE BELL, PH.D.
Associate Professor of Biology
GENE MONTE BROWN, PH.D.
Associate Professor of Biochemistry
MAURICE SANFORD FOX, PH.D.
Associate Professor of Genetics
PHILLIPS WESLEY ROBBINS, PH.D.
Associate Professor of Biochemistry
ROBERT MORRIS DOWBEN, M.D.
Associate Professor of Microbiology
CHARLES EDWARD HOLT, III, PH.D.
Assistant Professor of Biology
TOM DANIEL HUMPHREYS, II, PH.D.
Assistant Professor of Biology
JOEL EDWARD BROWN, PH.D.
Assistant Professor of Physiology (Visiting)

Lecturer

ATHANASIOS ELIAS EVANGELOPOULOS, PH.D.

Research Associates

GUY OCTO BARNETT, M.D.
DWIGHT JOE BAUGHMAN, M.D., PH.D.
LAWRENCE KENNETH CREAMER, PH.D.
JAMES FRANCIS DICKSON, III, M.D.
ROBERT CHARLES GESTELAND, PH.D.
GIOVANNI GIANNONI, D.CH.
ANNAMARIA TORRIANI GORINI, PH.D.
GEORGE DRAKE GUTHRIE, PH.D.
CHIEN HO, PH.D.
JUNKO HOSODA, PH.D.
WEI-TSE HSIEH, PH.D.
LOUIS KATZ, PH.D.
YUKIO KIHO, PH.D.
DAVID GEORGE IAN KINGSTON, PH.D.
AKIRA KUNINAKA, PH.D.
RUDOLF LATTRELL, DR.RER.NAT.
FRANCOISE GROS LEVINTHAL, PH.D.
ADELE MAGASANIK, PH.D. (*Absent*)
TURNER MCLARDY, M.B., CH.B.
HELEN RUTH REVEL, PH.D.
RONALD EFRON ROLFE, M.D.
SIDDHARTHA SARKAR, PH.D.
ROBERT BRADLEY SCOTT, M.D.
LAWRENCE STARK, M.D.
WERNER KARL STEUERNAGEL, E.E.
HUN HSUAN SUN, PH.D.
MARIO TERZI, PH.D.
BERT LESTER VALLEE, M.D.
GERALD HOWARD WHIPPLE, M.D.
ANDREW WRIGHT, PH.D.
HUSEYIN YILMAZ, 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.

THE UNDERGRADUATE CURRICULUM

Life Sciences (Course VII)

The undergraduate curriculum in the biological sciences is designed to prepare students for teaching and research careers in biology, for graduate study, and for work in industries which are concerned with biological materials and fermentation processes. The Life Sciences curriculum also prepares students for graduate study in nutrition, food science, and 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 Course in Life Sciences stresses 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. Since modern medicine is rapidly becoming less empirical and more scientific, it is especially important that those who wish to prepare for medical research become acquainted with the quantitative approach of the physical sciences to biological phenomena.

The student ordinarily takes general biology and organic chemistry in his second year; biochemistry, microbiology, physical and analytical chemistry, and genetics in his third year; and developmental biology and physiology in the fourth year. Both professional and general electives may be taken during the last two years.

Undergraduate Specialization

The curriculum in Life Sciences provides ample time for electives. Most students taking this curriculum 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: analytical biology, physiology, biochemistry, biophysics, medicine, and microbiology. Students interested in nutrition and food science should consult this Department prior to registration.

The Course leads to the degree of Bachelor of Science in Life Sciences. The curriculum requirements for the degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 163*)					176
PHYSICS 8.03 and 8.04 are prescribed.					
DEPARTMENTAL PROGRAM					
	Required subjects				
7.01	GENERAL BIOLOGY	4	1	6	
7.02	GENERAL BIOLOGY LABORATORY	1	6	2	
7.03T	[1]GENETICS	3	0	6	
7.031	[1]GENETICS AND MICROBIOLOGY LABORATORY	1	6	2	
7.04	[1]DEVELOPMENTAL BIOLOGY	2	0	4	
7.041	[1]DEVELOPMENTAL BIOLOGY LABORATORY	0	6	0	
7.05T	GENERAL BIOCHEMISTRY	4	0	6	
7.051	GENERAL BIOCHEMISTRY LABORATORY	0	8	0	
7.06	[1]GENERAL PHYSIOLOGY	3	0	6	
7.21	GENERAL MICROBIOLOGY	3	0	6	
5.41	ORGANIC CHEMISTRY I	4	0	4	
5.412T	ORGANIC CHEMISTRY LABORATORY I	1	5	0	
5.42	ORGANIC CHEMISTRY II	4	0	4	
5.14	ANALYTICAL CHEMISTRY I	3	0	3	
5.142	ANALYTICAL CHEMISTRY LABORATORY I	1	4	0	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
	THESIS		12		
					147
	Elective subjects				
	Unspecified				37
Total units required for the S.B. degree					360

[1] Students electing Nutrition or Food Science as their field of specialization may omit 7.03T, 7.031, 7.04, 7.041, and 7.06 and substitute other subjects pertinent to their field.

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: analytical biology, physiology, microbiology, biochemistry, and biophysics.

The Master's degree is not a prerequisite for a program of study leading to the doctorate. Master's candidates may, by permission, change to a doctoral program without loss of credit.

The Department has exceptional facilities for graduate education, not only in basic analytical biology but also in many specialized fields. Students may prepare for careers in teaching, in pure and applied biological research, in medical research, and in many fields of industry and industrial research, such as biophysical, biochemical, pharmaceutical, leather, oil, fermentation, and other industries. The educational program is based upon a number of general and specialized subjects and 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.

ANALYTICAL 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 intermediary metabolism. Bacterial and mammalian viruses are considered, with special emphasis on problems of reproduction. Microorganisms are compared with mammalian cells in tissue culture.

Entrance Requirements for Graduate Study

The Department modifies the general Institute requirements for graduate study (see Section 3) as follows:

Mathematics. CALCULUS (18.01, 18.02).
Physics. One year of college physics.
Chemistry. ORGANIC CHEMISTRY I (5.41).
Professional Subjects. GENERAL BIOCHEMISTRY AND PHYSIOLOGY OR MICROBIOLOGY.

Deficiencies in the subjects listed above may be removed, if not too extensive, while pursuing a graduate program.

Requirements for Advanced Degrees

There are no specified programs for degree work, since the subjects required vary with the field of specialization. Each student selects his own program, according to certain broad principles, after consultation with the Graduate Committee of the Department.

In addition to the general requirements for advanced degrees (see Section 3), the Department requires all students to take BIOLOGY SEMINAR (7.31, 7.32). A reading knowledge of French and German is required for a Doctor's degree.

Assistantships and Fellowships

A number of qualified students are appointed each year as teaching or research assistants. A research assistant may be permitted to use the results of his assigned research work in a graduate thesis, with possible acceleration of his program. In addition, a number of predoctoral and postdoctoral fellowships are available in analytical biology, physiology, biochemistry, and biophysics. Information is available from the Head of the Department; applications for the fall term must be made before March 31.

Department of Chemistry

ARTHUR CLAY COPE, PH.D., SC.D.
Professor of Organic Chemistry; Head of the Department
GLENN ALLEN BERCHTOLD, PH.D.
Associate Professor of Chemistry; Executive Officer
JAMES ALEXANDER BEATTIE, PH.D.
Professor of Physical Chemistry, Emeritus
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
JOHN WITHERS IRVINE, JR., PH.D., SC.D.
Professor of Chemistry
CHARLES GARDNER SWAIN, PH.D.
Professor of Chemistry
DAVID NEWTON HUME, PH.D. (*Absent*)
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
LOUIS HARRIS, PH.D.
Associate Professor of Physical Chemistry, Emeritus
NICHOLAS ATHANASIUS MILAS, PH.D., D.SC.
Associate Professor of Organic Chemistry, Emeritus
EDMUND LEE GAMBLE, PH.D.
Associate Professor of Inorganic Chemistry
LAWRENCE JOSEPH HEIDT, PH.D.
Associate Professor of Physical Chemistry
CARL WESLEY GARLAND, PH.D.
Associate Professor of Chemistry
IRWIN OPPENHEIM, PH.D.
Associate Professor of Chemistry
DIETMAR SEYFERTH, PH.D.
Associate Professor of Chemistry
GLEN EVERETT GORDON, PH.D.
Associate Professor of Chemistry
GORDON G. HAMMES, PH.D.
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
DANIEL SCHAEFFER KEMP, PH.D.
Assistant Professor of Chemistry
WILLIAM EDWARD OHNESORGE, PH.D.
Assistant Professor of Chemistry

Research Associates

GEORG ERNST ALBERS-SCHONBERG, PH.D.
HIROSHI AMANO, D.SC.
HANS ASCHENBACH, DR.
UDO FRIEDRICH AXEN, DR.RER.NAT.
FRANK JOHN BIROS, PH.D.
ELIZABETH PARKER BURROWS, PH.D.
WILLIAM DICKINSON BURROWS, PH.D.
EDWARD ALAN CARESS, PH.D.
MIROSLAV DADIC, PH.D.
CHRISTOPHER PIERS FALSHAW, PH.D.
WOLFGANG RICHARD FUNKE, DR.RER.NAT.
MICHAEL FRANCIS GRUNDON, PH.D.
DHARMENDRA NARAIN GUPTA, PH.D.
JOHN EMMETT JORDAN, PH.D.
KYOZI KAWASAKI, PH.D.
STUART ALLAN LEVISON, PH.D.

ROBERT HARRY McCORKELL, PH.D.
WALTER JOSEPH McMURRAY, PH.D.
CHARLES ROBERT MORGAN, PH.D.
FUJIO MURAI, D.SC.
STEPHEN MEARS NAGY, SC.D.
ATSUYOSHI OHNO, PH.D.
MELABHAI GULABBHAI PATEL, PH.D.
RAYMOND ALFRED ROUSSEAU, PH.D.
JOSEPH HERMAN SCHAUBLE, PH.D.
GIANCARLO SCIBONA, PH.D.
CLARA BRINK SHOEMAKER, PH.D.
GLYN DAVID SHORT, PH.D.
GURDIAL SINGH, PH.D.
HIROSHI SUGINOME, D.SC.
JORGE ERNESTO AGUSTIN TONI, DR. IN CHEM.
JÖST WILD, PH.D.

Professors Emeriti

FREDERICK GEORGE KEYES, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus
MILES STANDISH SHERRILL, PH.D.
Professor of Physical Chemistry, Emeritus
EARLE BOWMAN MILLARD, PH.D.
Professor of Physical Chemistry, Emeritus
WALTER CECIL SCHUMB, PH.D.
Professor of Inorganic Chemistry, Emeritus
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 a single undergraduate Course, sufficiently flexible in its electives so that it provides excellent preparation for careers in many different areas of chemistry, and graduate programs for three advanced degrees. There are excellent opportunities for study and research in physical, organic, inorganic, nuclear, and analytical chemistry. In addition, the Department is responsible for undergraduate and graduate instruction in chemistry for students in many other Institute Courses.

THE UNDERGRADUATE CURRICULUM

Chemistry (Course V)

The main objective of the Course in Chemistry is to provide a general education based on science, both for those who seek the Bachelor's degree and a career in some field in which a sound knowledge of chemistry is important and for those who wish to go on to graduate study and a professional career in chemistry. Students receive thorough instruction in the principles of inorganic, organic, analytical, and physical chemistry, supplemented by instruction in mathematics and physics and in the humanities and languages, and other nonprofessional subjects.

Elective time allows each student to extend his knowledge in fields of special interest. Students intending to take graduate work, for example, may elect subjects which will increase their ability to utilize the opportunities in graduate study. Students intending to enter industry may take subjects which offer the fundamentals in a selected field of science or engineering. Elective time may also be used for additional subjects in the humanities.

A curriculum has been established for those who have a special interest in chemical physics.

The Course aims to stimulate and develop the research attitude, and the curriculum includes a thesis in the fourth year, to give the student an opportunity to demonstrate his aptitude for creative effort.

The Course is a carefully planned sequence of required subjects with an opportunity for a choice of restricted electives in two fields of advanced chemistry, additional free elective time, and a liberal policy of substitution. The Course leads to the degree of Bachelor of Science in Chemistry. The curriculum requirements for the degree are given below.

1. CHEMISTRY PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 163*)					176
PHYSICS 8.03 and 8.04 are prescribed.					
DEPARTMENTAL PROGRAM					
	Required subjects				
5.41	ORGANIC CHEMISTRY I	4	0	4	
5.412T	ORGANIC CHEMISTRY LABORATORY I	1	5	0	
5.42	ORGANIC CHEMISTRY II	4	0	4	
5.422T	ORGANIC CHEMISTRY LABORATORY II	1	5	1	
5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	2	0	4	
5.428	QUALITATIVE ORGANIC ANALYSIS	2	7	1	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
5.613T	PHYSICAL CHEMISTRY LABORATORY I	0	4	3	
5.14	ANALYTICAL CHEMISTRY I	3	0	3	
5.141	ANALYTICAL CHEMISTRY LABORATORY I	1	8	0	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
5.623T	PHYSICAL CHEMISTRY LABORATORY II	0	4	3	
5.16	ANALYTICAL CHEMISTRY II	3	0	3	
5.161	ANALYTICAL CHEMISTRY LABORATORY II	1	4	2	
5.63	PHYSICAL CHEMISTRY III	4	0	4	
	[1]LANGUAGE	3	0	5	
	[1]LANGUAGE	3	0	5	
	THESIS		12		
					139
	Elective subjects				
	Specified				
	Inorganic chemistry — at least 6 units from:				
5.04	PRINCIPLES OF INORGANIC CHEMISTRY II	2	0	4	
5.09	RADIOCHEMISTRY	3	0	3	
	and				
5.091	RADIOCHEMISTRY LABORATORY	0	3	2	
	Organic chemistry — at least 6 units from:				
5.43	ORGANIC CHEMISTRY III	2	0	4	
5.44	ORGANIC CHEMISTRY IV	2	0	4	
5.51	ADVANCED ORGANIC CHEMISTRY: SYNTHESIS	2	0	4	
5.53	ADVANCED ORGANIC CHEMISTRY: TECHNIQUES	2	0	4	
5.54	PHYSICAL ORGANIC CHEMISTRY	2	0	4	
5.55	ORGANIC CHEMISTRY: NATURAL PRODUCTS	2	0	4	
					12
	Unspecified (including additional THESIS units not exceeding 18)				33
Total units required for the S.B. degree					360

[1] The language should be ELEMENTARY GERMAN (23.11 and 23.12) or INTERMEDIATE GERMAN (23.13 and 23.14). Russian or French may be substituted by those having a reading knowledge of German. All students should acquire a reading knowledge of German and French, and additional subjects in these languages will be credited as elective.

2. CHEMICAL PHYSICS PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 163*)					176
Physics 8.031 and 8.041 are recommended.					
DEPARTMENTAL PROGRAM					
	Required subjects				
5.41	ORGANIC CHEMISTRY I	4	0	4	
5.412T	ORGANIC CHEMISTRY LABORATORY I	1	5	0	
	(continued)				
	Required subjects (*continued*)				
5.42	ORGANIC CHEMISTRY II	4	0	4	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
5.613T	PHYSICAL CHEMISTRY LABORATORY I	0	4	3	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
5.623T	PHYSICAL CHEMISTRY LABORATORY II	0	4	3	
8.05	PHYSICS OF ATOMS AND MOLECULES I	4	0	8	
8.06	PHYSICS OF ATOMS AND MOLECULES II	4	0	8	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
	THESIS		12		
					97
	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				87
Total units required for the S.B. degree					360

GRADUATE STUDY IN CHEMISTRY

Graduate chemists have a wide choice of careers. They are needed to serve as investigators and to teach and direct investigational work in academic institutions, in industry, in endowed research institutions, and in government bureaus. Industries in particular have come to realize the desirability and even necessity of supporting fundamental scientific investigations relative to their processes, as a basis for their future development.

The Department of Chemistry offers graduate programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science in Chemistry. Details of these programs, which differ according to whether the candidate chooses to specialize in analytical, inorganic and nuclear, organic, or physical chemistry, are recorded below. Students working toward the doctorate are expected to choose one of these four fields of specialization; students working toward the Master's degree may make a similar selection or may take a program which includes an approved combination of these fields.

Attainment of the Master's degree is not prerequisite to a program of study leading to a doctorate. Master's candidates may, by permission, change to the corresponding doctoral program without loss of credit.

PHYSICAL CHEMISTRY

Graduate subjects in physical chemistry cover the fundamentals of thermodynamics, statistical mechanics, kinetic theory, and molecular structure. The Minor in mathematics and physics broadens this basis. The research gives intensive specialization in a narrower field and develops experimental technique and ability to carry on independent investigations.

Research in physical chemistry is being carried out in the following fields, and the laboratory is especially well, often uniquely, equipped for such research:

Heat capacities and latent heats at low temperatures.
Properties of gases at low pressures.
Diffusion of gases.
Scattering and other properties of molecular beams.
Electromotive force in concentration cells, and oxidation-reduction potentials.
Physical chemistry related to geochemistry.
Vapor pressures of liquid solutions.
Infra-red, ultra-violet and Raman spectroscopy.
Kinetics of fast reactions.
Kinetics of enzymatic reactions.
Properties of high polymers.
Properties of protein solutions.
Properties of ion exchangers.
Optical and electrical properties of thin metal deposits.
Study of crystal structure by X-ray and neutron diffraction.
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.
Absorption spectra of adsorbed molecules.
Theoretical electronic structure of molecules.
The Mössbauer effect.
Statistical mechanics of equilibrium and transport properties.

ORGANIC CHEMISTRY

Subjects offered in the graduate program aim to develop a sound knowledge of fundamentals and a familiarity with current progress in the most active and important branches of organic chemistry. Each student undertakes a research problem which forms the nucleus of his graduate work, and, through the experience of conducting an experimental investigation leading to the Doctor's or Master's thesis, learns the research attitude and method of approach and acquires training in the specialized techniques of organic research. Basic graduate subjects in organic chemistry give a broad coverage of organic reactions and their application to synthetic and structural problems and theoretical organic chemistry.

The principal areas of research in organic chemistry under study in the Department include investigations of natural products and physiologically active compounds (structure determination and synthesis of alkaloids, terpenes, steroids, antibiotics, peptides and vitamins); elucidation of the mechanisms of reactions and the relation of structure to reactivity; investigations directed toward the discovery and application of new synthetic methods; and investigations of organometallic compounds, peroxides, photochemical transformations, and mass spectrometry.

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 so-called inert gasses; the isolation of small quantities of the compounds of other hitherto unknown elements such as technetium (element No. 43) and promethium (element No. 61); and the utilization of certain nonmetallic elements, such as selenium and fluorine.

Inorganic chemistry has two aspects, the preparative and the physicochemical, which are by no means separate in practice.

In addition to the impetus which has resulted from the increased accessibility to study of new areas of the periodic table, the theoretical or physico-chemical side of inorganic chemistry has been offered challenging new means of attack on basic problems by recent developments of techniques and advances in theory. Infrared and Raman spectroscopy, visible and ultraviolet spectrometry, magnetic studies of various types including nuclear and electron resonance, as well as 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; a large cyclotron, linear accelerator, and Van de Graaff accelerator are available for the study of nuclear reactions and the preparation of radionuclides. The M.I.T. Reactor also offers excellent opportunities for activation with neutrons and for the study of the properties of radionuclides.

The research worker may undertake detailed studies of nuclear reactions in the low- or high-energy regions, including fission and spallation; or studies of nuclear properties as a function of nuclear structure, including search for and identification of new species. The radiochemical resources are favorable for a variety of studies of chemical properties by tracer methods, including the properties of elements at very low concentration and the factors to be controlled in the development of new separation methods for constituents of radioactive mixtures. Other studies involve the physical-inorganic principles underlying the chemical problems of nuclear science, the applications of radiotracer techniques to general chemical problems, and of solvent extraction of metal complexes and the chemical interaction of cation- and anion-exchange systems. Modern counting equipment is available in the Department.

ANALYTICAL CHEMISTRY

The graduate curriculum in analytical chemistry is designed to prepare men for leadership both in industrial and in academic laboratories. The program provides a broad background in inorganic, physical, and organic chemistry and places emphasis upon both organic and inorganic aspects of analytical chemistry. The subjects stress principles and methods; the thesis aims at providing a varied research experience 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 under way in polarography, electrode reaction rates and mechanisms, membrane potentiometry, 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, ion exchange in non-aqueous systems, 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 organo-metallic 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 (18.04).

Professional Subjects. All candidates for admission to graduate work in this Department must present equivalents of the following subjects:

GENERAL CHEMISTRY (5.01, 5.02)
QUALITATIVE INORGANIC ANALYSIS
QUANTITATIVE ANALYSIS
ANALYTICAL CHEMISTRY II (5.16)
ORGANIC CHEMISTRY I and II (5.41, 5.42)
ORGANIC CHEMISTRY LABORATORY I (5.412T)
ORGANIC CHEMISTRY LABORATORY II (5.422T)
QUALITATIVE ORGANIC ANALYSIS (5.428)
PHYSICAL CHEMISTRY I and II (5.61, 5.62)
PHYSICAL CHEMISTRY LABORATORY I and II (5.613T, 5.623T)

The Graduate Degrees

MASTER OF SCIENCE IN CHEMISTRY

In addition to the general requirements set forth in Section 3, the candidate must demonstrate by examination to the Department of Modern Languages his ability to read in either German, French, or Russian the scientific literature of his major field.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN CHEMISTRY

For the degree of Doctor of Philosophy or Doctor of Science in a field of chemistry, each candidate must fulfill the requirements listed below.

Candidates for the doctorate in any field of chemistry are required to complete a written qualifying examination. This is offered twice each year, in the weeks preceding the opening of the fall and spring terms (September and February). Doctoral candidates admitted for the summer or fall terms will take the examination just before the fall term begins, and those admitted at the beginning of the spring term will take the examination in the week preceding the opening of the spring term.

Successful completion of the examination upon entrance will enable the student, with the advice of his Registration Officer, to select a program of graduate subjects more advanced in character than would be possible otherwise and to make more rapid progress toward the doctoral degree. Students who fail any part of the examination may select a program that includes more elementary subjects in any field where such registration seems advisable; when the examination is next offered, they are required to repeat that part which they previously failed. Qualifying examination grades are not entered on the student's permanent record.

Satisfactory completion of the qualifying examination automatically certifies the candidate in all the undergraduate deficiencies in subjects in chemistry. A passing grade is prerequisite for the subsequent General Examination in the candidate's field of specialization.

In order to complete the language requirement, the student must pass written examinations in German and in scientific French or Russian before taking his General Examination.

To fulfill the Minor requirement, the student must take at least 24 units of subjects outside of his field of specialization. Candidates majoring in physical chemistry are expected to take the Minor in mathematics or physics.

Each candidate pursues a program of graduate subjects which varies according to his Major field but which ordinarily includes selections from the following subjects:

Analytical Chemistry

5.192, 5.193T, 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, 5.7[illegible] 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

5.43, 5.44, 5.51, 5.53, 5.54, 5.55, and during each year of residence 5.913 and 5.914.

Physical Chemistry

5.70, 5.71, 5.75, and any four of the following subjects: 5.72, 5.74, 5.76, 5.77, 5.78, 5.79 and 5.81; and during each year of residence 5.931 and 5.932.

After completing the program of Major subjects, the candidate must pass a comprehensive examination, including both written and oral parts, in his Major field.

In the interpretation of these requirements, the Department will consider the candidate's previous academic record and professional experience, together with his particular aims and objectives, and will take a liberal attitude toward substitution of other subjects of equivalent educational and scientific value. Graduate students are urged to select a research supervisor during the first or second academic term of residence and to plan their program of study in consultation with him and with the chairman of the Department's graduate committee.

Inquiries should be addressed to the Chairman of the Department Committee on Graduate Students.

Teaching Assistants

The Department appoints a number of teaching assistants who are candidates for the degree of Doctor of Philosophy 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

ROBERT RAKES SHROCK, PH.D.
Professor of Geology; Head of the Department
WILLIAM HENRY DENNEN, PH.D.
Associate Professor of Geology; Executive Officer
MARTIN JULIAN BUERGER, PH.D.
Institute Professor; Professor of Mineralogy and Crystallography
FRANCIS BITTER, PH.D.
Professor of Geophysics
PATRICK MASON HURLEY, PH.D.
Professor of Geology
HAROLD WILLIAMS FAIRBAIRN, PH.D.
Professor of Geology
COLUMBUS O'DONNELL ISELIN, D.SC.
Professor of Oceanography
WILLIAM STELLING VON ARX, SC.D.
Professor of 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.
Professor of Oceanography
ROLAND DANE PARKS, E.M., M.S. (*Absent*)
Associate Professor of Mineral Industry
ELY MENCHER, PH.D.
Associate Professor of Geology
WILLIAM HAMET PINSON, JR., PH.D.
Associate Professor of Geology
WILLIAM FRANCIS BRACE, PH.D.
Associate Professor of Geology
JOHN WILLIS KANWISHER, PH.D.
Associate Professor of Oceanography
THEODORE RICHARD MADDEN, PH.D.
Associate Professor of Geophysics
JOHN WIDMER WINCHESTER, PH.D.
Associate Professor of Geochemistry
GIORGIO FIOCCO, DR.ING.
Assistant Professor of Geophysics
LEE WALLACE DEAN, PH.D.
Assistant Professor of Geophysics
WILLIAM CLAIR LUTH, PH.D. (*Absent*)
Assistant Professor of Geochemistry
DAVID WILLIAM STRANGWAY, PH.D.
Assistant Professor of Geophysics

Lecturers

THOMAS CANTWELL, PH.D. *Geophysics*
DAVID GREENEWALT, PH.D. *Geophysics*
STEPHEN MILTON SIMPSON, JR., PH.D. *Geophysics*

Administrative Assistant

HENRY ADAMS MORSS, JR., PH.D.

Research Associate

JOSEPH BROUGHTON WALSH, PH.D.

Professors Emeriti

HERVEY WOODBURN SHIMER, PH.D., SC.D.
Professor of Paleontology, Emeritus
WALTER LUCIUS WHITEHEAD, PH.D.
Associate Professor of Geology, Emeritus

GEOLOGY AND GEOPHYSICS

The origin, age, history, and composition of the earth, the physical state of the earth's interior, and the origin and physical characteristics of the oceans and atmosphere are among the most challenging and perplexing problems of science. They all lie within the domain of the earth scientists — mineralogists, geologists, geochemists, geophysicists, meteorologists, and oceanographers — but they can be successfully attacked only by using the latest contributions from the physical and engineering sciences.

Our expanding industrial economy is making heavy demands on the petroleum and mineral industries and on the companies that find and develop the raw materials for these industries. Reserves of petroleum and natural gas, of metallic ores, and of many nonmetallic substances such as domestic water are increasingly difficult to maintain. Most of the easy discoveries have been made, the low-cost deposits have been exhausted, and industries must rely in the future on improvements and new developments in geological, geochemical, and geophysical methods in their exploration programs. Industry's needs for men trained in these fields of earth science are shared by research, government, military, and atomic energy organizations engaged in a wide variety of projects related to raw materials, defense, global strategy, and pure scientific discovery.

Thus, careers in mineralogy, geology, geochemistry, geophysics, and oceanography offer a wide variety of work in teaching and research, in governmental bureaus and private and industrial laboratories, in field work in many different parts of the world, and in independent consulting.

Students especially interested in minerals and rocks; in the mineral industries; in petroleum, natural gas, and water resources; or in outdoor work in geology or oceanography can arrange excellent programs of study by consulting the appropriate Faculty Counselor.

THE UNDERGRADUATE CURRICULA

Geology and Geophysics (Course XII)

The undergraduate program in Course XII provides students with an opportunity to acquire competence in some aspect of the earth sciences — geology, geophysics, geochemistry, oceanography, or meteorology. The offerings are of sufficient depth and breadth so that a student who completes the program can begin a career in his chosen field or continue with graduate studies. The program is built around a small core of prescribed professional subjects, a large amount of work in prescribed fields within which free selection of individual subjects may be made, and a generous allocation of free electives. A student is thus able to progress toward his own goals at his own pace.

The curriculum for the first year is described on pages 38–39.

In the second year it is expected that students will take MINERALOGY I (12.011), PHYSICAL GEOLOGY (12.301), and HISTORICAL GEOLOGY (12.302) in order to obtain a fundamental understanding of geological processes and materials. Omission of any of these subjects from a student's second-year curriculum will necessitate added effort in his later program. About 10 units of elective time are available in the second term of the second year for students following the usual program of prescribed Institute and Departmental subjects. This time may be used to take advantage of offerings in professional subjects in the prescribed elective areas of mathematics, physics, chemistry, or electrical engineering, in the humanities, or in unspecified electives.

In the third year it is expected that students will lay the groundwork for their areas of later concentration. The subjects taken should have broad applicability in the earth sciences in order to assure flexibility of future choice. The different goals of students in the earth sciences and the wide range of subject matter available make it most important that each student carefully consider his program with his Faculty Counselor.

Fourth-year students will, in general, be pursuing subject sequences which simultaneously enhance their professional knowledge, add to their store of fundamental understanding, and increase their appreciation for non-professional matters. The Bachelor's thesis, usually written in the second term but often based on field work done during the previous summer, is an opportunity for the student to take up the challenge of exploring in a professional manner some problem in the earth sciences. Every attempt is made to provide the student freedom of choice of his thesis problem and to provide appropriate time, environment, and supervision for its completion.

In choosing an undergraduate curriculum in Geology and Geophysics, each student should keep in mind the following essential pattern when arranging his program with his adviser:

1. Professional earth science subjects should be taken in an orderly sequence which goes from

subjects of broad applicability to those covering restricted topics in considerable depth.

2. Subjects in mathematics, physics, chemistry, or electrical engineering should be taken in an orderly sequence and so selected as to support the particular earth science program being followed.

The Course leads to the Degree of Bachelor of Science in Earth Sciences. The curriculum requirements for this degree are presented below.

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 163*)		176
PHYSICS 8.03 and 8.04 are taken except when plans for further study clearly indicate the need for the subject matter of PHYSICS 8.031 and 8.041[1].		
DEPARTMENTAL PROGRAM		
Required subjects		
THESIS		15
Elective subjects		
Specified		
Basic science and engineering subjects more advanced than the General Institute Requirements (mathematics, physics, chemistry, 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	
		174
Total units required for the S.B. degree		[3]365

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

[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).

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 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, except that the 15 units of undergraduate thesis are allotted to additional professional subjects.

The graduate requirement is 66 units of graduate study and 30 units of THESIS, a total of 96 units. (Up to 10 units of additional THESIS may be included in the 66 units of graduate study.)

GRADUATE STUDY

Geology and Geophysics

The Department of Geology and Geophysics offers a wide choice of graduate study and research for specialization in the following fields: geochemistry; geophysics; mineralogy; mineral industry; mineral deposits; mineral fuels; petroleum geology; petrology; sedimentation, stratigraphy, and marine geology; structural geology; and theoretical geology. In the borderland between geology, geophysics, geochemistry, and another science, the student may arrange a program of study and research under

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 applied geology, X-ray crystallography, geochemistry, and geophysics. Modern laboratory facilities, research instruments, and extensive collections of specimens and materials are available to qualified graduate students. Field studies are included as an essential part of the graduate curriculum in geology, geophysics, and geochemistry, and special arrangements may be made for summer employment and field research with industrial organizations and government agencies.

Oceanography

In cooperation with the Department of Meteorology and the Woods Hole Oceanographic Institution, a program in oceanography is now being offered. The oceans, the atmosphere, and the solid earth are so intimately related that they must often be studied together as parts of a single system. Certain subjects of instruction in geology and in meteorology are directly applicable to oceanographic problems. Three staff members of the Woods Hole Oceanographic Institution now hold part-time faculty appointments at M.I.T. in the two cooperating departments. These oceanographers offer formal lecture subjects and are also available by appropriate arrangement for individual consultation and for thesis advising. Arrangements may also be made for properly qualified M.I.T. graduate students to use the excellent facilities for 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 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.

The Minor requirement is generally satisfied by taking at least 24 units of approved study in another department.

Teaching and Research Assistants

The Department regularly appoints 15 to 20 assistants who are candidates for a graduate degree. Teaching assistants conduct regularly scheduled laboratory sections and examinations, grade papers, and prepare teaching materials. Research assistants do assigned work on one of the Department's projects and may be able to use some of the work done toward a thesis. Information about these appointments may be obtained by writing to the Head of the Department.

Department of Mathematics

WILLIAM TED MARTIN, PH.D.
Professor of Mathematics; Head of the Department

RICHARD DONALD SCHAFER, PH.D.
Professor of Mathematics; Deputy Head of the Department

PHILIP FRANKLIN, PH.D.
Professor of Mathematics, Emeritus

RAYMOND DONALD DOUGLASS, PH.D., SC.D.
Professor of Mathematics, Emeritus

NORMAN LEVINSON, SC.D.
Professor of Mathematics

ERIC REISSNER, DR. ING., PH.D.
Professor of Mathematics

CHIA-CHIAO LIN, PH.D.
Professor of Mathematics

CLAUDE ELWOOD SHANNON, PH.D.
Donner Professor of Science

WARREN AMBROSE, PH.D.
Professor of Mathematics

GEORGE WILLIAM WHITEHEAD, PH.D.
Professor of Mathematics

KENKICHI IWASAWA, DR.SCI.
Professor of Mathematics

ISADORE MANUAL SINGER, PH.D.
Professor of Mathematics

IRVING EZRA SEGAL, PH.D. (*Absent*)
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

HENRY PRATT MCKEAN, JR., PH.D.
Professor of Mathematics

NESMITH CORNETT ANKENY, PH.D.
Professor of Mathematics

HARVEY PHILIP GREENSPAN, PH.D.
Professor of 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

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

SIGURDUR HELGASON, PH.D. (*Absent*)
Associate Professor of Mathematics

ARTHUR PAUL MATTUCK, PH.D.
Associate Professor of Mathematics

FRANKLIN PAUL PETERSON, PH.D.
Associate Professor of Mathematics

GIAN-CARLO ROTA, PH.D.
Associate Professor of Mathematics

DAVID JOHN BENNEY, PH.D. (*Absent*)
Associate Professor of Mathematics

JAMES GILBERT GLIMM, PH.D. (*Absent*)
Associate Professor of Mathematics

JAMES RAYMOND MUNKRES, PH.D.
Associate Professor of Mathematics

MICHAEL ARTIN, PH.D.
Associate Professor of Mathematics

WILLIAM GILBERT STRANG, PH.D.
Associate Professor of Mathematics

ALAR TOOMRE, PH.D.
Assistant Professor of Mathematics

EDWARD BALDWIN CURTIS, PH.D.
Assistant Professor of Mathematics

CHRISTOPHER HUNTER, PH.D.
Assistant Professor of Mathematics

TAKESHI KOTAKE, DR.SCI. (*Absent*)
Assistant Professor of Mathematics

JOSEPH PEDLOSKY, PH.D.
Assistant Professor of Mathematics

Lecturers

ROE WILLIAM GOODMAN, PH.D.

ROBERT GEORGE HEYNEMAN, PH.D.

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.

C. L. E. Moore Instructors

THEODORE WILLIAM GAMELIN, PH.D.
CHARLES COFFIN SIMS, PH.D.
JOHN ALDEN THORPE, PH.D.
ALESSANDRO LUIGI FIGÀ-TALAMANCA, PH.D.
ROBERT LEON PENDLETON, PH.D.
DANIEL GRAY QUILLEN, PH.D.
DANIEL GISRIEL RIDER, PH.D.
LEONARD TODD, PH.D.

Instructors

JEAN-PHILIPPE MARCEL LABROUSSE, PH.D.
THOMAS JOSEPH LARDNER, PH.D.
WARREN LEE MAY, PH.D.
GERALD JOSEPH PORTER, PH.D.
NORTON STARR, PH.D.
NORMAN RAYFIELD WAGNER, PH.D.
JAMES ROBERT GEISER, S.B.
ANGUS CARMICHAEL KERR-LAWSON, PH.D.
ROBERT LEE KNIGHTEN, S.B.
TZEE-CHAR KUO, PH.D.
EDGAR GEORGE KENNETH LOPEZ-ESCOBAR, PH.D.
STEVEN IRA ROSENCRANS, PH.D.
EUGENE SPIEGEL, B.S.
JOHN JAMES UCCI, PH.D.
DIRK VAN DALEN, PH.D.

Research Associates

ROLAND GRAHAM, PH.D.
DIETRICH GOTTHELF LORTZ, DIPL.
DAVID COMPTON LUCKHAM, PH.D.
WILSON ALEXANDER SUTHERLAND, D.PHIL.

Professors Emeriti

HENRY BAYARD PHILLIPS, PH.D., LL.D.
Professor of Mathematics, Emeritus
PHILIP FRANKLIN, PH.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
SAMUEL DEMITRY ZELDIN, PH.D.
Associate Professor of Mathematics, Emeritus

CURRICULUM OF MATHEMATICS PROGRAM 1

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 163*)			176
PHYSICS 8.03 and 8.04 are prescribed.			
DEPARTMENTAL PROGRAM			
Required subjects			
18.21	ANALYSIS	3 0 9	
18.22	ANALYSIS	3 0 9	
	[1]LANGUAGE	16	
			40
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	3 0 6	
	or the following combination:		
18.25	MODERN ALGEBRA *and*	3 0 9	
18.26	MODERN ALGEBRA	3 0 9	
	either		
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		144
Total units required for the S.B. degree			360

CURRICULUM OF MATHEMATICS PROGRAM 2

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 163*)			176
PHYSICS 8.03 and 8.04 are prescribed.			
DEPARTMENTAL PROGRAM			
Required Subjects			
18.21	ANALYSIS	3 0 9	
18.651	INTRODUCTION TO APPLIED MATHEMATICS	3 0 9	
	[1]LANGUAGE	16	
			40
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	3 0 6	
	or the following combination:		
18.25	MODERN ALGEBRA *and*	3 0 9	
18.26	MODERN ALGEBRA	3 0 9	
	either		
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 6	
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] The language must be French, German, or Russian. Any student who has taken three or more years of French, German, or Russian before coming to M.I.T. or who demonstrates to his Faculty Counselor his ability to read mathematical literature in one of these languages may substitute 16 units of unspecified elective subjects for the language requirement.

Transfer from one program to the other may be made at any time. In either program the minimum algebra requirement is the one-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 would normally 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. The language requirement should be completed, if possible, by the end of the second year.

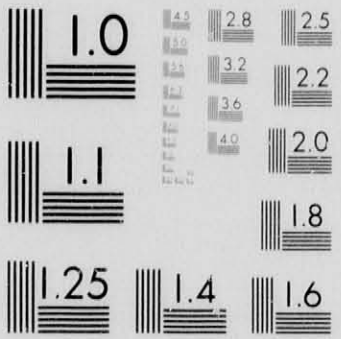
It is recommended that undergraduate students planning to pursue graduate work in elasticity, fluid mechanics, and related fields include the following elective subjects:

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



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M.I.T. ANNUAL CATALOGUES AND BULLETINS
1964/65

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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 96 units including THESIS (20–24 units) and four 12-unit graduate ("A") subjects offered by the Department. In addition, either as an undergraduate or as a graduate student, each student is expected to have completed four subjects (or their equivalents) from the following group:

METHODS OF APPLIED MATHEMATICS FOR ENGINEERS (18.15)
PROBABILITY (18.18)
LINEAR ALGEBRA (18.20)
or
MODERN ALGEBRA (18.26)
ANALYSIS (18.21, 18.22)
ELEMENTARY DIFFERENTIAL GEOMETRY (18.24)
or
RIEMANNIAN GEOMETRY (18.242)
INTRODUCTION TO TOPOLOGY (18.241)
MODERN ALGEBRA (18.25)
INTRODUCTION TO FUNCTIONS OF A COMPLEX VARIABLE (18.27, 18.28)
INTERMEDIATE DIFFERENTIAL EQUATIONS (18.29)
INTRODUCTION TO FLUID MECHANICS (18.60)
INTRODUCTION TO APPLIED MATHEMATICS (18.651, 18.652)
INTRODUCTION TO ELASTICITY (18.66)

Of the four subjects elected from this group, two may be counted for credit towards the Master's degree if taken while the student is a graduate student at M.I.T.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN MATHEMATICS

The general requirements for the Doctor of Philosophy and Doctor of Science degrees are those set forth in Section 3. As soon as possible after beginning graduate work, each student who plans to take a doctorate in mathematics should elect one of the following two plans of study:

Plan A, Qualifying Examination. A written qualifying examination on topics in algebra (primarily linear algebra), intermediate real analysis (based on a syllabus comparable to the current 18.21–18.22) and complex analysis (topics from 18.31). This examination will be given each year in November and in May. A graduate student is required to take the qualifying examination not later than the beginning of his second year (November). A student who has completed the necessary subjects before becoming a graduate student here should take this examination during his first year. The examination can be waived for students presenting to the Departmental Graduate Committee satisfactory evidence of having learned the material; for example, by having achieved sufficiently high standing in classes in these subjects at M.I.T. or elsewhere.

Plan B, General Examination. A written examination consisting of two parts; the first on Methods of Applied Mathematics I (based on 18.653–18.654), and the second on applications to physical subjects (based on 18.651–18.652, 18.60–18.61, and 18.66–18.67). Students should take this examination in their second graduate year. A written examination, together with an oral examination to be arranged with a prospective thesis supervisor selected by the student, will constitute the general examination under Plan B.

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 occasional 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.
Professor of Meteorology
VICTOR PAUL STARR, PH.D.
Professor of Meteorology
HENRY MELSON STOMMEL, S.B.
Professor of Oceanography
EDWARD NORTON LORENZ, SC.D.
Professor of Meteorology
ERIK LEONARD MOLLÖ-CHRISTENSEN, SC.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
NORMAN ALTON PHILLIPS, PH.D.
Associate Professor of Meteorology
FREDERICK SANDERS, SC.D.
Associate Professor of Meteorology
REGINALD EDWARD NEWELL, SC.D.
Assistant Professor of Meteorology

Technical Instructor

GARDNER PERRY, III, S.B.

Senior Research Associates

PAULINE MORROW AUSTIN, PH.D.
ALAN COGSWELL BEMIS, A.B., S.M.

Research Associates

ERIC ALBERT FREE, PH.D.
MARIO ROBERTO SCHAFFNER, DR.ENG.

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	METEOROLOGICAL INSTRUMENTS
19.34	STATISTICAL METHODS IN METEOROLOGY
19.45	SYNOPTIC METEOROLOGY III
19.46	NUMERICAL WEATHER PREDICTION
19.53	SYNOPTIC LABORATORY II
19.64	DYNAMIC METEOROLOGY II
19.67	PLANETARY FLUID DYNAMICS
19.71	RADAR METEOROLOGY
19.72	PHYSICAL METEOROLOGY
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. 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. 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 either full-time or part-time research assistants. Such active participation is considered a valuable supplement to the formal academic program and also provides some financial assistance.

The area surrounding Cambridge contains a number of institutions engaged in research in meteorology and related fields, such as the Air Force Cambridge Research Laboratories, the Woods Hole Oceanographic Institution, the Blue Hill Meteorological Observatory of Harvard University, and the Boston offices of the United States Weather Bureau. Close contact with the scientific personnel of these institutions is maintained through joint seminars and symposia as well as by more informal means.

OCEANOGRAPHY

In cooperation with the Department of Geology and Geophysics and the Woods Hole Oceanographic Institution, a graduate program in oceanography is now being offered. The equations that describe the motions of the atmosphere are the same as those for the oceans. The oceans and the atmosphere are closely coupled both mechanically and thermally so that they must often be considered as parts of a single system. Many of the subjects of instruction in meteorology are thus directly applicable to oceanography. Subjects in oceanography are now offered and more are planned. Certain subjects given by the Department of Geology and Geophysics are also directly applicable to the geological aspects of oceanography. Several staff members of the Woods Hole Oceanographic Institution hold part-time faculty appointments at M.I.T. They give formal subjects and are also available for individual consultation and serve as thesis advisers. Arrangements may be made for M.I.T. graduate students to use the excellent facilities for oceanographic research at Woods Hole.

Entrance Requirements for Graduate Study

Although an undergraduate program of the type described above is considered the best preparation for graduate study, it is not required; graduates of recognized institutions who present evidence of sound preparation in physics and mathematics and who meet the general requirements for admission to the Graduate School (see Section 3 of this Catalogue) may be admitted. However, training substantially equivalent to that provided by SYNOPTIC METEOROLOGY I (19.43), DESCRIPTIVE METEOROLOGY (19.02) and INTRODUCTION TO THEORETICAL METEOROLOGY (19.601) will make it possible for students to pursue a more advanced program of studies immediately after admission. Applicants with no previous training in meteorology will generally be required to take these subjects during their graduate study and therefore must expect to be in residence for a somewhat longer period.

The advanced subjects offered by the Department lead to the degrees of Master of Science in Meteorology, Master of Science in Oceanography, Doctor of Philosophy in Meteorology, Doctor of Philosophy in Oceanography, and Doctor of Science in Meteorology.

The Graduate Degrees

MASTER OF SCIENCE IN METEOROLOGY OR IN OCEANOGRAPHY

The 72 units of graduate ("A") subjects required for the Master of Science degree may be selected from those offered in meteorology or in oceanography and those in related fields offered by other departments. Undue specialization in one branch of the field is discouraged. There are no foreign language requirements for the degree.

DOCTOR OF PHILOSOPHY IN METEOROLOGY OR IN OCEANOGRAPHY AND DOCTOR OF SCIENCE IN METEOROLOGY

The general requirements for the degrees of Doctor of Science and Doctor of Philosophy are given in Section 3. Candidates for the doctorate in meteorology or in oceanography are required to demonstrate their ability to read scientific literature in English and in two other modern languages, one of which must be German or Russian. The second language must be one in which there is important meteorological or oceanographic literature. Among others, German or Russian (if not chosen as the first language), French, Norwegian, Swedish, Spanish, and Japanese satisfy this requirement.

Assistantships and Fellowships

The Department offers a limited number of research and teaching assistantships each year. Research assistants are assigned to work on one of the many research projects in the Department. Teaching assistants may be assigned to assist in laboratory instruction or to the preparation of teaching materials and the grading of papers. Information concerning these appointments may be obtained from the Head of the Department. The Department offers a few predoctoral fellowships in the atmospheric sciences and oceanography. Announcements and application forms are available around the first of the year and may be obtained from the Head of the Department.

Department of Nutrition 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
ALFRED EDWIN HARPER, PH.D.
General Foods Professor of Nutrition
SEYMOUR J. GRAY, PH.D., M.D.
Professor of Clinical Nutrition (Visiting)
CECIL GORDON DUNN, PH.D.
Associate Professor of Industrial Microbiology
JOHN THEODORE ROOSEVELT NICKERSON, PH.D.
Associate Professor of Food Technology
DONALD MORGAN WATKIN, M.D.
Associate Professor of Clinical Nutrition
GEORGE WOLF, D.PHIL.
Associate Professor of Physiological Chemistry
LEO FRIEDMAN, PH.D.
Associate Professor of Nutrition and Food Safety
PAUL MEDFORD NEWBERNE, D.V.M., PH.D.
Associate Professor of Pathology
ABRAHAM DANIEL RUBENSTEIN, M.D.
Associate Professor of Epidemiology (Visiting)
EMILY LIPPINCOTT WICK, PH.D.
Associate Professor of Food Chemistry
MIGUEL A. GUZMAN, PH.D.
Associate Professor of Biostatistics (Visiting)
MARCUS KAREL, PH.D.
Associate Professor of Food Engineering
SANFORD ARTHUR MILLER, PH.D.
Assistant Professor of Nutritional Biochemistry
LOUIS CHARLES FILLIOS, SC.D.
Assistant Professor of Physiological Chemistry
RICHARD ISAAC MATELES, SC.D.
Assistant Professor of Biochemical Engineering
GERALD NORMAN WOGAN, PH.D.
Assistant Professor of Food Toxicology
WILLIAM WALTER CARLTON, D.V.M., PH.D.
Assistant Professor of Animal Pathology
JANIS Z. GABLIKS, PH.D.
Assistant Professor of Cell Biology
PHILLIP ISSENBERG, PH.D.
Assistant Professor of Food Science
QUINTON RAY ROGERS, PH.D.
Assistant Professor of Physiological Chemistry
GERALD SILVERMAN, PH.D.
Assistant Professor of Food Microbiology
STEVEN ROBERT TANNENBAUM, PH.D.
Assistant Professor of Food Science

Administrative Officer

JOHN PAUL KARLE, B.S., M.A.

Lecturers

AARON M. ALTSCHUL, PH.D.
JOAQUIN CRAVIOTO, M.D.
CHARLES N. FREY, PH.D., D.SC.
JOHN EVERETT GORDON, PH.D.
ARNOLD JOHN LEHMAN, PH.D., M.D.

Instructor

JOSEPH JOHN LICCIARDELLO, PH.D.

Research Associates

JIMMY CLARENCE ADYE, PH.D.
NORLIN BENEVENGA, PH.D
THOMAS COLIN CAMPBELL, PH.D.
ADA GOLDBERG, PH.D.
JEAN-PIERRE HABICHT, M.D.
MITSUO KOSHIKA, PH.D.
ERICH MENDEN, DR.NAT.SCI.
JANICE LILLY MILLER, D.V.M.
JUAN MARCELO NAVIA, S.M.
ABRAHAM EDWARD NIZEL, D.M.D., M.S.D.
RUTH SCHWARTZ, PH.D.
MICHA THEINER, PH.D.
JAMES CARROLL WOODARD, D.V.M.
RICHARD FRANK ZIMPEL, S.B.

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). This curriculum (described on page 165) emphasizes fundamental subjects in the physical and biological sciences. These, together with the subjects prescribed under the General Institute Requirements (page 163), 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 the 53 units of 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 Physiology 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 for this program.

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.

Oral Science

Research in disorders of the teeth and soft tissues of the mouth requires a thorough knowledge of the basic sciences, including the use of special techniques and instruments. The program in oral science in the Department, supported by a grant from the National Institute of Dental Research, is designed to prepare graduate students, postdoctoral dental investigators, and others for research careers in oral science. It is expected that at the end of the training program such students will have completed requirements for the Ph.D. or Sc.D.

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 indi-

viduals 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:

CHEMICAL AND BIOCHEMICAL TECHNIQUES IN FOOD AND NUTRITION RESEARCH (20.32)
HUMAN NUTRITION (20.36)
SEMINAR IN NUTRITION AND FOOD SCIENCE (20.61).

For the degree of Master of Science in Food Science and Technology, the following graduate subjects are strongly recommended:

CHEMICAL AND BIOCHEMICAL TECHNIQUES IN FOOD AND NUTRITION RESEARCH (20.32)
ADVANCED FOOD SCIENCE (20.51)
SEMINAR IN NUTRITION AND FOOD SCIENCE (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 doctorates must demonstrate proficiency in two foreign languages chosen in consultation with the Graduate Registration Officer.

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.

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; Harry B. Higgins Professor of the Solid State

PHILIP MCCORD MORSE, PH.D., SC.D.
Professor of Physics; Director of the Computation Center; Director of the Operations Research Center

BERTRAM EUGENE WARREN, SC.D.
Professor of Physics

HANS MUELLER, D.SC.
Professor of Physics

NATHANIEL HERMAN FRANK, SC.D.
Professor of Physics

ROBLEY DUNGLISON EVANS, PH.D.
Professor of Physics

JERROLD REINACH ZACHARIAS, PH.D., L.H.D.
Professor of Physics

BRUNO BENEDETTO ROSSI, PH.D.
Professor of Physics

VICTOR FREDERICK WEISSKOPF, PH.D., SC.D. (*Absent*)
Professor of Physics

ALBERT GORDON HILL, PH.D.
Professor of Physics

WILLIAM PHELPS ALLIS, SC.D.
Professor of Physics

MARTIN DEUTSCH, PH.D., 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

BERNARD TAUB FELD, PH.D.
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. (*Absent*)
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.
Professor of Physics; Provost

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

WILLIAM LESTER KRAUSHAAR, PH.D.
Professor of Physics

PHILIP MORRISON, PH.D.
Professor of Physics (Visiting)

ROBERT INSLEE HULSIZER, 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.
Professor of Physics

RAYMOND FRANCIS SAWYER, PH.D.
Professor of Physics (Visiting)

KARL UNO INGARD, PH.D.
Associate Professor of Physics

JOHN GORDON KING, PH.D.
Associate Professor of Physics

GEORGE WHIPPLE CLARK, PH.D.
Associate Professor of Physics

GEORGE BERNARD BENEDEK, PH.D.
Associate Professor of Physics

KERSON HUANG, PH.D.
Associate Professor of Physics

KENNETH ALAN JOHNSON, PH.D. (*Absent*)
Associate Professor of Physics

EARLE LEONARD LOMON, PH.D.
Associate Professor of Physics

STANISLAW OLBERT, PH.D.
Associate Professor of Physics

LEE GRODZINS, PH.D. (*Absent*)
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

EDWIN FLORIMAN TAYLOR, PH.D.
Associate Professor of Physics (Visiting)

JOHN FRANCIS COCHRAN, PH.D.
Assistant Professor of Physics

RUDOLF WILHELM BAUER, PH.D.
Assistant Professor of Physics

PAUL GERARD FEDERBUSH, PH.D.
Assistant Professor of Physics

ARON MYRON BERNSTEIN, PH.D.
Assistant Professor of Physics

KENNETH WILLIAM BILLMAN, PH.D.
Assistant Professor of Physics

ALAN JAY LAZARUS, PH.D.
Assistant Professor of Physics

FRANK SCHERB, PH.D.
Assistant Professor of Physics

RICHARD HOUZET LEMMER, D.SC., PH.D.
Assistant Professor of Physics

CLIVE HOWE PERRY, PH.D.
Assistant Professor of Physics

JOHN HERBERT WOOD, PH.D.
Assistant Professor of Physics;
Director of the Cooperative Computing Laboratory

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

JACQUES DOMINIQUE DUCUING, D.SC.
Assistant Professor of Physics

RAINER WEISS, PH.D.
Assistant Professor of Physics

GORDON PAUL GARMIRE, PH.D.
Assistant Professor of Physics

EUGENE CHEN LOH, PH.D.
Assistant Professor of Physics

Administrative Officer

EDWARD SENTMAN ARENTZEN, S.M.

Lecturers

HERBERT SAGE BRIDGE, PH.D.
Research Physicist

FREDERIC JOHN EPPLING, PH.D.
Research Physicist

DAVID ALLEN HILL, PH.D.
PAUL DAVID LUCKEY, JR., PH.D.
CHARLES PHILIP SARGENT, PH.D.
WILLIAM ERNEST TURCHINETZ, PH.D.

Instructors

JOHN BRAYTON BRONZAN, PH.D.
WILLIAM EDWIN DORENBUSCH, PH.D.
JOHN CHARLES INGRAHAM, PH.D.
JOHN IRWIN, PH.D.
JAMES WILCOX OVERBECK, PH.D.
JOHN FRANK READING
STANLEY BENEDICT KOWALSKI, PH.D.
DAVID JOHN PULLEN, PH.D.
MALCOLM HARRIS SKOLNICK, PH.D.
RICHARD KUMEO YAMAMOTO, 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

ARTHUR COBB HARDY, SC.D.
Professor of Optics and Photography, Emeritus

WAYNE BUCKLES NOTTINGHAM, PH.D.
Professor of Physics, 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 2000 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. There is, in

addition, an IBM 709 computer on the M.I.T. campus used primarily for solid state and molecular calculations.

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, and Center for Materials Science and Engineering. These laboratories provide close relationship 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 36–40.

In the second year it is recommended that the student take ELECTRONIC NETWORKS AND DEVICES (6.14) in the second term in order to acquire familiarity with and a knowledge of electronic devices which will be useful in his subsequent laboratory subjects. Omission of this subject from a student's second-year curriculum will necessitate added effort on his part in connection with his third-year laboratory work. Adequate elective time is made available in the second year — something of the order of 18 units in the first term and 6 to 9 units in the second term (assuming that 6.14 is taken in this term) — and for most students it is wise to plan to satisfy the departmental requirement of one subject in chemistry during this year.

The departmentally prescribed subjects 8.05, 8.06, 8.08, 8.09, 8.10T, and 18.05 are normally taken in the third year. In addition, students generally find it to their best advantage to take the prescribed mathematics elective subject subsequent to 18.05. Students interested in molecular and solid state physics may prefer to substitute INTRODUCTION TO SOLID-STATE PHYSICS (8.44) for ELECTRONICS (8.08). Part of the elective time available in the second term of the third year may be used effectively in a variety of ways. For example, a student may take 8.07 or 8.72 to obtain greater flexibility in his fourth-year program; he may elect INTRODUCTION TO NUCLEAR PHYSICS (8.053) if his interests lie in this direction. 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 8.11T, 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 (8.11T) 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 8.11T 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 163*)					176
PHYSICS 8.031 and 8.041[1] are prescribed but PHYSICS 8.03 and 8.04 are acceptable, when completed with good grades, in the case of students transferring to Course VIII.					
DEPARTMENTAL PROGRAM					
Required subjects					
6.14	ELECTRONIC NETWORKS AND DEVICES	4	2	6	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
8.05	[2]PHYSICS OF ATOMS AND MOLECULES I	4	0	8	
8.08	ELECTRONICS	4	0	6	
8.09	EXPERIMENTAL ATOMIC PHYSICS I	0	6	6	
8.06	[2]PHYSICS OF ATOMS AND MOLECULES II	4	0	8	
8.10T	EXPERIMENTAL ATOMIC PHYSICS II	0	6	6	
8.711	MECHANICS I	4	0	8	
8.11T	EXPERIMENTAL PHYSICS	2	0	2	
8.72	ELECTROMAGNETIC RADIATION	4	0	8	
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	6	
	THESIS		12		
					129
[3]*Elective subjects*					
Specified					
One additional subject in mathematics					
One subject in chemistry					
Unspecified subjects as needed to fulfill the total elective unit requirement of					55
Total units required for the S.B. degree					360

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

[2] In special cases 8.051 and 8.053 will be accepted in place of 8.05 and 8.06.

[3] It is recommended that, in general, a student take no more than 24 units of elective subjects in the second year, 21 units in the third year, and 32 in the fourth year.

GRADUATE STUDY IN PHYSICS

The Department of Physics offers graduate work leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Physics. No stated curriculum of subjects of instruction is required for any of these degrees; instead, individual curricula are chosen in consultation with the Registration Officer, in accordance with certain broad principles.

Subjects of study include work in almost all of the experimental fields described in the paragraphs above, and in the various branches of theoretical physics as well. Graduate students are expected to gain real familiarity with several of the branches of physics, not merely with one specialty. They will be well prepared for either academic work or industrial research, since the training includes a broad and thorough understanding of both the fundamentals of physics and its advanced applications.

A number of half-time 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 (8.11T)
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 AIR SCIENCE

JACK DWYER ALEXANDER, M.A., M.B.A.
Major, U. S. Air Force
Professor of Air Science; Head of the Department

JOSEPH AQUINAS HART, B.S.
Major, U. S. Air Force
Associate Professor of Air Science

LEO BRACHTENBACH, B.S.
Captain, U. S. Air Force
Associate Professor of Air Science

Instructors

ROBERT EARL GROTE
Technical Sergeant, U. S. Air Force

JOHN JAMES HOFFMAN
Staff Sergeant, U. S. Air Force

THOMAS PHILIP NAGLE
Technical 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

Computation Center

PHILIP McCORD MORSE, PH.D., SC.D.
Director

FERNANDO JOSÉ CORBATÓ, PH.D.
Deputy Director

Cooperative Computing Laboratory

JOHN HERBERT WOOD, PH.D.
Director

Laboratory for Nuclear Science

PETER THEODORE DEMOS, PH.D.
Director

National Magnet Laboratory

BENJAMIN LAX, PH.D.
Director

ARTHUR JAY FREEMAN, PH.D.
Associate Director

DONALD THOMAS STEVENSON, PH.D.
Assistant Director

JAMES MAITLAND WEST, A.B.
Assistant Director

Operations Research Center

PHILIP McCORD MORSE, PH.D., SC.D.
Director

RONALD ARTHUR HOWARD, 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

JAMES Q. WILSON, PH.D.
Director

LLOYD RODWIN, PH.D.
Chairman of the Faculty Committee

DEPARTMENT OF MILITARY SCIENCE

JAMES WESLEY GILLAND, M.C.E.
Lieutenant Colonel, Corps of Engineers
Professor of Military Science;
Head of the Department

PAUL LAWRENCE GURNEE, B.S.
Major, Ordnance Corps
Associate Professor of Military Science

LEVERNE ELWOOD ALLEN, B.B.A.
Major, Signal Corps
Associate Professor of Military Science

HIRAM JACK THOMAS, M.S.
Captain, Chemical Corps
Associate Professor of Military Science

Bandleader

FREDERICK AUGUSTUS HARRIS, JR., B.MUS., ED.M.
Major, Infantry, Retired

Instructors

RALPH THOMAS PEMBERTON, JR.
Master Sergeant, U. S. Army

ROBERT SEAGRAVE SIMPSON
Staff Sergeant, U. S. Army

Administrative Assistant

JOSEPH CLARENCE TADLOCK
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

VICTOR HENRY MATTFELD, PH.D.
Organist

DEPARTMENT OF NAVAL SCIENCE

HARRY MARVIN PUGH, M.S.
Captain, U. S. Navy
Professor of Naval Science; Head of the Department

JOSEPH ALLEN MATTHEWS, B.S.
Commander, U. S. Navy
Associate Professor of Naval Science

JOHN BAPTIST CASTANO, A.B.
Lieutenant, U. S. Navy
Assistant Professor of Naval Science

PAUL ERNEST GUAY, B.S.
Lieutenant, U. S. Navy
Assistant Professor of Naval Science

Instructors

ROBERT JAMES EMBRY, B.S.
Yeoman First Class, U. S. Navy

MILLARD LOWELL SCUDDER
Yeoman Second Class, U. S. Navy

ELLIS FRANKLIN LEAMER
First Sergeant, U. S. Marine Corps

ALBERT GUS YARBROUGH, JR.
Storekeeper First 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 1964–65 will be published with the class schedules prior to the beginning of each term.

"T" at the end of a subject number indicates that (1) a change has been made in the content or units of the subject or (2) the number was previously assigned to a different subject.

"J" at the end of a subject number indicates that the subject is a joint offering of more than one department.

"(A)" following the name of a subject indicates that it is an approved subject for a graduate degree.

"(R)" following the name of a subject indicates that it is restricted to special groups because of content; all subjects open only to special groups are so noted at the end of the description of the subject.

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

1. The number(s) of prerequisite subjects, if any. Numbers in italics indicate subjects which may be taken simultaneously with the subject described.
2. The year classification (and term) for which the subject is normally scheduled. This is indicated as follows: "1" is a first-year subject only, and not accepted for upperclass credit; "U" is an undergraduate subject above the first year; "G" is a graduate subject.
3. The time distribution of the subject, showing in sequence the units allotted to: recitation and lecture; laboratory, drawing, or field work; and preparation. Each unit represents 15 hours of work. The total unit credit for a subject is obtained by adding together all the units shown. One unit of recitation or lecture credit, and two units of laboratory or drawing credit, are each equivalent to one semester hour.

"*Arr.*" indicates that time units are specially arranged.

4. The name of the instructor(s) in charge, when known at press time.

1.
Civil Engineering

1.01 *Geotechnical Sciences*
Prereq.: 1.05
Year: U (1) 2–0–4
Fundamentals of physical geology and hydrology related to the planning and development of engineered construction projects. Origin and composition of the shallow portions of the earth's crust with special emphasis on water as a geomorphic agent. Engineering importance of surface and subsurface waters; basic principles of sedimentary geochemistry, weathering, erosion and transport processes. *Hirschfeld*

1.05 *Fluid Dynamics*
Prereq.: 2.02, 2.403, 18.04
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; conservation of mass, momentum, and energy principles; kinematics; laminar and turbulent motion; energy transfer and energy dissipation; momentum and mass transfer — mixing and diffusion; flow through ducts and porous media; boundary layers, separation, lift, and drag. Laboratory experiments and demonstrations. *Harleman*

1.06 *Particulate Mechanics*
Prereq.: 1.05, 2.01
Year: U (1) 3–2–5
A study of the principles governing the behavior of assemblages of mineral particles. Consideration of particles ranging from colloids to gravel-size. Treatment of both two-phase (mineral and liquid or gas) and three-phase (mineral, liquid, and gas) systems. Discussion of subjects such as: fluid flow through porous media; interaction of particles; strength and compressibility of multiphase systems. *R. V. Whitman*

1.07 *Engineering I*
Prereq.: 1.05, 1.15, 1.511
Year: U (1) 3–3–3

1.08 *Engineering II*
Prereq.: 1.07
Year: U (2) 3–3–3
Introduction to formulation and solution of engineering problems. Design and decision-making in 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. Subject taught through the development of a series of case studies based on actual engineering projects drawn from professional experiences of the senior faculty of the Department. *Lambe*

1.09 *Operational Systems Analysis* (A)
Prereq.: 1.15; 6.27J or 18.10
Year: G (2) 3–0–6
Formal treatment of selected topics in linear algebra and matrix theory, followed by mathematical applications in linear programming, network flow theory, and Markov processes. Formulation of quantitative models for solution of operational problems in analysis and design of engineering systems. Problems selected from such areas as highway and air traffic systems, structural systems, water resources systems, and construction management. *Bisbee*

1.10 *Numerical Methods for Engineering Analysis*
Prereq.: 1.15, 18.04
Year: G (1) 3–0–6
Introduction to proper utilization of numerical analysis methods for civil engineering problems. Application of numerical methods, including relaxation, iteration and finite differences to equilibrium, eigenvalue, and propagation problems. Idealization of continuous systems for numerical analysis. Specific applications to problems in structural analysis, soil mechanics, and hydromechanics. *Logcher*

1.15 *Computer Approaches to Engineering Problems*
Prereq.: ——
Year: U (1, 2) 2–2–2
Introductory subject to prepare engineering students to make effective use of computers in their educational programs. Introduction to the basic concepts of machines which process information and the approaches to communication with machines. Stored program concepts, programming languages and systems, problem-oriented languages, and the computer as a component in information systems. Extensive laboratory experience in placing problems on digital and analog computers. Subject designed for undergraduate and graduate students at all levels. Laboratory and problem assignments depending on the level of each student. (*Limited enrollment.*) *C. L. Miller*

1.155 *Computer Laboratory*
Prereq.: 1.15
Year: U (1, 2) 0–5–0
For students registered in 1.15 desiring more extensive laboratory experience in the use of computers. Additional problem assignments, supervised laboratory work, and term project beyond the requirements of 1.15. (*Limited enrollment.*) *C. L. Miller*

1.16J *Special Studies in Information Systems* (A)
(same subject as 2.191J, 6.604J, 16.362J)
Prereq.: 1.09
Year: G (2) 2–4–6
Introduction to basic techniques employed in planning and design of information systems associated with a large operational complex. 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. (Project for 1964: Preliminary design of an advanced orbiting astronomical observatory OAO.) Students selected by interview on basis of their potential to contribute actively and effectively.
C. L. Miller, Baumann, Seifert, Li

1.19 *Engineering of Location* (A)
Prereq.: 1.15, 1.21
Year: G (2) 2–2–4
Engineering methods and computer techniques for analysis and evaluation of the location of physical components of transportation, water resources, and communication systems. Procedures and techniques for conducting preliminary engineering and economic analysis of civil engineering projects. Data acquisition methods including photogrammetry and aerial surveys. Advanced computer-oriented engineering systems for location analysis including an introduction to the Digital Terrain Model System. Case studies of highway location problems and projects. *P. O. Roberts*

1.21 *Fundamentals of Transportation Systems* (A)
Prereq.: 1.07
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 and assignment to modes and components; design of ways, terminals, and control systems. Applications to real situations. *Bone*

1.221J *Flight Transportation* (A)
(Same subject as 6.671J, 15.483J, 16.751J)
Prereq.: 1.09 or 1.21 or 1.251
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, Cootner, 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, Cootner, 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.: 6.27J or 18.10
Year: G (1) 3–0–6
Derivation of interval and counting probability distributions for Poisson and more general renewal processes in traffic flow streams. Discussion of gaps and other derived processes. Queuing and moving queue models in single- and multi-lane flows. Branching, merging, and passing operations with space-time velocity and transformations. Applications in road and air traffic with consideration of experimental problems. *Bisbee*

1.252 *Urban Highway Systems* (A)
Prereq.: 1.21 or 1.251
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. Economic evaluation of alternate schemes. Applications to specific projects. *Bone*

1.27 *Special Studies in Transportation Engineering* (A)
Prereq.: 1.21 or 1.251
Year: G (1 or 2) *Arr.*
Advanced study of a particular phase of highway, railway, or airport engineering, selected with the approval of the instructor. *Staff*

1.30 *Soil Engineering*
Prereq.: 1.06
Year: U (2) 3–0–6
Application of soil mechanics to the analysis and design of foundations and soil structures. Applications including problems involving bearing capacity, lateral earth pressure, settlement, and slope stability. Emphasis on building foundations. Consideration of methods of subsurface investigation and the importance of such investigations in defining the actual problem. Evaluation of actual foundation performance by field measurements. Study of results of recent field measurements. *Horn*

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) 3–3–5
Detailed study of the engineering properties of granular and cohesive soils, including experimental determination of these properties. Emphasis on systematic organiza-

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tion of available data concerning such topics as secondary compression; effects of anisotropic consolidation, intermediate principle stress and strain rate on shear strength; and effect of type of compaction on the behavior of compacted clays. *Ladd*

1.322 *Soil Technology* (A)
Prereq.: 1.06
Year: G (1) 3–0–5
M.neralogy 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.: 2.02
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*

1.341 *Physics of Clay-Water Systems* (A)
Prereq.: 1.322 or 3.14 or 3.31
Year: G (2) 2–0–4
Nature and possible magnitude of forces acting in clay-water systems on a submicroscopic level. Emphasis on crystal chemistry and crystal structure of layer silicate minerals, electrical double layer theory as applied to clay, van der Waals forces in clay systems, and thermodynamics of clay-water systems with special emphasis on sorption phenomena. *R. T. Martin*

1.343 *Physics of Granular Systems* (A)
Prereq.: 1.06
Year: G (2) 2–0–4
Development of stress-strain laws for an assemblage of grains through consideration of deformation and slip at the contacts between individual grains. Hertz-Mindlin theory for contact behavior of two spheres; systems of ideally packed elastic spheres; random packings of elastic spheres. Use of theory to organize stress-strain data observed for real materials. *R. V. Whitman*

1.35 *Advanced Soil Engineering* (A)
Prereq.: 1.361
Year: G (2) 3–0–5
Study and analysis of deep foundations, harbor and waterfront developments, earth and rockfill embankments. Consideration of seepage, stability, settlement, and soil-structure interaction. Theoretical interpretation of soil behavior from measured performance of structures. Case studies. *Wolfskill*

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*

1.39 *Special Studies in Soil Engineering* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For graduate students desiring further study of special topics. *Staff*

1.42 *Structural Materials* (A)
Prereq.: 3.14
Year: G (2) 3–2–4
Mechanical behavior of important materials in civil engineering structures. Principles relating composition and structure to such behavior. Emphasis upon basic factors to facilitate understanding and use of new materials and combinations. Elastic, plastic, viscoelastic, and other time-dependent types of deformation. Influence of defects and imperfections. Consideration of creep and fracture phenomena, adhesion and corrosion, composites and multi-phase systems. Reference to present and anticipated materials. Laboratory primarily concerned with structure-composition-mechanical property interactions. *Jones, McGarry*

1.451 *Highway and Airport Pavements* (A)
Prereq.: 3.14
Year: G (1) 2–2–4
Characterization of highway and airport traffic loads. Stress-strain distribution in single and multilayer pavements under various loading. Rational and empirical design methods for elastic and viscoelastic layered pavement systems. Materials used and under development for pavement components. Formulating the composition of Portland cement, bituminous concrete, and other mixes. Basic steps in construction and control of materials for layered pavement. Laboratory demonstrations and experiments to illustrate principles. *Staff*

1.46 *Concrete and Cementitious Materials* (A)
Prereq.: 3.14
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. *Staff*

1.471 *Mechanical Behavior of Plastics* (A)
Prereq.: 3.14
Year: G (1) 3–2–4
Relation between chemical composition, physical structure, and mechanical behavior of plastics or synthetic high polymers. Study of types of polymers; fundamentals of viscoelastic phenomena such as creep, stress relaxation, stress-rupture, mechanical damping, impact; effects of chemical composition and structure on viscoelastic and strength properties; methods of mechanical property evaluation. Influences of plastics fabrication methods. Emphasis on recent research techniques and results. Laboratory on individual project basis investigating problems related to current 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 *Viscoelastic and Rheological Properties of Materials* (A)
Prereq.: 1.42
Year: G (2) 3–0–6
Thorough consideration of modern theories of the viscoelastic and rheological properties of materials. Discussion of mathematical principles and basic phenomenological theory, formulated in terms of a distribution of relaxation times. Description of detailed physical mechanisms responsible for this behavior in various classes of materials. Particular attention to the case of plastics and other polymers in the solid state. Study of the behavior of asphalt, soils, wood, glasses, and metals. (*Not offered 1964–65.*) ——

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*

1.501 *Structural Mechanics*
Prereq.: 2.01
Year: G (1) 3–0–6
Elementary analysis of stress, strain, and deflection of typical structural members. Elastic and plastic behavior of both statically determinate and indeterminate arrangements. Elementary consideration of plates and shells and of buckling and dynamic response of structures. (*Primarily for selected officers of the U.S. Navy and Coast Guard.*) *Mirabelli*

1.502 *Naval Structural Engineering*
Prereq.: 1.501
Year: G (2) 3–1–5
Application of the principles of elementary structural mechanics, and of behavior of materials to analysis and design of typical naval structural arrangements. Development of proper perspective of analysis and design by consideration of simple structural design problems. Laboratory work with models to illustrate behavior of typical structural types. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Mirabelli*

1.503 *Naval Structural Analysis*
Prereq.: 1.502
Year: G (2) 3–1–5
Comprehensive study of methods of structural analysis of two- and three-dimensional frames and frameworks under both elastic and plastic conditions; such as, superposition equations, Castigliano's theorems, slope-deflection, and moment distribution. Brief consideration of stiffness and flexibility matrix methods suitable to use of digital computers. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Mirabelli*

1.511 *Structural Analysis and Design I*
Prereq.: 2.01
Year: U (1) 3–2–5

1.512 *Structural Analysis and Design II*
Prereq.: 1.511
Year: U (2) 3–2–5
Two-term sequence prerequisite for graduate ("A") subjects in structural engineering. Application of the principles of elementary structural mechanics and behavior of materials to analysis and design of typical steel, concrete, and wood structures involved in bridge and building construction. Analysis of elastic and plastic behavior of both statically determinate and statically indeterminate structures considered. Emphasis on beam, truss, and frame structures with a brief consideration of slab, plate, and shell structures. Development of proper perspective of analysis and design by consideration of simple structural design problems. Laboratory work with models to illustrate behavior of typical structural types. *Mirabelli (1.511), Holley (1.512)*

1.521 *Model Laboratory for Structural Design* (A)
Prereq.: 1.512
Year: G (1) 2–3–1
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.: 1.512
Year: G (1) 3–0–6
Consideration of the actual behavior and strength of various concrete structural members and panels involving a critical comparison of present theory and accepted design procedures with significant experimental and analytical investigations, and with current design specifications. Flexural behavior of reinforced concrete beams including thorough discussion of shear, diagonal tension, and bond; behavior of both short and long columns; buckling of columns, flat and curved panels, and slender flexural members; behavior of shear walls, deep beams, and prestressed members. *Holley*

1.542 *Advanced Reinforced-Concrete and Prestressed-Concrete Design* (A)
Prereq.: 1.541
Year: G (2) 2–0–4
Application of theory and characteristic behaviors discussed in 1.541 to design of civil engineering structures

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such as slabs, precast decking, rigid frames, arches, prestressed concrete tanks, continuous prestressed concrete girders, etc. *Holley*

1.551 ***Advanced Structural Design*** **(A)**
Prereq.: 1.512
Year: G (1) 3–0–6
General principles of structural design. 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. *Biggs*

1.552 ***Advanced Design of Metal Structures*** **(A)**
Prereq.: 1.512
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.: 1.512
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. *Connor*

1.571 ***Advanced Structural Analysis*** **(A)**
Prereq.: 1.512
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 by specializing the general three dimensional principles of stationary complementary energy. Formulation of governing equations for a system of member elements using matrix notation and consideration of the various solution procedures. *Connor*

1.582 ***Structural Reliability*** **(A)**
Prereq.: 1.512
Year: G (2) 2–0–4
Systems analysis and probability theory as applied to structural engineering. Resistance and loading functions as continuous random variables. Logarithmic transforms. Extreme value theory. Probability of failure or survival. Risk functions. Probabilistic approach to structural design based on consequences of failure. Expected life. Cost versus reliability. Quality control. Practical applications. *Biggs*

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. *Connor*

1.586 ***Structural Dynamics*** **(A)**
Prereq.: 1.512
Year: G (2) 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. *Biggs*

1.591 ***Numerical Methods of Structural Analysis*** **(A)**
Prereq.: 1.10, 1.561, 1.571
Year: G (1) 3–0–6
Application of mathematical and numerical techniques to advanced topics in equilibrium, buckling, and vibration problems. Approximate methods, including perturbation, collocation, and calculus of vibrations. Error analysis for numerical and approximate methods. Evaluation of alternate numerical techniques and methods of idealization of continuous systems. Selection of methods especially appropriate for digital computers. *Connor*

1.60 ***Applied Fluid Dynamics***
Prereq.: 1.05
Year: U (2) 3–0–6
Sequel to 1.05. One-dimensional analysis of steady, uniform, and non-uniform free surface flows; dynamics of one-dimensional compressible flow of gases and liquids; introduction to field theory with application of theorems of Kutta and Blasius to problems of lift and energy conversion; problems in unsteady incompressible flows such as mass oscillation, flow induced vibrations, and the propagation of flood waves. *Eagleson*

1.612 ***Fluid Mechanics***
Prereq.: 2.02
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
Dynamics and kinematics of nonviscous and viscous fluid motions. General equations of motion, continuity,

deformation, rotation and circulation, sources and sinks, velocity, potential and stream functions, two- and three-dimensional potential flows. Conformal mapping, vortex motions. Navier-Stokes equations. Laminar motion, creeping flows. *J. F. Kennedy*

1.632 *Advanced Hydromechanics II* (A)
Prereq.: 1.631
Year: G (2) 3–0–6
Dynamics and kinematics of fluid motions continued, with applications to structures and fluid machinery. Laminar and turbulent flow in ducts, boundary layers. Laminar flow stability, generation of turbulence, structure of turbulence in homogeneous and shear flows. Boundary layers in pressure gradients, stall, separation, and secondary flows, boundary layer control. Turbulent mixing, diffusion and transport. Cavitation principles and other two-phase flows. Introduction to non-Newtonian fluid mechanics. *J. F. Kennedy*

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. Modeling of hydraulic structures, flows with erodible beds, transport processes, rotating fluid systems, hydraulic machinery, wave and tidal phenomena. Shape and roughness effects in distorted models. Electrical analogies. Practical methods of establishing dynamic similarity in models. Instrumentation, experimental techniques, and analysis of errors. *Harleman*

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. *Harleman*

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. *J. F. Kennedy*

1.71 *Hydrology* (A)
Prereq.: 6.27J or 18.10
Year: G (1) 3–0–6
Comprehensive treatment of physical and statistical hydrology. Basic principles of meteorology, climatology, and the hydrologic cycle. Stochastic processes in hydrology and in the behavior of hydrologic systems. Application to the problems of data analysis, basin yield, streamflow prediction. *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 *Hydraulic Engineering* (A)
Prereq.: 1.05
Year: G (1) 2–0–4
Application of hydrology and fluid mechanics to planning and design of hydraulic structures. General features of hydraulic structures and machinery for irrigation and drainage, river control, hydropower, water transport, water supply, and ground water utilization. Interaction of hydraulic components in systems. *McLaughlin*

1.732 *Water Resources Development* (A)
Prereq.: 1.731
Year: G (2) 2–0–4
Engineering problems and economic factors relating to multi-purpose water resources development. Planning of design features of hydraulic and water-quality components for system performance. Integrated use of surface and ground water, waste water, and salt water conversion. Modern trends in large-scale projects for water supply, power, and other water use. Application of systems methodology. *McLaughlin*

1.77 *Water Quality Control* (A)
Prereq.: 1.05
Year: G (2) 3–3–6
Combined effects of convection, turbulence, sedimentation, and biological, chemical, or nuclear processes in flowing fluid. Continuity equations for matter in each phase and state, interpretation of boundary conditions occurring in nature, methods of solution and approximations, similitude in water quality systems. Application to pollution of surface and ground water, design of water quality control facilities, water quality monitoring systems. Laboratory exercises and computation periods. (For additional prerequisites in chemistry and microbiology, consult instructor.) *McLaughlin*

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1.80 ***Applied Earth Sciences Seminar*** **(A)**
Prereq.: ——
Year: G (1, 2) 2–0–4
Review of current research on selected topics in hydrology, sedimentary mineralogy, dynamics of soil water systems, geomorphology and oceanography. Applications to problems in water resources development, river and estuary processes, soil mechanics and engineering geology. Interdisciplinary studies designed for staff and advanced students in civil engineering and the earth sciences. (At least one graduate subject in hydrology, hydrodynamics, soils, geology, meteorology, or oceanography is required as a prerequisite. Consult instructor for appropriate subjects.) *Drinker, Eagleson*

1.92J ***Building Process***
(Same subject as 4.40J)
Prereq.: ——
Year: U (1) 3–3–4
Analysis of the building process as influenced by structure, environment, and materials and by social, legal, and industrial processes. Evolution of building systems and detailed examination from both functional and expressive possibilities. Elements of environmental control and site factors. Primarily an 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.: 1.09 or 15.592
Year: G (1) 3–0–6
Organization of large projects, time schedules, job and office organization, integration of construction procedures, contract documents, handling of labor, and expedition of materials. Techniques for solving optimization problems encountered in construction organization, including allocation of resources and transportation-type problems. Introduction to data processing, programming for computer solutions of problems, and linear programming; detailed study of critical path scheduling as means of construction organization and control. *Dietz*

1.952 ***Construction Management Seminar*** **(A)**
Prereq.: 1.951
Year: G (2) 3–0–6
Continuation of 1.951 in seminar form. Introduction to PERT and dynamic programming. Study of professional relations in construction. Field trips to illustrate difficult situations. Participation of builders, architects, and engineers from a variety of projects. Field surveys, library research, term paper. Extensive contributions by students. *Dietz*

2.
Mechanical Engineering

2.00 ***Introduction to Engineering Systems***
Prereq.: ——
Year: 1 (2) 2–0–4
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*

2.01 ***Mechanics of Solids I***
Prereq.: 8.02, 18.02
Year: U (1, 2) 3–0–5
Introduction to engineering applications of static behavior of rigid and deformable systems. Definition of state of stress and state of strain at a point. Dependence of strain upon stress and temperature. Basic analysis of relations between force balance and geometrically compatible deformation for systems built of rigid, elastic or plastic materials. Applications to stress distributions and deformations in rods, beams, shafts and simple structures. Stability of systems with both rigid and deformable elements. *Cook*

2.011J ***Introductory Mechanics and Electromechanics***
(Same subject as 6.00J)
Prereq.: 8.031, 18.03
Year: U (1) 3–0–5
The concept of a continuum and continuum variables. Geometric variables and laws, force variables and laws, and the law of conservation of mass as used for continuua. Observed properties of real materials. Constitutive relations and examples for elastic solids and viscous fluids.
Kurtz, White

2.02 ***Dynamic Systems***
Prereq.: 8.02, 18.03
Year: U (2) 3–0–6
Dynamic analysis of linear and quasi-linear physical systems involving storage and transfer of matter and energy. Speed of response and degree of damping. Dynamically interacting systems. Derivation and solution of governing differential equations by direct analysis and by analog and digital computer methods. Use of complex numbers in determination of exponential response, including step and sinusoidal inputs. Block diagram representation of interacting variables and system characteristics. Use of linear circuit analysis and impedance concepts. Subject developed and taught by interdepartmental staff to include applications to mechanical, electrical, fluid, and thermal systems. *Richardson*

2.03 ***Dynamics***
Prereq.: 2.02, 18.04
Year: U (1, 2, S) 3–0–6
Formulation of dynamic equations of motion in mechanical, electrical, and fluid systems by use of Hamilton's principle. Treatment of lumped-parameter and continuous systems. Applications to vibrations, wave motions, and frequency response of transducers. Primary effort on formulation of problems, but some discussion devoted to the nature of solutions with emphasis on effects of nonlinearities. Illustration of use of computing machine. *Crandall*

2.032 ***Advanced Mechanics*** **(A)**
Prereq.: 2.03 or 2.06
Year: G (2) 3–0–9
The foundations of dynamics leading to Lagrange's equations and Hamilton's principle. Gyroscopic effects in mechanical systems. Analysis of the stability of steady motions. Self-excited vibrations and nonlinear vibrations. *Den Hartog*

2.06 *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. *Newland*

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. Use of variational methods, Green's functions and the Wiener-Hopf technique. Selected topics from the following: propagation through periodic structures, propagation through inhomogeneous, moving or random media, nonlinear waves. *Crandall*

2.063 *Sound and Structural Vibration* (A)
Prereq.: 18.06
Year: G (1) 3–0–9
Acoustic wave equation, wavespeed, energy density and intensity, sound absorption. Statistical description of sound fields, direct and reverberant sound, mean free path, modal density, etc. Generation of sound, radiation impedance. Flexural and longitudinal waves in plates, phase and group velocity, normal modes, reverberation, energy density, absorption, and decay. Generation of vibration, point sources and impedance, pure tone and random behavior, statistical analysis of average response and fluctuations. Coupling of sound to structural vibration, generalized force and radiation impedance, reciprocity, analogies with statistical mechanics. Applications to noise and vibration transmission, impact and flow noise. Role of structural damping in limiting response and radiation. *Newland*

2.08 *Strength of Materials*
Prereq.: 2.01
Year: U (1, 2) 3–0–6
Stress and strain in the elastic as well as the plastic states. Failure theories. Elastic and plastic torsion. Thick cylinders and rotating discs. Energy methods. Beams on elastic foundations. Introduction to plates and shells. Limit design. *Berg*

2.082 *Plasticity* (A)
Prereq.: 2.01
Year: G (2) 3–0–9
Tensor notation for stress, strain and equilibrium and geometrical conditions. Yield criteria and associated flow rule for mono- and polycrystalline material compared to data. Uniqueness. Limit analysis. Plane strain. Applications to deformation, residual stress, and fracture in bars, beams, and tubes. Other current problems. R. Hill, *Mathematical Theory of Plasticity*. *McClintock*

2.083 *Advanced Mechanics* (A)
Prereq.: 2.08
Year: G (1) 3–0–9
Stress and strain at a point in three dimensions. Introduction to the theory of elasticity with examples of solutions in two dimensions. Consideration of bending of flat plates; energy methods in elasticity; elastic stability problems. *Den Hartog*

2.085 *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. Physical fundamentals. 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. *Kurtz*

2.101 *Computer Models of Physical and Engineering Systems I*
Prereq.: ——
Year: 1 (1, 2) 2–2–2
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*

2.14 *Control System Principles*
Prereq.: 2.03; 2.201 or 2.211; 6.14 or 6.42; 18.04
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*

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2.151 ***Advanced Control Systems*** **(A)**
Prereq.: 2.14 or 6.213 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. Use of basic physical laws relating to motion, flow, energy, and properties of matter in the determination of causal relationships for components and systems. Linear and nonlinear systems, lumped-parameter and distributed-parameter systems. Linear approximations, models of nonlinear systems. Mathematical and machine solution of problems in order to meet design requirements of stability, speed of response, allowable errors, and transient peak conditions. Multiloop control, sampled data systems, state-space analysis. *S. Y. Lee*

2.153 ***Distributed Systems*** **(A)**
Prereq.: 2.062 or 2.14 or 2.161 or 6.07 or 16.30; 18.05
Year: G (1) 3–0–9
Signal and power flow in distributed media, with emphasis on transmission lines. Elastic, acoustic, fluid, thermal and electromagnetic energy. Terminations, junctions, transfer functions, scattering variables, frequency and transient response, frequency-dependent dispersion, channel capacity and bandwidth. Matching of electromechanical, fluid-mechanical, thermal-electric, and other energy transducers involving distributed media. Lumped and distributed modelling. Feedback control of nonminimum-phase-lag processes. Specific examples such as scattering of an elastic wave at a boundary, the thermal-viscous dispersion in fluid lines and skin effect in electro-magnetic lines, acoustic drivers and horns, instrumentation transducers, fluid jet amplifiers, control of systems with time delays. *F. Y. Brown*

2.161 ***Analysis and Design of Engineering Systems I*** **(A)**
Prereq.: 2.03, 2.201, 2.403
Year: G (1, 2) 3–0–9
Application of general system concepts to wide range of physical and engineering processes. Emphasis on variable flow of matter, energy, entropy, and information, directed toward predicting performance for specified designs. Introduction of central theme of functional reticulation into multiported elements. Systematic study of relations and interactions in terms of logical operations, transformations, matrices, ordinary and partial differential equations, signal flow graphs, block and bond diagrams, analogies, and computing systems. Lectures and problem work cover electrical, mechanical, fluid, thermal, chemical, nuclear, and biological systems.
Paynter

2.162 ***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. *Paynter*

2.171 ***Hydraulic and Pneumatic Controls*** **(A)**
Prereq.: 2.14; 2.201 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.: 2.02 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 6.37 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. Computor simulation of man-machine systems with emphasis on engineering application. Several experimental projects or case studies. *Sheridan*

2.191J ***Special Studies in Information Systems*** **(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 information systems associated with a large operational complex. 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. (Project for 1964: Preliminary design of an advanced orbiting astronomical observatory OAO.) Students selected by interview on basis of their potential to contribute actively and effectively.
Baumann, C. L. Miller, Seifert, Li

2.201 ***Fluid Mechanics***
Prereq.: 2.02, *2.403*, 18.04
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; drop; boundary layer; head losses; fluid machinery. *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*

2.211 ***Fluid Dynamics***
Prereq. 2.02, *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, 2.404, 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*

2.22 ***Fluid Machines***
Prereq.: *2.202*
Year: U (1) 3–0–6
Momentum and energy transfer in dynamic fluid machines. Fundamental principles of axial and centrifugal compressors, turbines, and ducted jets. Design considerations and phenomena which limit performance of particular machines. Exercise in design, construction and testing a working model. *P. G. Hill*

2.25 ***Advanced Fluid Mechanics*** **(A)**
Prereq.: 2.201, *18.05*
Year: G (1) 3–0–9
Survey of principal concepts and methods of fluid dynamics. Statics. Continuity, momentum, and energy relations for continuous fluids. Kinematics of fluid motion. Governing equations for motion of non-viscous fluid. Vorticity and circulation. Kelvin's theorem. Helmholtz' theorem. Crocco's theorem. Stream function. Potential flow. Conformal transformation. Theory of lift. Navier-Stokes equation for motion of real fluids and applications. Boundary layer theory. Turbulence. Drag. Applications to fluid machinery, propulsion systems, process industries, and aerodynamics. *Shapiro*

2.26 ***Kinetic Theory of Ionized Gases*** **(A)**
Prereq.: 2.46; *6.03* or *8.72*
Year: G (1) 3–0–9
Thermodynamic equilibrium of ionized gases. Motion of particles in magnetic and electric fields. The Boltzmann equation and formulation of macroscopic conservation laws. Transport properties. Multiple fluid model of plasmas. Application to magnetohydrodynamic flows. *J. A. Fay*

2.271 ***Compressible Fluid Mechanics*** **(A)**
Prereq.: 2.201, 2.403, 18.05
Year: G (2) 3–0–9
Survey of gas dynamics. Fundamentals of wave phenomena. One-dimensional steady flow, with effects of area change, friction, heat transfer, chemical reaction. Shock waves. Supersonic diffusers and wind tunnels. Subsonic high-speed flow. Supersonic flows. Unsteady flows and waves in ducts. Experimental methods. *Shapiro*

2.272 ***Viscous and Turbulent Flows*** **(A)**
Prereq.: 2.25
Year: G (1) 3–0–9
Viscosity and dissipative phenomena; the Navier-Stokes and energy equations, their formulation, properties, and some exact solutions; creeping flows at low Reynolds numbers; laminar boundary layers and their solution; laminar stability, transition, and turbulence; turbulent boundary layers; jets, wakes, and separated flows; thermal boundary layers; compressible boundary layers with chemical reactions, dissociation, and ionization; effects of mass addition and surface catalysis. *Probstein*

2.273 ***Molecular Gasdynamics*** **(A)**
Prereq.: 2.201, *18.05*
Year: G (1) 3–0–9
Introduction to fluid flows from the molecular point of view. Molecular models and elementary kinetic theory of gases including pressure, mean free path and transport phenomena. Equilibrium kinetic theory, Maxwellian velocity distribution, collisions and relaxation. The interaction of a flowing gas with solid surfaces. Approach to thermodynamic equilibrium in fluid flows. Formulation of continuum conservation laws beginning with particle concepts. *Probstein*

2.274 ***Magnetohydrodynamics*** **(A)**
Prereq.: 2.211 or 2.25; 6.03 or 8.72
Year: G (2) 3–0–9
Dynamics of electrically conducting fluids in the presence of magnetic and electric fields. Kinematic concept of flow affecting field and dynamic concept of field affecting flow. Moving fields and the electromagnetic equations; the MHD limit; fluid mechanical equations and boundary conditions; kinematics including vorticity analogy and infinite conductivity theorems; transverse and parallel incompressible flows and flowmeters; Maxwell stresses and magnetohydrostatics; containment and stability; the $\mathbf{j} \times \mathbf{B}$ force and fluid analogies; Alfvén waves, incompressible Hartmann flow and boundary layers; linearized MHD and upstream wakes; steady compressible channel flows; magnetoacoustic waves, finite amplitude wave propagation and shock waves; steady, compressible, inviscid and boundary layer flows. *Probstein*

2.281 ***Combustion Gas Dynamics*** **(A)**
Prereq.: 2.201 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 transfer of heat, mass, and momentum. Combustion thermodynamics. Applied chemical kinetics. Transport coefficients in reacting mixtures. Conservation

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equations considering chemical reaction and multi-species diffusion. Detonation waves. Propagation of laminar and turbulent flames. Flame stabilization. Diffusion flames. Heterogeneous combustion. Ignition. Combustion in boundary layers. High-temperature gas flow in nozzles and in hypersonic boundary layers. Applications to engineering problems. *Toong*

2.282 *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.
J. A. 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.: 2.01, 3.14
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 motion; 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.* *McClintock*

2.301 *Mechanical Behavior of Materials*
Prereq.: 2.01, 3.14, 8.051, 18.05
Year: U (1, 2) 3–2–4
Similar to 2.30, but with more advanced treatment of certain topics. *Argon*

2.303 *Physics of Strength and Plasticity* (A)
Prereq.: 2.30, 3.14
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.: 2.01; 2.30 or 3.14
Year: G (1) 3–0–9
Derivation from elastic theory of the properties of dislocations in isotropic and anisotropic materials. Interactions between dislocations and other imperfections. Dislocations in particular crystal structures. Applications to theories of yield points, solution hardening, work hardening, creep and fracture. *Argon*

2.34 *Non-Metallic Materials*
Prereq.: 3.14
Year: U (2) 3–0–6
Chemical, structural, physical, and mechanical properties of polymers, including rubbery materials, glasses, ceramics, textiles, and other non-metallic materials. Production, testing, and engineering use of non-metallic materials. *Orowan*

2.399 *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*

2.401 *Thermodynamics of Fluid Flow*
Prereq.: 8.02, 18.03
Year: U (2) 3–0–6
Laws of thermodynamics with special emphasis on fluid flow and work-producing systems employing gaseous working fluids. Kinetic theory of gases using the rigid sphere model, transport properties, and interpretation of transport phenomena. *Gouse*

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, 18.03
Year: U (1, 2) 4–0–8
Thermodynamic concepts; the laws of thermodynamics; equilibrium; absolute temperature; entropy and availability; the phase rule; perfect systems; mixtures; flow processes; chemical potential; chemical equilibrium. *Hatsopoulos*

2.404 *Statistical Mechanics and Kinetic Theory*
Prereq.: 2.403
Year: U (1, S) 3–0–6
Classical mechanics of systems of particles and motion in phase space. Quantum mechanical aspects of particle motion. Most probable distribution. Thermodynamic properties of perfect gas and crystal, electron gas, thermal radiation. Elementary kinetic theory using mean free path concept. Transport properties. Boltzmann equation. *J. A. Fay*

2.412 *Heat Engineering*
Prereq.: 2.402, 2.54
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*

2.451 *Advanced Engineering Thermodynamics* (A)
Prereq.: 2.403, *18.05*
Year: G (1) 3–0–9
Equilibrium; axiomatic thermodynamics; first law, second law, and state principles; criteria for equilibrium; absolute temperature, entropy, and availability; Maxwell's relations; open systems; the phase rule; systems of one and two components; idealized gases, mixtures, and solutions; equations of state; thermodynamic potentials; chemical reactions and chemical equilibrium. *Hatsopoulos*

2.452 *Advanced Engineering Thermodynamics* (A)
Prereq.: 2.451
Year: G (2) 3–0–9
Law of stable equilibrium; systems at positive and negative Kelvin temperatures; criteria of equilibrium and stability; equilibrium of heterogeneous systems; solutions and electrolytes; gravity, electrostatic, and electromagnetic fields; ionized gases; third law; relativity; statistics of ensembles. Thermodynamics of irreversible processes; Onsager reciprocal relations; diffusion; electronic phenomena in solids, vacua, and plasmas. *Keenan*

2.453 *Advanced Projects in Thermodynamics* (A)
Prereq.: 2.451
Year: G (1) *Arr.*
Selected subjects of current interest in thermodynamics, including the relationship between thermodynamics and other sciences such as mechanics of materials, statistical mechanics, kinetic theory, and quantum theory. No formal lectures; assigned reading or experiment will be arranged on an individual basis in consultation with instructor. *Keenan, Rohsenow*

2.454 *Direct Energy Conversion* (A)
Prereq.: 2.404
Year: G (1) 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*

2.46 *Statistical Mechanics* (A)
Prereq.: 2.403 or 2.404
Year: G (2) 3–0–9
Introductory subject for graduate engineering students. Classical mechanics of systems of particles and motion in phase space. Quantum mechanical concepts and energy of microscopic systems. Most probable distribution. Determination of thermodynamic properties of gases, crystals, black body radiation field. Fluctuation theory. Application to plasmas, thermionics, masers, cryogenics. *J. A. Fay*

2.47 *Space Power Concepts*
Prereq.: 2.201 or 2.211 or 2.50 or 16.02; 2.401 or 2.403
Year: G (1) 3–0–6
Study of space power with emphasis on the production of shaft power or electricity. General First and Second Law limitations on closed cycle and open process power systems. Energy sources and storage problems and various types of direct and indirect energy conversion processes and systems. Heat rejection in outer space. Consideration of the effect of various fundamental and technological limitations, such as combined thermal and mechanical stress in stationary and rotating machine elements, on the selection and design of space power systems. Extensive study of a particular system with emphasis on the application of fundamental principles, within the framework of practical limitations, to the design of the power system. *Gouse, Hill*

2.50 *Heat and Mass Transfer*
Prereq.: *2.201*, 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 itn solids with and without heat sources; finned surfaces. Condensation. Boiling. Heat exchanger design; heat transfer in nuclear reactors, including liquid metals. Radiation at surfaces and in enclosures. Combined heat and mass 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. Radiation from luminous and non-luminous gases. *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*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

2.611 ***Elementary Internal Combustion Engines***
Prereq.: 2.02, 2.403
Year: U (1) 3–0–6
Application of engineering principles to analysis of engine performance. Spark ignition and Diesel cycles. Combustion, friction, cooling, carburetion, and other factors affecting power, efficiency, and general performance. *Rogowski*

2.612 ***Internal Combustion Engines***
Prereq.: 2.47 or 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 or *2.612*
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.: 2.611
Year: G (1) 3–0–9
For students with previous training or experience in this field. Analytical approach to problems of the Diesel engine, gasoline engine, and other types. Fluid flow, thermodynamics, combustion and performance. Taylor and Taylor, *The Internal Combustion Engine*, second edition. *Rogowski*

2.616 ***Advanced Internal Combustion Engines* (A)**
Prereq.: 2.615
Year: G (2) 3–0–9
Continuation of engine theory. Philosophy of design and design procedure. Choice of optimum design to satisfy a given performance specification. A design study for a particular engine selected by student. *Rogowski*

2.617 ***Special Problems in Internal Combustion Engines* (A)**
Prereq.: 2.611 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.: 2.22
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; 2.401 or 2.402
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 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.: 2.201 or 2.50 or 16.02; 2.401 or 2.403
Year: G (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, Chato*

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) 2–1–5
Experimental techniques presented for observation and measurement of fundamental quantities arising in mechanical engineering, such as: displacement, force, time, velocity, acceleration (linear and angular), temperature, roughness, viscosity and wear. Quantities for carrying out these measurements, including the following: electrical (resistance, capacitance, and inductance) mechanical, pneumatic, hydraulic, and optical (including photography). Emphasis on measurement methods employing radioactive tracer technology. Principles analyzed and demonstrated in class and used in laboratory assignments. Discussion of reliability and significance of experimental data; use of statistical methods whenever applicable. *Cook, Rabinowicz*

2.652 ***Experimental Stress Analysis***
Prereq.: 2.01
Year: U (1 or 2) 2–3–4
Common experimental methods of analyzing stress distributions. Photoelasticity, birefringent coatings, brittle lacquers, strain gage techniques and instrumentation, and analogies, 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*

2.671 ***Experimental Engineering***
Prereq.: 2.02, 2.403
Year: U (1, 2, S) 2–4–2*
Engineering laboratory subject for all Mechanical Engineering juniors, extending over two semesters. This subject and 2.672 to play parallel and complementary roles. Major emphasis on interplay between analytical and experimental methods in the solution of research and development problems. A few formal familiarization exercises followed by project investigations of some depth to develop major emphasis in specific case studies. Small student groups supervised by faculty members; facilities of most of the laboratories in Mechanical Engineering Department to be utilized. Lectures to supplement laboratory experience. *G. A. Brown*

** Subject carries total credit of 8 units: 1–2–1 units to be spent in first term, 1–2–1 in second term.*

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2.672 *Engineering Projects*
Prereq.: 2.671
Year: U (2) 2–0–4
Engineering synthesis and design subject for all Mechanical Engineering seniors. This subject and 2.671 to play parallel and complementary roles. Major emphasis placed upon identification of critical problem areas in comprehensive engineering situations and upon interplay of the many disciplines required to reach acceptable solutions. No formal lectures. Small student groups to work on a few projects with advice of faculty members. Projects drawn from research and development activities and engineering practice of staff. *Griffith*

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*

2.711 *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*

2.721 *Graphical Concepts*
Prereq.: ——
Year: 1 (1, 2) 0–4–2
Graphical methods applied to the formation of concepts and their subsequent analysis. Freehand sketching and drawing as a means of recording and modifying initial ideas, both concrete and abstract, and as a means of analysis and communication. Problems and projects varying from term to term, chosen from various fields: design of mechanisms, optical systems, rocket solid propellants, switching circuits, computer programs, airplane shapes. Topics such as modern geometry, periodic functions, symbolic logic, graphical calculus, and information flow diagrams studied within this graphical framework. *Coons*

2.722 *Descriptive Geometry*
Prereq.: ——
Year: 1 (1, 2) 0–4–2
Representation of three-dimensional space relations by two-dimensional diagrams. Analysis of problems involving points, lines, planes, and surfaces into fundamental components. Development of methods of attack and of capacity to think in space terms. 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 (1, 2) 3–0–9
Study of newly emergent techniques for manipulation of large scale digital computers in connection with the design process. Graphical input and output programs with their influence on techniques of shape description. Mathematics and graphics of general curved surfaces, curve fitting, curve smoothing. Graphical and symbolic methods for communication of the logical structure of problem solutions. *Coons*

2.731 *Engineering Design*
Prereq.: 2.02; *2.30 or 2.301*; 2.861
Year: U (2) 3–3–6
Instruction and experience in the integrated aspects of creative design and design analysis. Design of novel device or system by each student; over-all concept and engineering competence equally stressed; evaluation of work by visiting experts from industry as well as academic staff members. Lectures devoted to comprehensive case studies illustrating the design process in energy conversion and control in electro-mechanical and fluid power systems, and computer utilization in design analysis and optimization, with the objective of demonstrating how rational design criteria are developed through application of fundamentals and correlation with experiments. *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 partici-

pating 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.: 2.01, 18.03
Year: U (1) *Arr.*
Comprehensive treatment of displacement, velocity, and acceleration in plane and space motion. Classical and modern higher analytical methods. Chebychef polynomials, matched points, and adjustable parameters. Classical geometry for synthesizing generator linkages and coupler-point curves. Modern nomographic synthesis of generator linkages. Modern space-linkage synthesis using complex variables and dual numbers. Computer programming techniques for optimizing modern kinematic solutions and for plotting them.
D. P. Adams

2.861 *Engineering Design and Manufacture*
Prereq.: ——
Year: U (1) 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 (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 and their statistical treatment. 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, McNamara*

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, McNamara*

2.905 *Physics of Fibrous Materials* (A)
Prereq.: 18.04
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, Morgan*

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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, Morgan*

2.911 ***Fiber Research Laboratory*** **(A)**
Prereq.: 2.905
Year: G (1) 0–6–2
Introduction to modern instrumentation of fiber research. Emphasis on statistical planning and analysis of experiments and on engineering interpretation of test mechanisms. Techniques of microscopy and photomicrography instrumentation for studying stress-strain relationships, high speed impact measurements, determination of sonic modulus, evaluation of mechanical aesthetic qualities, heat and fluid flow measurements, use of instrument components in design of measuring systems. *Backer, Morgan*

2.912 ***Fiber Research Laboratory*** **(A)**
Prereq.: 2.911
Year: G (2) 0–6–2
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, Morgan*

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, Andrews*

2.951 ***Industrial Practice***
Prereq.: ——
Year: U (S) 40 h.p.w.
2.952T ***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

3.00 ***Thermodynamics I***
Prereq.: 5.02, 8.02
Year: U (2) 4–0–6
Essential concepts of thermodynamics and their application to the behavior of metals and materials. The First Law of thermodynamics, thermochemistry, energy balances. Treatment of energies and enthalpies of reaction, transformation and solution. Energy balances of chemical processes. Introduction to the Second Law, entropy and chemical potential. *Elliott*

3.01 ***Heat and Fluid Flow***
Prereq.: 3.00, 18.04
Year: U (2) 4–3–6
Development of the fundamentals of transport phenomena. Energy and momentum relationships for fluid flow. Study of modes of heat transport in steady-state and transient phenomena. Laboratory experiments illustrating the principles and methods of measurement in fluid and heat transport and providing experience in solution of representative problems. *Meadowcroft*

3.02 ***Chemical Metallurgy***
Prereq.: 3.01
Year: U (1) 4–3–5
Fundamental treatment of important metallurgical processes according to stoichiometric, thermodynamic and kinetic principles. Gas-solid reactions, such as oxidation of metals and roasting of sulphides; reduction of metallic oxides in shaft furnaces and fluid beds. Slag-metal and slag-matte reactions in smelting. Gas-liquid processes such as converting, distillation, and halide reduction. Refining processes such as zone melting and solid phase precipitation; slag and salt-metal refining, vacuum melting, and degassing. Laboratory work to illustrate significant variables in actual processes and to measure thermodynamic quantities in related reactions. *T. B. King*

3.03 ***Process Metallurgy*** **(A)**
Prereq.: 3.02
Year: G (2) 3–0–6
Study of integrated metallurgical processes. Application of the fundamental treatment of 3.02 to the extractive metallurgy of the more common metals, such as iron, copper, zinc and aluminum, and of less common metals such as titanium, molybdenum, and chromium. *T. B. King*

3.09 ***Structure of Materials***
Prereq.: ——
Year: 1 (1, 2) 3–0–3
Lectures and demonstrations on selected topics of atomic, molecular, and crystal structure. Correlation of some physical and chemical properties with structure using common engineering materials as examples. *Wulff*

3.10 ***Structure and Properties of Materials Laboratory***
Prereq.: 3.09
Year: 1 (1, 2) 1–2–3
Laboratory experiments planned and conducted for small groups of students relating a limited number of chemical and physical properties of metals, ceramics, and polymers to atomic, molecular, and crystal structure. *Wulff*

3.11 *Introduction to Solids*
Prereq.: 5.02, 8.02
Year: U (1) 3–0–5
Universality of crystalline solids; reasons for crystallinity. Interatomic forces and various types of bonding. Criteria for packing in crystals; relationships between bonding and crystal structure. Dependence of electrical conductivity, semiconductivity, magnetic properties, and other physical properties on structure and bonding. Brief systematic approach to the geometry of crystals. Methods of crystal growth. Crystal defects and their effects on the physical properties of solids. *Gatos*

3.12 *Materials Processing*
Prereq.: 3.14 or 3.31
Year: U (2) 3–3–6
Basic principles of shaping and treating metallic, ceramic, and polymeric materials with emphasis on the physical laws underlying those patterns of behavior which cut across many phases of processing. Consideration of economics, innovation, and design of product and operation, as related to choice of process and trends in processing. Application of theory to problems of practice. Relationships of structure, composition, and properties of materials to the making of useful shapes and devices. Complementary to other specific or comprehensive courses in engineering materials and materials science. Laboratory investigations of engineering problems in industrially important processing operations. *C. M. Adams, Backofen, Flemings*

3.13 *Solidification Processing* (A)
Prereq.: 3.14 or 3.31
Year: G (1) 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*

3.14 *Engineering Materials*
Prereq.: 5.02, 8.02
Year: U (1, 2) 4–2–4
Principles underlying the structure, properties, and behavior of materials used in structures and devices. Topics discussed include atomic arrangements and imperfections in crystalline and noncrystalline phases; equilibrium and nonequilibrium phase relationships in one-, two- and three-component systems; kinetics of nucleation, diffusion and phase transformations; elasticity, microplasticity and fracture; corrosion. Correlation of structure with properties in the development of the above subject matter in which metallic, ceramic, and polymeric materials are used. Laboratory work on the common techniques used in the study of structure and measurement of properties. *Wulff, Flemings*

3.15 *Welding Engineering* (A)
Prereq.: 3.14 or 3.31
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*

3.16T *Statistical Thermodynamics of Materials*
Prereq.: 3.20
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*

3.18 *Deformation Processing*
Prereq.: 2.01; 3.14 or 3.31
Year: U (1) 3–0–6
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 too-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*

3.20 *Thermodynamics II*
Prereq.: 3.00
Year: U (1) 4–0–4
Basic laws of thermodynamics. Application of these laws to the analysis of the physical and chemical behavior of metals and other substances. Emphasis on the use of free energy relationships, enthalpies, heat capacities, entropies, activities, etc. in treating phase transformations, chemical equilibria, metallic solutions, and electrochemical phenomena. *C. M. Adams*

3.21 *Thermodynamics in Metallurgy* (A)
Prereq.: 3.20
Year: G (1) 4–0–6
Advanced treatment of the thermodynamic properties of metallurgical systems. Free energy relations among compounds of metals. Properties of substitutional, interstitial, and liquid metallic solutions. Reactions of metals with metallic compounds, gases, slags, and refractories. *Elliott*

3.24 *Thermodynamics in Process Metallurgy* (A)
Prereq.: 3.02, 3.21
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*

3.26 *Kinetic Problems in Metallurgy* (A)
Prereq.: 3.20, 3.31
Year: G (2) 3–0–6
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. *Coble*

3.31 *Materials Science I*
Prereq.: 5.02; 8.04 or 8.041; 18.04
Year: U (1) 4–3–5
Principles underlying the properties and behavior of materials which make them useful in structures, machines, and devices, including atomic arrangements and imperfections in crystalline and noncrystalline phases; equilibrium and nonequilibrium phase relationships in

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one-, two-, and three-component systems; elasticity, microplasticity, and fracture; recovery, recrystallization, and grain growth; mechanisms and kinetics of diffusion and phase transformations; chemical behavior and corrosion. Introduction of metallic, ionic, and polymeric materials to correlate structure with properties in illustrating the above subjects. Laboratory experiments on some of the basic techniques for revealing the essential nature of real materials. *M. Cohen*

3.32 *Physical Metallurgy*
Prereq.: 3.14 or 3.31
Year: U (2) 3–3–6
Extension of the principles of materials science to the metallic state; nucleation and growth; diffusion-controlled and diffusionless transformations; heat treatment and hardenability; thermal and transformation stresses; relaxation processes; continuous and discontinuous yielding; shear and cleavage fracture; quench aging and strain aging; engineering alloy systems. Laboratory experiments planned and conducted by the students in small groups, providing introduction to research in physical metallurgy; emphasis on report writing, in cooperation with the Department of Humanities.
M. B. Bever, M. Cohen

3.33 *Applied Physical Metallurgy*
Prereq.: 3.32
Year: U (2) 2–4–4
Factors affecting mechanical, chemical, and physical behavior of materials in service. Property, processing, and economic considerations in materials selection. Laboratory on commercial metals and alloys, with emphasis on microstructures and their interpretation. Classes of alloys; examination of normal and defective materials. *Grant*

3.34 *Advanced Physical Metallurgy* (A)
Prereq.: 3.20, 3.32, 3.50
Year: G (1) 4–0–8

3.35 *Advanced Physical Metallurgy* (A)
Prereq.: 3.34
Year: G (2) 4–0–8
Advanced treatment of important subjects within the general field of physical metallurgy, including application of generalized thermodynamics to metallic systems, thermodynamic aspects of deformation processes, thermodynamics of solid solutions, atomic arrangements in solid solutions, diffusion, nucleation and growth, phase transformations (precipitation, eutectoid decomposition, martensitic reactions, order-disorder transitions), dislocation theory, grain boundary phenomena, recrystallization and grain growth, crystal elasticity and plasticity, anelastic phenomena. The more recent publications covering these topics. *M. B. Bever, Cahn*

3.391 *Properties of Metals*
Prereq.: ——
Year: G (1) 3–1–3

3.392 *Properties of Metals*
Prereq.: 3.391
Year: G (2) 3–1–3
Properties of metals with reference to materials used in ship construction. Microstructure, processing, heat treatment, joining and corrosion resistance of nonferrous and ferrous metals. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Floe*

3.396 *Nuclear Metallurgy and Radiation Damage*
Prereq.: 3.14 or 3.31 or 3.391
Year: G (1) 2–0–4
Physical and nuclear requirements, metallurgical properties and production of fuel, moderator, and control materials used in nuclear reactors. Macroscopic and microscopic effects of high energy radiation damage in metal and ceramic reactor materials. *Ziebold*

3.42 *Electrochemistry* (A)
Prereq.: 5.62
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*

3.43 *Corrosion* (A)
Prereq.: 3.20
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 protection; metallic, inorganic and organic coatings; inhibitors; treatment of water and steam systems; selection of materials. *Uhlig*

3.44 *Behavior of Metals at Elevated Temperatures* (A)
Prereq.: 3.32
Year: G (2) 2–0–4
Study of metal and alloy behavior at temperatures at or above the recrystallization temperature (or equi-cohesive temperature). Correlation of alloy preparation variables with the structure and properties of the alloy. Study of the pertinent binary systems prominent in heat resistant alloys. Quantitative evaluation of the present heat resistant alloy field. *Grant*

3.46 *Electronic Materials* (A)
Prereq.: 3.51 or 5.62 or 6.08 or 8.07
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*

3.50 *X-ray Metallurgy*
Prereq.: 3.31
Year: U (1) 2–2–4
Theory of X-ray production, absorption, and diffraction. Detailed treatment of these topics for application to study of atomic structure of materials. *Ogilvie*

3.51 *Materials Science II*
Prereq.: 3.14 or 3.31; 5.63 or 8.051
Year: U (2) 4–3–5
Consideration of atomic, molecular and lattice properties by methods of quantum physics. Topics included: experimental basis of quantum mechanics, electron energy levels in free atoms and in molecules, three-dimensional packing, free-electron models, atomic vibrations, normal modes, elastic constants, potential functions, lattice energies, specific heat, thermal conductivity. Laboratory experiments in particle scattering, atomic spectra, X-ray diffraction. Student use of digital computer in solving problems and in handling experimental data.
Averbach, Kaplow

3.52T *Electron Optics*
Prereq.: 3.31
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*

3.53T ***Advanced X-ray Metallurgy*** **(A)**
Prereq.: 3.50
Year: G (2) 1–3–2
More detailed treatment of principles discussed in 3.50. Short research projects that deal with the study of particle size, strain, phase diagrams, diffusion, hardening and related topics carried out in the laboratory. *Ogilvie*

3.54 ***Physics of Solids I***
Prereq.: 3.51
Year: G (1) 4–3–5
Electron statistics, crystal structure, reciprocal space, three-dimensional periodic potentials and electron energies. Band structure and Fermi surfaces from theoretical and experimental approaches. Techniques of self-consistent calculations. Laboratory including a research project and use of digital computer for theoretical and experimental problems. *Averbach, Moss*

3.55 ***Physics of Solids II***
Prereq.: 3.54
Year: G (2) 4–3–5
Electrical, magnetic and optical properties of solids by methods of quantum physics and transport theory. Considerations of statistical thermodynamics. Interaction between radiation and matter. Laboratory involving an extended research problem. Computer calculations combined with lectures and laboratory. (*Not offered 1964–65.*) *Averbach*

3.62 ***Special Problems in Metallurgy*** **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Minor investigation in one of the special branches of metallurgy. (*Open only to graduate students properly qualified in the special field.*) *Staff*

3.63 ***Applications of Digital Computers***
Prereq.: 18.04
Year: G (1) 2–1–4
Programming and use of I.B.M. 7094. Instruction in Fortran programming and digital computation techniques using examples of analysis useful in metallurgical and solid-state research. Series expansion, integration, table look-up and interpolation, iterative solutions, matrix operations, least square fitting, Fourier transforms, solution of differential equations, simple Monte Carlo problems, and examples of specific theoretical calculations and data reductions. *Kaplow*

3.70 ***Ceramics***
Prereq.: 5.02, 8.04
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*

3.701 ***Ceramics Laboratory***
Prereq.: 3.70
Year: U (2) 0–3–0
Laboratory work to accompany 3.70 with commercial processes carried out on a small scale. *Kingery*

3.71 ***Ceramics Seminar*** **(A)**
Prereq.: 3.70 or 3.76
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. *Coble*

3.73 ***Ceramic Processes*** **(A)**
*Prereq.:*3 .70
Year: G (1) 3–0–6
A brief treatment of the phenomenological theory of transport processes. Application of these concepts to ceramic processes including vapor deposition, nucleation and crystal growth in viscous liquids, mixing in continuous flow systems, annealing, thermal and chemical tempering of glass, sintering and hot pressing, particle size control, and other subjects. *Coble*

3.75 ***Special Problems in Ceramics*** **(A)**
Prereq.: 3.70 or 3.76
Year: G (1, 2) *Arr.*
Advanced work in this field. Lectures, conferences, assigned readings, and laboratory work. *Kingery*

3.76 ***Physical Ceramics I***
Prereq.: 3.31
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*

3.79 ***Physical Ceramics II*** **(A)**
Prereq.: 3.76
Year: G (2) 3–0–6
Discussion of effects of composition and microstructure on properties. Treatment of various subjects concerned with the thermal, mechanical, and optical properties of ceramic products, including recent publications on these topics. *Kingery*

3.791T ***Physical Ceramics III*** **(A)**
Prereq.: 3.79
Year: G (1) 3–0–6
Electrical and magnetic properties of ceramic products as related to composition and microstructure, including recent publications on these topics. *Coble*

3.81 ***Principles of Materials Separation***
Prereq.: 3.00
Year: U (2) 4–3–5
Separation of materials in solid, liquid, or gaseous form according to bulk or surface properties. Movement in fluids, mass transfer, and chemistry of solutions and surfaces. Consideration of physical separations according to size, density, surface characteristics, magnetic, electrical, and kinetic phenomena. Chemical separations include adsorption, solution, precipitation, distillation, segregation, solvent extraction, and electrolysis. Principles applied to representative processes. Laboratory work using real materials and separation techniques. *de Bruyn, Witt*

3.82 ***Mineral Engineering***
Prereq.: 3.81
Year: U (1) 3–2–5
Principles discussed in 3.81 applied to problems in mineral engineering. Physical and chemical separation processes such as classification, filtration, flotation, leaching, and ion exchange. Laboratory exercises. *Gaudin, Witt*

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3.86 ***Quantitative Mineragraphy*** **(A)**
Prereq.: 3.81
Year: G (1) *Arr.*
Advanced subject in mineragraphy in which the quantitative approach is stressed. *Gaudin*

3.89J ***Physics and Chemistry of Surfaces*** **(Same subject as 10.61J)**
Prereq.: 5.62
Year: U (1) 3–0–6
Thermodynamic, structural, and kinetic factors underlying surface and interfacial phenomena. Molecular aspects of phase boundaries, intermolecular forces, and origins of surface tension. Capillarity and related phenomena. Thermodynamics of surfaces: surface activity, adsorption, and orientation at interfaces. Spreading, wetting, adhesion, and related processes. Electrical phenomena at interfaces, origins of surface potential, structure of the diffuse double layer, electrocapillarity. Survey of the importance of surface phenomena in processes such as flotation, detergency, corrosion, and catalysis. *de Bruyn, Michaels*

3.90 ***Structure and Properties of Interfaces*** **(A)**
Prereq.: 3.20 or 5.71; 5.62
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*

3.901 ***Advanced Mineral Dressing Laboratory*** **(A)**
Prereq.: 3.81
Year: G (1) *Arr.*
Study of an ore, a process, or a machine in the field of mineral dressing. *Gaudin*

3.91 ***Materials Separation Processes*** **(A)**
Prereq.: 3.02, 3.81
Year: G (1) 2–0–4
Critical study of integrated processes of materials separation, particularly in the areas of extractive metallurgy and mineral engineering. Flow sheet design. Economic considerations in process and plant design. *Gaudin*

4.
Architecture and Planning

4.011 ***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*

4.021 ***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*

4.021 ***Form and Design***
Prereq.: ——
Year: U (1, 2) 2–4–4
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*

4.022 ***Form and Design***
Prereq.: 4.021
Year: U (1, 2) 2–4–4
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*

4.03 ***Form and Color***
Prereq.: 4.022
Year: U (1, 2) 2–0–4
Study of the modifying conditions of hue, value, and chroma in relation to shape, volume, and structure, to understand and control the visual influence of color upon designed three-dimensional configurations. 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*

4.031 ***Visual Design Problems***
Prereq.: ——
Year: U (1, 2) 2–6–0
Studio participation in problems of visual invention, organization, and expression as a means of gaining confidence and ability to create visual form. 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 art. Seminars and demonstrations related to studio problems to encourage perceptual awareness, discrimination, and analysis of non-verbal experience. *Preusser*

4.032 ***Visual Design Projects***
Prereq.: 4.031
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*

4.033T *Creative Photography*
Prereq.: ——
Year: U (1, 2) 2–6–0
Development of visual awareness and creative capacity through the practice of photography. Use of the camera as both analytical tool and medium of expression in visual design. 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. ——

4.04 *Light and Color*
Prereq.: 4.022
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*

4.06 *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*

4.121T *Architectural Design*
Prereq.: ——
Year: U (1) 2–7–7
4.122T *Architectural Design*
Prereq.: 4.121T
Year: U (2) 0–9–7
Use of small-scale problems of familiar subject matter to establish the basic concepts of architectural order through harmonious relationships between use and form, building and land, structure and space, materials and appearance. Emphasis on acquisition of skill in the conventional methods of representing architectural form with orthographic, perspective, and freehand drawing and by models. *Staff*

4.131 *Architectural Design*[1]
Prereq.: 4.122T
Year: U (1) 0–9–9
4.132 *Architectural Design*[1]
Prereq.: 4.131
Year: U (2) 0–9–9
A series of projects for simple buildings, to develop, as rapidly as possible, awareness of the principal issues facing the contemporary architectural designer and the range of possibilities available to him for effective satisfaction of the common environmental needs of our culture. Work on separate building units with definitely stated use patterns with ample opportunity for experimental study of appropriate structural systems and search for the uses of building materials most expressive of their physical properties. *Staff*

4.141 *Architectural Design*[1]
Prereq.: 4.132, 4.32T
Year: U (1) 0–12–8
4.142 *Architectural Design*[1]
Prereq.: 4.141
Year: U (2) 0–12–8
Introduction of problems arising in connection with more complex plan organization, the grouping of buildings, buildings of multistory construction, mass circulation movements, and areas requiring specialized space forms or equipment or having multiple uses. Consideration of the thermal problems of buildings, the distribution of daylight and artificial light, and the control of sound in buildings as they influence the design concepts and also in the material and special installations associated with them. *Staff*

4.151 *Architectural Design*[1]
Prereq.: 4.142
Year: U (1) 0–12–8
Final term of design with emphasis on the setting of architectural work as part of an organized community in projects having to do with built-up areas as well as those on new sites. Study of plans for long-range development giving students increasing experience in the analysis of real-life situations requiring program research. *Staff*

4.153 *Thesis Research*
Prereq.: 4.142
Year: U (1, 2) 0–6–0
Selection of subject and site for undergraduate thesis project and determination of the requirements and conditions to be met in the solution. Independent work under the guidance of the Thesis Committee. *Staff*

4.161 *Architectural Design* (A)[1]
Prereq.: 4.151
Year: G (1) 0–15–15
4.162 *Architectural Design* (A)[1]
Prereq.: 4.161
Year: G (2) *Arr.*
Concentration of project work on areas of architectural expression which have been most inadequately resolved in contemporary urban life, with the aim of orienting the mature student toward a serious contribution to some of these problems. Exploration of the full implications of the subject under study through organized group research and seminar activity leading to individual and team solutions. *Staff*

4.163 *Thesis Research* (A)
Prereq.: 4.161
Year: G (1, 2) 0–6–0
Selection of subject for graduate thesis project and preparation of a program to guide the design phase of the thesis. Independent work under the guidance of the Thesis Committee. *Staff*

4.17 *Architectural Design, Special Problems*
Prereq.: ——
Year: U (1, 2) *Arr.*
Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff. *Staff*

[1] ***A note about the subjects in Architectural Design***
The sequence of undergraduate subjects in Architectural Design provides cumulative experience with a large number of design problems, ranging over the whole field of architectural practice. In general, each problem is presented as a design situation in a complete context; it requires an evaluation of all pertinent factors of site, climate, purpose and social setting, and provides scope for the application of the student's growing knowledge of materials and building techniques, his skill in arranging space, his sense of relative values, and his artistic sensitivity.

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4.18 *Collaborative Design* (A)
Prereq.: 4.142 or 4.261
Year: G (1) 0–12–12
Project work on design problems which will benefit from collaboration between architects and city planners or between these groups and other disciplines. *Staff*

4.19 *Special Problems in Architectural Design* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Supplementary design work for graduate students. Registration subject to prior arrangement for subject matter and supervision by staff. *Staff*

4.233 *Representation*
Prereq.: ——
Year: G (1) 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*

4.241 *Community Planning Design*
Prereq.: 4.233, 4.53
Year: G (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*

4.261 *City and Regional Planning* (A)
Prereq.: 4.241
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*

4.262 *Problems in City Planning* (A)
Prereq.: 4.261
Year: G (1) 0–8–12
Advanced problems in city planning, including pioneering studies and studies in specialized areas. *Staff*

4.263 *Problems in Urban Design* (A)
Prereq.: 4.18, 4.261
Year: G (2) 0–12–12
Advanced problems in planning for the visual form of the environment at the scale of cities or regions. *Lynch*

4.264 *Problems in Regional Planning* (A)
Prereq.: 4.56, 4.84, 4.86
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. *Friedmann*

4.30 *Structures I*
Prereq.: 8.02, 18.02
Year: U (2) 3–3–4
Loads and forces, interactions and static equilibrium. Behavior of structures as a whole under load; determination of reactions. Stresses in internal members of planar and three-dimensional structures. Definition of stress and strain. Transverse loading of beams; shears, moments, deflections. Simple and continuous beams, simple structures. Models to demonstrate concepts of load, deformation, reactions, moments, internal stresses, and behavior of planar and three-dimensional structures. *Staff*

4.31T *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. ——

4.32T *Structures III*
Prereq.: 4.31T
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. ——

4.33T *Structures IV*
Prereq.: 4.32T
Year: U (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*

4.34T *Structures V*
Prereq.: 4.33T
Year: U (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*

4.35 *Structures Seminar*
Prereq.: ——
Year: G (1) 2–0–4

4.36 *Structures Seminar*
Prereq.: ——
Year: G (2) 2–0–4
Comparative analytical study of those properties of structural systems and materials which should find a characteristic and clear formal expression in contemporary architecture. (*Restricted to graduate students; others by permission of instructor.*) *Weidlinger*

4.40J *Building Process*
(Same as 1.92J)
Prereq.: ——
Year: U (1) 3–3–4
Analysis of the building process as influenced by structure, environment, and materials and by social, legal, and industrial processes. Evolution of building systems and detailed examination from both functional and expressive possibilities. Elements of environmental control and site factors. Primarily an 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 of interest in building. Principles underlying 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. Selected laboratory exercises and projects. *Dietz*

4.42 *Materials*
Prereq.: 8.02
Year: U (2) 3–2–3
Emphasis on organic materials of construction. Growth of wood and its influence on micro- and macro-structure. 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. Basic 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, principles of fabric structure, engineering and aesthetic qualities of fabrics. Selected 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. *Staff*

4.47 *Site Planning*
Prereq.: ——
Year: G (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, Myer*

4.49 *Industrialization and Design* (A)
Prereq.: ——
Year: G (1) 2–2–4
Architectural design of single and multi-family housing, considered in the light of production problems in the industries producing basic materials, prefabricated dwellings, and new site developments. Improvements in design consistent with the conditions imposed by mass production. Seminars, evening discussions, field trips, reading, preparation of papers and sketches. (*Limited registration.*) *C. Koch*

4.51 *Introduction to City and Regional Planning*
Prereq.: ——
Year: G (1) 1–0–2
Objectives and scope of comprehensive physical planning as applied to urban and rural areas. Basic concepts and theories of planning. Examples of comprehensive plans for cities and regions. (*Not offered 1964–65.*) *F. J. Adams*

4.53 *Components of the Urban Environment*
Prereq.: ——
Year: G (1) 3–0–6
Physical nature and characteristics of the urban environment and its component parts. Land uses for residences, commerce, industry, institutions, etc. Circulation elements: streets, expressways, transit, parking. Physical structure and relationship of parts of city and regional development. *J. T. Howard*

4.54 *City Planning Techniques*
Prereq.: 4.53
Year: G (2) 3–0–6
Survey, analysis, and design methods and practices in comprehensive planning: population and economic development, land use, circulation, other components of the city or metropolitan general plan; relationship of planning to implementation techniques, zoning, urban renewal, etc. *J. T. Howard*

4.55 *City Planning Administration* (A)
Prereq.: 4.54
Year: G (1) 2–0–4
Methods and practices of planning and implementation; organization of planning agencies, relationships to government and private operations; techniques of administration. *Oppermann*

4.56 *Resource Problems and Policies*
Prereq.: 4.81
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. *Friedmann*

4.571 *Urban Landscape* (A)
Prereq.: 4.121T or 4.53
Year: G (1) 2–0–4
The city and its components as aesthetic elements. Role of plan organization, spatial relations, symbol, silhouette, scale, view, movement, light, color, sound, detail, etc. Presentation through field observation, group projects, and seminar discussion. *Lynch*

4.572 *City Design* (A)
Prereq.: 4.571
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*

(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.

4.58 *Theory of City Form* (A)
Prereq.: 4.54
Year: G (1) 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.*) ——

4.59 *Theory of the Planning Process* (A)
Prereq.: 4.54
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*

4.601 *Introduction to the Visual Arts I*
Prereq.: ——
Year: U (1) 3–0–5
Introduction to the major media of artistic expression. Discussion of form in painting, sculpture, architecture, and related arts from the early Near Eastern civilizations to the Renaissance. Analysis of problems and environmental conditions facing the artist. Purpose: to develop the student's visual perception, expose him to methods of visual analysis, and provide a historical framework for understanding past and contemporary artistic achievements. Lectures, group conference, and museum visits. *Andersen*

4.602 *Introduction to the Visual Arts II*
Prereq.: ——
Year: U (2) 3–0–5
Same as 4.601, but covering the period from the Renaissance to the present day. *Andersen*

4.603 *Classical Tradition in America*
Prereq.: ——
Year: U (1) 3–0–5
Study of the Fine Arts in the period of transformation from colony to nation. Analysis of the changing political, social, and economic requirements of a new society; emphasis on art, architecture, and town planning. *Kirker*

4.604 *Romantic Tradition in America*
Prereq.: ——
Year: U (2) 3–0–5
Social history of the Fine Arts from the Age of Jackson to the present. Emphasis on the problem of artistic excellence in a democracy as well as the critical evaluation of the results of advanced technology and mass production. *Kirker*

4.605 *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. The Fauve style to 1908; Picasso and Cubism to ca. 1915. Required readings from letters and other writings by the artists, their artist and writer friends, and their critics. *Andersen*

4.606 *Sculpture in the Twentieth Century*
Prereq.: ——
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. *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*

4.62 *Architecture 1400-1750*
Prereq.: ——
Year: U (2) 3–0–5
Analysis of role of mass, space, structure, light, surface, and related social, political, and economic factors in architecture and urban design from the beginning of the Renaissance to the beginning of modern times. *Millon*

4.63 *Architecture in the Middle Ages*
Prereq.: ——
Year: U (1) 3–0–5
Analysis of mass, space, structure, light and surface in 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
Analysis of mass, space, structure, light and surface in selected buildings and urban complexes from the mid-eighteenth century to the present. Special attention given to the influence on the architect of architectural traditions as well as significant social, political and economic factors. *S. Anderson*

4.641 *Modern Architecture in Germany from 1895 to the Bauhaus*
Prereq.: ——
Year: U (2) 3–0–5
Architecture in Germany between 1895 and the closing of the Bauhaus in 1933. Intensive study of the men, the buildings, and the controversies from which the new architecture emerged and that shaped the conversion of American architecture to the image and ideals of the European "Modern Movement." Included in the subject: such architects as Wagner, Loos, van de Velde, Behrens, Poelzig, Gropius, Bruno Taut, Mies van der Rohe, van Doesburg, Mendelsohn, Häring, Höger, May, Stam, and Hannes Meyer; such organizations as the Viennese *Sezession*, the *Werkbund*, and the *Bauhaus;* and such historical concepts as the "International Style." *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. Successive consideration of three kinds of topics: exposition of general problems in the theory of knowledge, extension of these problems and theories to the field of architecture, 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*

4.67 *History of Urban Form* (A)
Prereq.: 4.61, 4.62, 4.63, 4.64
Year: G (2) 3–0–5
History of the city as an architectural form. Study of the physical growth of cities as an expression of a developing social structure as well as with reference to artistic ideals. *Staff*

4.68 *Selected Topics in the History of Art and Architecture* (A)
Prereq.: 4.602; 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.: 4.602; 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. Range of subjects from the work of an individual to the artistic production of an age or the history of a single significant building. *Staff*

4.701 *Urban Social Structure and Process*
Prereq.: ——
Year: G (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*

4.702 *Seminar on Urban Social Structure*
Prereq.: 4.701
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*

4.705 *Urban Planning and Social Policy* (A)
Prereq.: 4.241, 4.701
Year: G (1) 2–0–6
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*

4.71 *Law of Land Use* (A)
Prereq.: 4.54
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, Sullivan*

4.74 *Methods of Research in City Planning* (A)
Prereq.: 4.53
Year: G (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*

4.77 *Housing Problems*
Prereq.: 4.53 or 4.81 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 1964–65.*) *Rodwin*

4.78 *Housing Seminar* (A)
Prereq.: 4.77
Year: G (2) 2–0–6
Open to a limited number of students who have taken 4.77 or have the equivalent experience or background. Examination of selected housing problems and research topics. Extensive readings and written reports. *Abrams*

4.81 *City Structure and Economic Development*
Prereq.: ——
Year: G (1) *Arr.*
Economic, social, and technological factors which affect the functions and physical environment of the city and region; analytical techniques for evaluating urban, intrametropolitan, and inter-regional characteristics; an evaluation of the issues posed by national policy for urban and regional development. *Rodwin, Friedmann*

4.82 *Land Economics Seminar* (A)
Prereq.: 4.81
Year: G (2) 2–0–6
Intensive analysis of techniques for regional economic studies and of the historical development of land system and policy in the United States. Two reports by each student dealing with an economic base study, a regional land problem, or the implications for land use of a normative theory of urban organization. (*Not offered 1964–65.*) *Abrams*

4.84 *Metropolitan and Regional Planning in Developing Countries* (A)
Prereq.: 4.81
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. (*Not offered 1964–65.*) *Rodwin*

4.85 *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 of real estate and buildings — with emphasis on low-cost housing. *Abrams*

4.86 *Programming for Urban and Regional Development* (A)
Prereq.: 4.54, 4.74, 4.81
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. *Friedmann*

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4.861 ***The Urban Transportation Problem*** **(A)**
Prereq.: 4.53, 4.81
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*

4.862 ***Transportation and Urban Form*** **(A)**
Prereq.: 4.53, 4.81
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*

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 ***General Chemistry***
Prereq.: ——
Year: 1 (1) 4–2–5
Fundamental principles of chemistry: gas laws; mass and energy relationships in chemical changes; writing and the use of chemical equations for quantitative calculations; factors affecting the rate and equilibrium of a chemical reaction; correlation of equilibrium conditions through the mass-action law and the electromotive force of voltaic cells; atomic structure, chemical reactivity of elements, and the Periodic Table; chemistry of certain of the elements of groups 1, 2, and 3 of the Periodic Table. Laboratory work largely quantitative in nature and integrated with lectures and recitations. *Stephenson*

5.02 ***General Chemistry***
Prereq.: 5.01
Year: 1 (2) 4–2–5
Application of chemical principles to the correlation of the chemical behavior of the common elements; stability of the various oxidation states; chemistry of the ionic species; quantitative application of the principles of equilibrium to chemical reactions; structural chemistry of crystals and of molecules; acid-base systems; introduction to the chemistry of carbon; nuclear reactions. Laboratory work emphasizing chemical properties of the elements in aqueous solution. Use of facts and principles to develop a scheme for the qualitative separation of the elements. Analysis of unknown mixtures. *Gamble*

INORGANIC CHEMISTRY
Undergraduate Subjects

5.03 ***Principles of Inorganic Chemistry I***
Prereq.: 5.02, *5.42, 5.61*
Year: U (1) 2–0–4
Presentation of the theoretical principles of chemical bonding and molecular structure, and their application in a survey of the chemistry of all the elements of the periodic system. Emphasis on the lighter nontransition elements. *Cotton*

5.04 ***Principles of Inorganic Chemistry II***
Prereq.: 5.03, 5.62
Year: U (2) 2–0–4
Theory and descriptive material relating to the heavier elements and the transition elements. Special emphasis on ligand field theory. (*Must be taken in the term following 5.03.*) *Davison*

INORGANIC CHEMISTRY
Graduate Subjects

5.065 ***Advanced Inorganic Chemistry*** **(A)**
Prereq.: 5.04
Year: G (1) 2–0–4
Extended treatment of special topics of current interest in modern inorganic chemistry, e.g. organometallic compounds, 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 1964–65.*) *Cotton*

5.09 ***Radiochemistry*** **(A)**
Prereq.: 5.62
Year: G (1) 3–0–3
Introduction to nuclear science and chemical aspects of the nuclear energy industry. Chemistry of production, isolation, and identification of radioactive atoms, and techniques of preparation and measurements of radioelements. Applications of radiotracers to chemical problems. *Coryell, G. E. Gordon*

5.091 ***Radiochemistry Laboratory*** **(A)**
Prereq.: 5.09
Year: G (1) 0–3–2
Laboratory study of special topics including radiochemical analysis, the fission process, and the reactions following nucleogenesis. *Coryell, Irvine*

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, ion exchange, solvent extraction, etc. *G. E. Gordon*

ANALYTICAL CHEMISTRY
Undergraduate Subjects

5.14 *Analytical Chemistry I*
Prereq.: 5.41
Year: U (2) 3–0–3
Principles of quantitative separations and determinations. Application to the determination of inorganic constituents and organic functional groups. Practice in stoichiometrical calculations. *Biemann, Hercules, Roe*

5.141 *Analytical Chemistry Laboratory I*
Prereq.: 5.14
Year: U (2) 1–8–0
Application of volumetric and gravimetric methods to the determination of typical inorganic constituents and organic functional groups. Introduction to potentiometry, colorimetry, and flame photometry. *Biemann, Hercules, Roe*

5.142 *Analytical Chemistry Laboratory I*
Prereq.: 5.14
Year: U (2) 1–4–0
Abridgement of 5.141. *Biemann, Hercules, Roe*

5.16 *Analytical Chemistry II*
Prereq.: 5.14, 5.141, 5.61
Year: U (1) 3–0–3
Instrumental analysis. Theory and application of modern optical and electrical instruments in the solution of chemical problems. Basic electronics. Polarography, potentiometry, and conductometry, ultra-violet, visible and infra-red spectro-photometry; colorimetry, light scattering, fluorimetry, flame photometry, gas chromatography, and automatic instruments. *Hercules, Roe*

5.161 *Analytical Chemistry Laboratory II*
Prereq.: 5.16
Year: U (1) 1–4–2
Laboratory coordinated with the topics in 5.16. *Roe*

ANALYTICAL CHEMISTRY
Graduate Subjects

5.192 *Principles of Separation Methods* (A)
Prereq.: 5.14, 5.62
Year: G (2) 2–0–4
Survey of separation methods, including liquid-liquid extraction, ion exchange, volatilization, zone refining, and precipitation. Emphasis on chromatographic methods and relevant rate theories. Detailed consideration of the concepts of heterogeneous equilibria as applied to basic single and multi-stage partitioning processes. (*Alternate years.*) *Roe*

5.193T *Advanced Chemical Analysis* (A)
Prereq.: 5.14
Year: G (1) 3–0–6
Consideration of the principles pertinent to analytical methods based on chemical reactions, both organic and inorganic. Discussion of equilibrium, complex formation, nonaqueous solvents, oxidation-reduction systems, kinetic methods, and organic functional group analysis. (*Alternate years.*) *Biemann, Hercules*

5.194 *Design and Analysis of Experiments* (A)
Prereq.: 5.14
Year: G (1) 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 1964–65.*) *Hume*

5.195 *Selected Topics in Physical Methods of Analysis* (A)
Prereq.: 5.16
Year: G (2) 3–0–6
Discussion of the theory and applicatic of selected physical and instrumental methods, particularly in electrochemistry, spectrochemistry, mass spectrometry and magnetic resonance. Study of the following topics: interpretation of mass and resonance spectra; molecular electronic absorption and emission spectra; electrode reaction kinetics, electrode mechanisms, and electric double-layer theory. (*Alternate years. Not offered 1964–65.*) *Biemann, Hercules, Roe*

ORGANIC CHEMISTRY
Undergraduate Subjects

5.41 *Organic Chemistry I*
Prereq.: 5.02
Year: U (1) 4–0–4
Introduction to the chemistry of carbon compounds. Survey of the principal classes of aliphatic and aromatic compounds and their reactions. *Sheehan*

5.412T *Organic Chemistry Laboratory I*
Prereq.: 5.02, *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. *Kemp, Whitesides*

5.42 *Organic Chemistry II*
Prereq.: 5.41
Year: U (2) 4–0–4
Continuation of 5.41. Study of organic reactions, with emphasis on the relation between structure and reactivity. *F. D. Greene*

5.422T *Organic Chemistry Laboratory II*
Prereq.: 5.412T, *5.42*
Year: U (2) 1–5–1
Introduction to the literature of organic chemistry. Study of advanced preparations involving special techniques. (*Only for those intending to major in chemistry.*) *Kemp, Whitesides*

5.428 *Qualitative Organic Analysis*
Prereq.: 5.42, 5.422T
Year: U (1) 2–7–1
Identification of organic compounds, including current research techniques used for the determination of the structure of organic molecules. *House*

5.43 *Organic Chemistry III*
Prereq.: 5.42
Year: U (1) 2–0–4
Introduction to the theoretical interpretation of reactivity, reaction mechanisms and molecular structure of organic compounds. Application of theories of electronic structure, steric hindrance, and stereochemistry to ionic and free radical reactions, with emphasis on recent developments. *F. D. Greene*

5.44 *Organic Chemistry IV*
Prereq.: 5.42
Year: U (2) 2–0–4
Discussion and evaluation of general synthetic methods of organic chemistry; emphasis on isolation, characterization, and synthesis of products of biological significance (antibiotics, peptides, steroids, and alkaloids). *Sheehan*

(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.

ORGANIC CHEMISTRY
Graduate Subjects

5.51 ***Advanced Organic Chemistry: Synthesis*** **(A)**
Prereq.: 5.44
Year: G (2) 2–0–4
Organic reactions and the methods by which they are applied to synthetic problems in organic chemistry. *House*

5.53 ***Advanced Organic Chemistry: Techniques*** **(A)**
Prereq.: 5.42
Year: G (1) 2–0–4
Modern techniques for organic research, including spectroscopy, mass spectrometry, and chromatography. Application of modern techniques to purification and elucidation of the structure of organic molecules. *Berchtold*

5.54 ***Physical Organic Chemistry*** **(A)**
Prereq.: 5.43
Year: G (2) 2–0–4
Mechanism of representative organic reactions in homogeneous liquid systems. Kinetic and other physical methods useful in studying organic reactions. Types of experimental evidence upon which current theoretical interpretations of reactivity are based. *Swain*

5.55 ***Organic Chemistry: Natural Products*** **(A)**
Prereq.: 5.44
Year: G (1) 2–0–4
The chemistry and physiological action of natural products. Methods of isolation; determination of structures and synthesis. *Büchi*

PHYSICAL CHEMISTRY
Undergraduate Subjects

5.61 ***Physical Chemistry I***
Prereq.: 5.02, *8.03, 18.03*
Year: U (1) 4–0–4
First and second laws of thermodynamics; properties of solutions; phase equilibrium; chemical equilibrium and the third law of thermodynamics; ionic equilibria and voltaic cells. *Oppenheim*

5.613T ***Physical Chemistry Laboratory I***
Prereq.: 5.61
Year: U (1) 0–4–3
Coordinated with topics of 5.61. *Hammes, Kinsey*

5.62 ***Physical Chemistry II***
Prereq.: 5.61
Year: U (2) 4–0–4
Elementary kinetic theory and statistical mechanics; transport properties of gases and liquids; rates of chemical reactions. *Amdur*

5.623T ***Physical Chemistry Laboratory II***
Prereq.: 5.613T, *5.62*
Year: U (2) 0–4–3
Coordinated with topics of 5.62. *Hammes, Kinsey*

5.63 ***Physical Chemistry III***
Prereq.: 5.61, 18.04
Year: U (1) 4–0–4
Introductory quantum chemistry: elementary atomic spectra; particles and waves; wave mechanics; atomic structure and the Periodic Table; valence theory; experimental methods of determining molecular structure; structure of crystals and liquids; photochemistry.
J. S. Waugh

5.64 ***Structural Chemistry***
Prereq.: 5.02; *8.04* or *18.04*
Year: U (2) 3–0–5
Structure and bonding in molecules and crystals. Introduction to crystallography; nature of ionic, covalent, and metallic bonds; molecular and crystalline structure determination; relation of structure to chemical, mechanical, electrical, and magnetic properties. *D. P. Shoemaker*

5.68 ***Kinetics of Chemical Reactions*** **(A)**
Prereq.: 5.62
Year: G(2) 2–0–4
Experimental and theoretical aspects of advanced topics including: collision and transition state theories, homogeneous reactions in gas and liquid phases, enzymatic reactions, very fast reactions in solution, gas phase reactions in shock tubes and in molecular beams.
Amdur, Hammes

PHYSICAL CHEMISTRY
Graduate Subjects

5.70 ***Introduction to Statistical Thermodynamics*** **(A)**
Prereq.: 5.62
Year: G (1) 2–0–4
Elementary statistical mechanics, with applications to simple physical and chemical systems. *J. S. Waugh*

5.71 ***Chemical Thermodynamics I*** **(A)**
Prereq.: 5.62
Year: G (1) 2–0–4
Fundamental definitions and concepts; first and second laws of thermodynamics with applications to chemical systems, ideal and real gases, ideal and real solutions; partial molar quantities, chemical equilibrium; third law of thermodynamics and applications to chemical systems; free energy calculations. *Beattie*

5.72 ***Chemical Thermodynamics II*** **(A)**
Prereq.: 5.71, *18.05*
Year: G (2) 3–0–6
Development of the general thermodynamic theory from the first and second laws. Application of the theory to homogeneous and heterogeneous systems in which chemical reactions may take place. *Beattie*

5.74 ***Molecular Quantum Mechanics*** **(A)**
Prereq.: 5.75, *18.06*
Year: G (2) 3–0–6
Perturbation theory, variation method. Symmetry properties of wave functions. Theory of many-electron atoms and the self-consistent field; the central field approximation, Russell-Saunders coupling. One-electron theories of molecular binding, molecular orbital and valence bond theories. Hybridization, approximate methods for molecules, special topics. (*Alternate years.*) *Thorson*

5.75 ***Introductory Wave Mechanics*** **(A)**
Prereq.: 5.62, 8.04
Year: G (1) 2–0–4
Mathematical treatment of wave trains and wave packets; applications of the Schroedinger wave equation to simple and atomic and molecular systems, including use of the operator algebra; the variation method, with application to the hydrogen molecule ion. *L. Harris*

5.76 ***Molecular Spectra and Molecular Structure*** **(A)**
Prereq.: 5.75, 18.05
Year: G (2) 3–0–6
Rotational, vibrational and electronic spectra of molecules; use of spectra to find dissociation energies, force constants, inter-atomic distances, molecular symmetry

and related quantities; other techniques for study of molecular structure such as dipole moments, magnetic susceptibilities, and nuclear magnetic resonance. (*Alternate years.*) *Lord*

5.77 *Crystal Structure and the Chemical Bond* (A)
Prereq.: 5.75
Year: G (1) 3–0–6
Application of X-ray, electron and neutron diffraction to the determination of the structures of molecules and crystals. Interpretation of structural results in terms of modern theories of chemical binding. (*Alternate years.*) *D. P. Shoemaker*

5.78 *Statistical Mechanics* (A)
Prereq.: 5.70, 5.71, 5.75, 18.05
Year: G (2) 3–0–6
Introduction to the principles and methods of statistical mechanics. Classical and quantum statistics, grand ensembles, fluctuations, cooperative phenomena, molecular distribution functions, and other selected topics, with applications to gases, liquids and solids. (*Alternate years.*) *Oppenheim*

5.79 *Kinetic Theory* (A)
Prereq.: 5.71, 18.05
Year: G (1) 3–0–6
Fundamental concepts of the kinetic theory of gases. Properties of gases at low densities; transport phenomena in relation to molecular interactions; introduction to fluctuations and Brownian motion. (*Alternate years.*) *Amdur*

5.81 *Magnetic Resonance* (A)
Prereq.: 5.75, 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.*) *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. *Cope*

5.915 *Seminar in Analytical Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2
5.916 *Seminar in Analytical Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of topics of current interest in analytical chemistry by graduate students and staff members.
Biemann (5.915), 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. *Hammes*

5.941 *Seminar in Inorganic and Nuclear Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2
5.942 *Seminar in Inorganic and Nuclear Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of current research in inorganic and nuclear chemistry by graduate students and staff.
Seyferth (5.941), G. E. 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), Biemann (5.952)*

***Research* (A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Research for any of the advanced degrees in inorganic, analytical, organic, or physical chemistry. *Staff*

6.
Electrical Engineering

6.00J *Introductory Mechanics and Electromechanics*
(Same subject as 2.011J)
Prereq.: 8.031, 18.03
Year: U (1) 3–0–5
The concept of a continuum and continuum variables. Geometric variables and laws, force variables and laws, and the law of conservation of mass as used for continuua. Observed properties of real materials. Constitutive relations and examples for elastic solids and viscous fluids.
Haus, Kurtz

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

6.01 ***Introductory Circuit Theory I***
Prereq.: 8.037, 18.03
Year: U (1, 2) 4–0–8

6.013 ***Introductory Electric Circuit Theory***
Prereq.: 8.037, 18.03
Year: U (1) 4–0–8

6.02 ***Introductory Circuit Theory II***
Prereq.: 6.01
Year: U (2) 4–0–8

6.023 ***Electronic Devices and Circuits***
Prereq.: 6.013
Year: U (2) 4–0–8

Two-term sequence for students majoring in electrical engineering. Kirchhoff's laws, network equilibrium equations, algebraic and graphical solutions for resistive 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. Analysis of circuits containing simple nonlinearities, with emphasis on graphical and piecewise-linear methods. Control valves such as transistors and triodes and their description by circuit models. Power amplification by means of control valves, nonlinear energy storage elements, and negative resistance. Circuits exhibiting negative resistance and their role in oscillators. Examples of useful electronic circuits for linear and nonlinear processing of signals.
Bose, Stevens (6.01); Bose (6.013); Susskind, Kain (6.02, 6.023)

6.03 ***Electromagnetic Fields and Energy***
Prereq.: 6.02, 8.041, *18.05*
Year: U (1, 2, S) 4–0–8

6.033 ***Electromagnetic Fields and Energy***
Prereq.: 6.023, 8.041, *18.05*
Year: U (1) 4–0–8

Basic subject for undergraduates majoring in electrical engineering. Treatment of electromagnetism based on Maxwell's equations and built upon the work in second-year physics. Static and quasi-static fields; energy, power flow, and impedance; the field theory of circuit components. Transverse electromagnetic waves in steady state. *Morgenthaler*

6.05 ***Circuits, Signals, and Systems***
Prereq.: 6.02, *18.05*
Year: U (1, 2, S) 4–0–8

6.053 ***Circuits, Signals, and Systems***
Prereq.: 6.023, *18.05*
Year: U (1, 2) 4–0–8

Basic subject for students majoring in electrical engineering. Terminal behavior of linear circuits and systems. Impulse response, convolution, and superposition integrals. Complex frequency and system function. Fourier series and Fourier-Laplace integral representations for signals. Feedback systems and stability. Introduction to random signals and noise, correlation functions and spectra, modulation, and detection. *Siebert*

6.06 ***Fields, Forces, and Motion***
Prereq.: 6.02, 6.03
Year: U (1, 2, S) 3–0–6

6.063 ***Fields, Forces, and Motion***
Prereq.: 6.023, 6.033
Year: U (1, 2) 3–0–6

Required subject for electrical engineering students. Electromagnetic fields in the presence of moving material bodies, power flow, and energy conversion. General properties of lumped-parameter electromechanical models. Field theory of electromechanical systems containing rigid and elastic bodies and incompressible and compressible fluids. Hydromagnetic waves and their interaction with fields. *Woodson*

6.07 ***Energy Transmission and Radiation***
Prereq.: 6.03, 18.05
Year: U (1, 2) 3–0–6

6.073 ***Energy Transmission and Radiation***
Prereq.: 6.033, 18.05
Year: U (1, 2) 3–0–6

Basic subject for students majoring in electrical engineering. Elementary characteristics of oscillations and waves in one-, two-, and three-space dimensions, with reference to transmission and radiation problems in electrical engineering. Emphasis on steady-state and transient wave motion on transmission lines; time and frequency domain descriptions of resonance of distributed systems in terms of spatial field configurations and energy; uniform and non-uniform plane waves; radiation and reception of dipole antennas and simple arrays.
Barrett (6.07), Bers (6.073)

6.08 ***Molecular Engineering***
Prereq.: 8.051
Year: U (1, 2) 3–0–6

6.083 ***Molecular Engineering***
Prereq.: 8.05
Year: U (1, 2) 3–0–6

Core curriculum subject. Role of materials in electrical engineering from the viewpoint of thermodynamics and statistical mechanics. Thermodynamics of materials interacting with electric, magnetic, mechanical, and thermal fields; applications to energy storage, conversion, and control. Thermodynamic equilibrium; phase changes; chemical potential and Fermi energy. Connections to the microscopic models of physical systems; particle in a box; multiparticle systems. Statistics of simple systems; Fermi-, Bose-Einstein and Maxwell-Boltzmann statistics; partition function. "Derivation" of macroscopic material properties from microscopic models; ideal gas, electron gas; system of dipoles; phonon and photon gases. *Epstein (6.08), Blair (6.083)*

6.11 ***Project Seminar***
Prereq.: ——
Year: U (1) 2–0–4

6.12 ***Project Seminar***
Prereq.: ——
Year: U (2) 2–0–4

Special activity for students in Course VI Program 2. Study and evaluation of professional literature, oral presentation and active open discussion of topics drawn from and extending beyond those treated in the regular curriculum. Flexible organization, comprising a few students under guidance of a staff member. *Eden*

6.13 ***Electric and Magnetic Properties of Matter***
Prereq.: 6.03 or 6.033; 8.05 and 8.06 or 8.051
Year: U (1, 2) 3–0–6

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.: 8.031, 18.03
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. *Rafuse*

6.17 *Illumination*
Prereq.: 8.04
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

6.18 *Fundamentals of Electrical Engineering*
Prereq.: 8.03, 18.04
Year: U (1, 2) 3–2–5
Introductory subject for students not majoring in electrical engineering. Basic linear electric-circuit theory, elementary treatment of magnetic and dielectric materials and circuits, including energy and force relations, with applications to electromagnetic, electrostatic, and electromechanical components. Laboratory work to illustrate practical and theoretical questions considered in classroom. *Frazier, Kingsley*

6.20 *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. *Edgerton*

6.213 *Feedback Control Principles*
Prereq.: 6.05 or 6.18; 18.05
Year: U (1, 2) 3–2–5
An elective terminal subject for seniors. Theoretical background for analysis and synthesis of feedback control systems. Representation of physical systems by transfer functions and introduction to first-order vector differential equations representations. Stability theory. Frequency response. Exact and approximate methods for graphical representation of frequency response. The root-locus method. Analysis of the effects of feedback compensation techniques to improve performance. Study of nonlinear systems through the use of the describing function and the phase. Laboratory. *L. A. Gould*

6.214 *Feedback Control Laboratory*
Prereq.: 6.213
Year: U (1, 2) *Arr.*
Supervised investigation of special projects in feedback control system analysis and synthesis; laboratory investigations utilizing the facilities of the feedback control laboratory. Program and hours to be arranged with interested staff member, subject to approval of instructor.
L. A. Gould

6.216 *Dynamics of Electric Machines* (A, except for Course VI)
Prereq.: 6.01 or 6.18 or 6.42
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, *6.06*
Year: U (1 or 2) 3–0–6
Elective subject given by notable practicing engineers to show the whole problem faced by the engineer. May discuss economic, legal, and other non-technical aspects, as well as technical engineering. Faculty counselors to be consulted about availability, field, and instructor.
C. E. Tucker, 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*

6.25 *Digital System Application*
Prereq.: 6.05 or 18.05
Year: U (1, 2) 3–1–5
Information processing and retrieval. Short review of Boolean algebra and logical design. Computer system organization and capacity. Construction of programming languages for the specification of algorithms. Simulation of physical systems, discussion of numerical techniques, and control of error. Laboratory work on the TX-0 and IBM 7094 computers. *Teager*

6.251 *Digital Computer Programming Systems*
Prereq.: 6.41 or 6.45; 18.04
Year: U (1, 2) 3–2–7
Basic principles of programming systems. Techniques for translation from problem-oriented languages to machine languages. Computer organization, programming, program planning and organization. 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 6.41–6.45 prerequisite. *Corbato*

6.252 *Digital Systems Engineering*
Prereq.: 6.05
Year: U (1, 2) 3–0–6
Introduction to basic concepts in design of digital systems, with emphasis on logical aspects. Brief treatment of computer organization and digital representation of information. Boolean algebra. Methods for logical synthesis of switching networks, both combinational and sequential. Utilization of electronic devices as bivalued elements in digital building blocks. Organization of these blocks into counters, arithmetic and control ele-

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ments, and memory units. Self-checking and self-correction in digital systems. *Susskind, Hennie*

6.253 *Introduction to Theories of Computation*
Prereq.: 6.41 or 6.45
Year: U (2) 3–0–6
Introduction to contemporary ideas on theoretical models for machine computation. Elementary procedures, their representation, and equivalence relations. Properties of finite and infinite state abstract machines. Introduction to the theory of computability. Applications to syntactic analysis and translation of formal languages.
Dennis

6.26 *Special Topics in Molecular Engineering*
Prereq.: 6.08 or 6.083
Year: U (2) 3–0–6
Elective for undergraduates in electrical engineering. Primarily concerned with physics of solids and applications of physical principles to device analysis and design. Varying subject matter from term to term. Representative topics to be included: ferroelectricity and ferromagnetism, principles and device applications; maser and parametric amplifiers; microwave ferrites; theory of conduction in metals and semiconductors; propagation of waves in periodic structures. *Epstein*

6.27J *Probabilistic Systems Analysis*
(Same subject as 15.094J)
Prereq.: 18.04
Year: U (1) 3–0–6
A subject serving both as a self-contained development for students wishing to become familiar with the theory and application of probabilistic concepts and as a foundation for graduate subjects in engineering, science, and management. Theory of probability presented on an axiomatic basis. Topics ranging from algebra of events to stochastic processes and simulation. Heavy emphasis on sample space concept for both discrete and continuous random variables. Discussion of operations on random variables, discrete and continuous transform techniques, common distributions, limit theorems, statistics, renewal processes, and computer analysis. Consideration of implications of probability theory for decision making, data analysis, and system modeling. Applications presented concurrently with development of the theory.
R. A. Howard

6.291 *Radar-System Engineering*
Prereq.: 6.05, *6.07*
Year: U (1, 2) 3–0–6
Professional elective for students in Electrical Engineering. Study of radar and radar measurements from a systems viewpoint. Methods of measuring target range, azimuth, elevation, and velocity; accuracy, ambiguity, and resolution of radar measurements in the presence of noise; signal detection, probability, and signal-processing receivers; thresholds and decision criteria; radar antenna systems; propagation phenomena pertaining to radar such as atmospheric effects, rain attenuation, ground reflections, and clutter; coherent radar systems. *Reintjes*

6.311 *Principles of Communication*
Prereq.: 6.05, 18.04
Year: U (1, 2) 3–0–6
Probabilistic formulation of the communications problem. Mathematical description of signals and noise. Elements of decision processes and performance of ideal receivers for interesting classes of modulation. Interchange of bandwidth and signal-to-noise ratio. Introduction to channel capacity, error-correcting codes, and error-free communication over noisy channels.
Wozencraft

6.312 *Radio Communications*
Prereq.: 6.07, 6.311
Year: U (2) 3–0–6
Introduction to the system concept in radio communications. Analysis of main parts of a radio communications system and of the way in which they contribute to the process of communication. Discussion of concepts mainly with reference to communications systems of current research interest. *(Not offered 1964–65.)*

6.32 *Plasma Physics and Magneto-gas Dynamics*
Prereq.: ——
Year: U (2) 3–0–6
Broad introductory coverage of both the theoretical and experimental aspects of plasma physics. Development of areas of physics and engineering related to the study of plasmas. Working knowledge of vector calculus assumed for electromagnetic phenomena beginning with Lorentz force equation and Maxwell's equations. Continuum aspects of plasma related to the Boltzmann equation. Subject matter including the following: motions of particles in electromagnetic fields, kinetic theory and elementary processes, macroscopic equations and transport coefficients, creation of ionized gas, ionized gas as a fluid and the magnetohydrodynamic approximation, MHD flows, propagation of waves and instabilities, and discussion of the natural and man-made applications. Admission by approval of professor in charge.
Whitehouse, Jackson

6.341T *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. *Adler*

6.342T *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. Related laboratory work concerned with the use of feedback in transistor circuits and circuit applications.
Adler

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. *Heinz*

6.36 *Speech Communication*
Prereq.: 6.05 or 6.35
Year: U (2) 3–0–6
For well-qualified students with a serious interest in speech communication. Survey of structural properties of natural languages with special emphasis on the sound pattern. Acoustical theory of speech production:

anatomical considerations; the vocal tract as a generator of acoustical signals; acoustical correlates of vocal-tract configurations, both stationary and dynamic. Perception of speech: the auditory capabilities of man; the role of set in perception; analysis by synthesis. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. *Halle, Stevens*

6.37 *Sensory Communication*
Prereq.: 6.05
Year: U (1) 2–2–5
Designed to give an understanding of the emerging principles of man's sensory performance and to prepare the student for graduate study in the communication sciences. Introductory discussion of sensory transducers, sensory coding, and organization of the central nervous system in relation to signal processing. Stimulus-response relations derived from the behavior of the organism: responses to visual, auditory, and other sensory stimuli. Absolute and differential sensitivity. Psychophysical methods, including scaling techniques. Information handling capabilities and operating characteristics of human observers in various communication tasks. Temporal characteristics of sensory performance. Laboratory experiments illustrating these principles.
Rosenblith, S. J. Mason

6.372T *Introduction to Neuroelectric Potentials*
Prereq.: 8.04 or 8.041; 18.04
Year: U (2) 2–2–5
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*

6.38 *Pulse Circuit Analysis*
Prereq.: 6.02
Year: U (2) 3–0–6
Analysis and design of circuits used in radar, television, pulse-communication, electronic computation, cathode-ray instrumentation and similar applications. Approximation methods based on piecewise-linear circuit models and simple transients. *Zimmermann*

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 multi-dimensional nature of the inputs and the destination of the output, and therefore depend on a study of the properties of pictures, the properties of observers, and the effect of the parameters of the system on the quality of the transmission. Topics including historical developments, mathematical description of images, objective measures of picture quality, scanning and quantizing, picture processing and coding, color systems, and relevant properties of human vision. Term paper or project required. (*Not offered 1964–65.*) *Schreiber*

6.41 *Introduction to Automatic Computation*
Prereq.: ——
Year: 1 (1, 2) 2–0–4
Principles of describing computation processes and programming digital computers to do them. Emphasis on concepts of computation processes and their realization by machine rather than on proficiency in art of programming. Stored program computers; binary, octal, and decimal number systems; practice in writing programs in machine language and in algebraic language and running them on an IBM 7094; important kinds of programming languages; elementary treatment of theory of computation. Suitable elementary numerical problems in mathematics and physics; some non-numerical uses of computers. *Corbató*

6.42 *Electromechanical Components and Systems*
Prereq.: 2.02 or 6.01
Year: U (1, 2) 3–2–5
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. *Frazier, Kingsley*

6.43 *Introduction to Electrical Science*
Prereq.: 8.04 or 8.041
Year: U (1, S) 4–2–4

6.44 *Introduction to Electrical Science*
Prereq.: 6.43
Year: U (2) 4–0–6
Two-term sequence for students not majoring in electrical engineering or electrical science. Introduction to the communications aspects of electrical science. Linear and nonlinear operations upon electrical signals. Synthesis of basic operations by means of electric and electronic circuits. Emphasis on transistor circuits. General properties of linear circuits and systems. The correlation concept. Analysis of signals and their spectra, some examples of random signals and noise. Modulation and detection processes. Fields and waves. Transmission and radiation of signals. *S. J. Mason, Rafuse*

6.45 *Introduction to Automatic Computation*
Prereq.: 18.02
Year: U (1, 2) 2–0–4
Principles of describing computation processes and programming digital computers to do them. Emphasis on concepts of computation processes and their realization by machine rather than on proficiency in art of programming. Stored program computers; binary, octal, and decimal number systems; practice in writing programs in machine language and algebraic language and running them on an IBM 7094; important kinds of programming languages; elementary treatment of theory of computation. Numerical problems of mathematics and physics as well as some non-numerical problems. Assumption of a general background of first-year subjects. Note: 6.45 is not open to first-year students, and 6.45 and 6.41 may not both be taken for credit. *Corbató*

6.46 *Fundamentals of Discrete Systems*
Prereq.: 18.01
Year: U (1) 2–0–7
Fundamental concepts underlying systems in which simple components interact in complicated ways. Topics connected with inductive and recursive definitions, Boolean sets and functions, finite-state machines and languages, switching and McCulloch-Pitts networks, turing machines computers and programming languages and compilers. Introduction to logic, combinatorial analysis, and mathematics associated with theories of machines. *Minsky*

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*

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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 6.08 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. *White*

6.525 *Magneto-Fluid Dynamics* (A)
Prereq.: 6.03, 6.06, 18.05
Year: G (1) 3–0–9
Introductory treatment of interactions between electrically conducting fluids and electromagnetic fields and their engineering applications. Properties of conducting fluids. Review of fluid dynamics. The magnetofluid-dynamic approximations, equations and dimensionless groups. Incompressible and compressible flows. Wave motions in conducting fluids. Shock waves and their production. Stability considerations and turbulence. Applications selected from the fields of energy conversion and communications. *Jackson*

6.526 *Magnetohydrodynamic Energy Conversion* (A)
Prereq.: 2.274 or 6.06 or 6.525 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*

6.531 *Theory of Automata* (A)
Prereq.: 18.20
Year: G (1) 3–0–9
Behavioral languages for finite automata, especially state graphs, transition graphs (i.e., non-deterministic state graphs or signal flow graphs) and regular expressions. Varieties of growing automata (e.g., Turing machines), especially those that compute under a memory or time limitation, and their ability to process languages. Emphasis on certain fundamental discoveries made since 1962. *McNaughton*

6.533 *Algorithms for Optimization and Approximation* (A)
Prereq.: 18.06
Year: G (1) 2–1–9
Algorithms for the solution of certain systems of nonlinear equations, for minimization of certain functions of many variables, for linear and convex programming, for Tchebycheff approximation and for the solution of certain problems in the calculus of variations. Time will be available on the IBM 7090 computer to run programs based on the above algorithms. *R. A. Howard*

6.535 *Structure of Computing Machines* (A)
Prereq.: 6.25 or 6.251
Year: G (1) 3–0–6
Study of the design of general purpose digital computing systems in relation to the languages to describe procedures, the devices and technology employed in fabrication, interaction between procedures and system environment, and the efficient utilization of resources. Basic properties of procedures and their representation. Models of program structure suitable for the study of machine organization. Languages for describing the structure of digital machines. Examples of subsystem designs. Realization of arithmetic operations. Instruction code design. Organization of memory systems. Multi-processor systems. Allocation and scheduling techniques. Survey of selected contemporary computer system designs. Highly parallel computer structures. *Dennis*

6.536J *Systems Engineering and Operations Research* (A)
(Same subject as 15.594J)
Prereq.: 6.27J 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 non-stationary, Markov and semi-Markov processes. Optimization of probabilistic systems over short and long time periods by means of dynamic programming. Concurrent presentation of examples in the areas of system reliability, congestion processes, automatic control, maintenance and replacement policies, search procedures, inventory control, and other operating problems of systems. Discussion of unsolved problems and promising areas of research. *R. A. Howard*

6.537 *Switching Circuits* (A)
Prereq.: 18.05
Year: G (1) 3–0–9
Description of combinational circuits by switching algebra; problems relating the simplification of algebraic form to the reduction of circuit complexity. Complete sets of elements; universal elements. The finite state machine model for sequential circuits; equivalence experiments and the simplification of terminal description. Realization of sequential circuits in pulsed or level form using bilateral and unilateral elements and elements with threshold, delay, and refractory period. Special limitations and advantages of synchronous and asynchronous circuits; races and hazards. Reliability and theoretical limitations of finite state machines. Special classes of sequential circuits, such as linear, self-synchronous, and information lossless. *Hennie*

6.538 *Switching Circuits* (A)
Prereq.: 6.537
Year: G (2) 3–0–9
Investigation of circuit models for processing time or space sequences of inputs. Analysis and synthesis of finite-state models such as non-deterministic sequential circuits, bilateral iterative networks, and information lossless networks. Capabilities of various types of infinite-

state models, including sequential iterative networks and push-down storage machines. Relationships between the behavior of these models and the properties of formal languages. Discussion of synthesis problems, including stability and redundancy, with emphasis on real-time applications. Turing machines and the concepts of "algorithm" and "decidability." Development of a number of undecidability results about the basic behavior of the models studied; discussion of the practical implications of these results. *Hennie*

6.539 *Mathematical Theory of Computation and Symbol Manipulation* (A)
Prereq.: ——
Year: G (2) 3–0–9
Symbolic expressions and computation with symbolic expressions. The LISP programming language. Synthesis of processes from elementary processes, and data spaces from elementary data spaces. Methods of proving theorems about programs. Relations between mathematical logic and computing. Some applications to tree-searching, theorem proving, and other topics in artificial intelligence. This subject and 6.544J recommended as a two term introduction to artificial intelligence. *Minsky*

6.54 *Sampled and Quantized Systems* (A)
Prereq.: 6.571 or 6.601
Year: G (2) 3–0–9
Analysis of discrete linear systems in the time and z-transform domains. Consideration of discrete matrix systems describable by non-commutative flow graphs. Optimization of discrete systems with deterministic inputs. Investigation of the processes of sampling continuous signals and interpolating discrete signals. Analysis of mixed systems containing impulse modulators in addition to discrete and continuous filters. Exact and approximate inversion methods for transforms rational in both s and z. Determination of the response of discrete linear systems to discrete random signals by means of correlation functions and transforms; design of statistically optimum discrete systems. Analysis of amplitude quantization as a linear process in the probability domain. Discussion of recent research in dynamic programming and related areas as applied to system optimization. *R. A. Howard*

6.541J *Language, Symbolic Processes, and Computers* (A)
(Same subject as 23.791J)
Prereq.: 6.25 or 8.07 or 18.18 or 18.25 or 23.751
Year: G (1) 3–0–9
Symbols, their storage and manipulation: formal systems of symbols; natural languages; computer programming languages; codes; notation systems of mathematics, logic, physics, etc.; relation of symbols and symbol systems to the physical means of representation and manipulation and to the subject represented and its systematization; symbolic processes, induction, deduction, reasoning; translation and translatability. *Yngve*

6.542J *Mechanical Translation and Language Processing* (A)
(Same subject as 23.792J)
Prereq.: 6.541J
Year: G (2) 3–0–9
A survey of research in the area of language processing by machine. Successes and inadequacies of current techniques. Remaining obstacles to adequate mechanical translation. Morphology; syntax; lexicography; semantics; automatic analysis and synthesis of sentences. Structure of English, German, and other languages. Syntax and semantics of programming languages. *Yngve*

6.543 *Advanced Computation Systems Seminar* (A)
Prereq.: 6.25 or 6.251
Year: G (1) 3–0–9
Analysis in depth of the state of the art in the systems, programming, and end usages of computation systems. Consideration of advanced system elements, such as associative memories, problem-oriented languages, and human capability. Definition and evaluation of models for the machine information processing aspect of specific present and foreseeable problems taken from areas such as pattern recognition, information retrieval, process control, and real-time, man-machine systems. Primary viewpoint: specification and comparison of possible and feasible man-machine systems for definite and measurable objectives, utilizing the most promising developments in languages, devices, and other system components. Objective: development of a unified approach to information processing problems. Moderate experience with computer usage, programming, and design is required; students selected by interview. *Teager*

6.544J *Heuristic Programming* (A)
(Same subject as 18.16J)
Prereq.: 6.41 or 6.539 or *18.18* or 18.89; 18.04
Year: G (1) 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*

6.55 *Linear System Theory* (A)
Prereq.: 6.02
Year: G (1) 3–0–9
Study of methods useful in the consideration of signals and their effect upon linear systems. Exponential signals with complex frequencies. The impulse and the step function. Impedance and admittance concepts and their relation to the natural behavior of systems. The general constant-parameter ordinary differential equation and the algebraic properties of its solution. Exponential Fourier series and integrals and their properties. The concept of a spectrum. The Laplace transform as a generalized Fourier integral. The convolution integral and its properties. The relationship between Fourier methods and convolution methods and their use in determining system response. The sufficiency of the real part of a Fourier spectrum in the determination of the associated signal. The Hilbert transform. Sampled and band-limited signals. Emphasis throughout on the use of the impulse for the simplification of methods. Introductory subject for graduate students entering from other schools. *Stockham*

6.56 *Mathematical Methods in Electrical Engineering* (A)
Prereq.: 18.05
Year: G (1) 3–0–9
A subject emphasizing the physical and geometrical interpretations and their effective use in electrical engineering problems, rather than the abstract symbolic formalism of mathematical methods. Selected topics from: theory of determinants and matrices including the

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Binet-Cauchy theorem and the use of compound matrices; linear transformations and quadratic forms; functions of a complex variable emphasizing the basic aspects for analysis of problems common to the fields of electrical communications and electrical control; approximation and convergence properties of Fourier, Laplace and Hilbert transforms, analytic and numerical methods for their evaluation. *Schwab*

6.561 *Network Analysis and Synthesis* (A)
Prereq.: 6.30 or 6.55; 6.56
Year: G (1, 2) 3–0–9

6.562 *Network Analysis and Synthesis* (A)
Prereq.: 6.561
Year: G (2) 3–0–9

Advanced treatment of linear passive network theory with primary emphasis upon synthesis aspects; application to design of networks for prescribed driving-point and transfer characteristics; fundamental work of Foster, Cauer, Brune, Darlington, Bott and Duffin, Fialkow and Gerst; the topological transmission rules and their implications for transformless synthesis; time and frequency domain aspects of the pertinent approximation problem; questions regarding the ultimate response characteristics obtainable from linear passive networks. Discussion of presently unsolved problems. *H. B. Lee*

6.571 *Statistical Theory of Communication* (A)
Prereq.: 6.05 or 6.55
Year: G (1, 2) 3–0–9

Messages and noise as stationary random processes. Elementary probability theory, statistical characteristics of messages and noise, particularly correlation functions and spectra. Measurement of correlation functions. Detection of signals in the presence of noise by correlation. Determination of impulse response of linear systems by correlation. Theory of the statistical optimum filter, predictor, compensator, differentiator, and general linear system operator. Synthesis of optimum linear systems by normal and orthogonal functions. *Y. W. Lee*

6.572 *Statistical Theory of Nonlinear Systems* (A)
Prereq.: 6.571
Year: G (1, 2) 3–0–9

Operators and functionals. Functional power series representation of nonlinear systems. Stability and convergence. Functional representation when the input of a nonlinear system is a constant, a transient, a sinusoid, and a random process. An algebra for nonlinear systems. System transforms. Representation of nonlinear systems by an orthogonal system of functionals. The optimum nonlinear filter, predictor, feedback system, and general operator. The method of iteration in nonlinear theory. Special classes of nonlinear systems. Systems with multiple inputs. *Y. W. Lee*

6.573 *Random Signals and Noise* (A)
Prereq.: 6.05 or 6.053 or 6.311; 6.27J; 18.05
Year: G (1, 2) 3–0–9

Fundamentals of the theory of random processes such as occur in communications, radar and control systems. Review of probability theory. Characterization of random processes. Linear operations on processes, correlation functions and spectra. Detailed study of the generalized Poisson process and Gaussian process. Fourier series expansions, sampling theorems, general orthogonal expansions, and narrow-band random processes. Various additional topics such as non-linear operations on processes and certain optimization problems. *Davenport, Siebert*

6.574 *Transmission of Information* (A)
Prereq.: 6.311 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. Participation by several staff members. *Elias*

6.576 *Statistical Theories of Signal Detection* (A)
Prereq.: 6.573
Year: G (1, 2) 3–0–9

Application of statistical methods such as hypothesis testing and maximum likelihood to various detection problems of engineering interest. Discrete decision problems, relationship between various criteria, sequential testing, and problems of resolution. Estimation theory for signals described by finite parameter sets, estimate variances and signal ambiguity functions. Estimation theory for continuous messages processes. Structure and performance of efficient demodulators for continuous modulation systems. *Siebert, Van Trees*

6.583 *Advanced Topics in Continuum Electrodynamics* (A)
Prereq.: 2.201 or 6.06; 6.03 or 8.72
Year: G (1) 3–0–9

Precise material to be covered and prerequisites to differ from year to year according to interest of the instructor in charge. Typical subjects: electromagnetism of moving media, electromechanical dynamics, waves in dispersive media, and force in moving media. In 1964–65, electromechanical waves. Generalization of electromechanical networks to surface and bulk-coupled systems. Dispersion, resonance, static instability and over-stability as demonstrated by examples from magnetohydrodynamics, electrohydrodynamics and electro-elasticity. Field-coupled forms of Rayleigh-Taylor and Kelvin-Helmholtz instabilities. Growing waves and non-linear wave phenomena. *Melcher*

6.584 *Electromagnetic Theory* (A)
Prereq.: 6.02, 18.05
Year: G (1) 3–0–9

Selected topics from fields, energy and forces, energy transmission and radiation, treated from an advanced viewpoint. (*For first year graduate students.*) *Chu*

6.586 ***Engineering Applications of Field Theory*** **(A)**
Prereq.: 18.04
Year: G (2) 3–0–9
Engineering solutions of Laplace, Poisson, diffusion, and wave equations by separation of variables in a large number of coordinate systems. Practical applications to electrostatic, magnetic, thermal, and electromagnetic-wave problems. *Moon*

6.59 ***Bioelectric Signals*** **(A)**
Prereq.: 6.37 or 6.372
Year: G (2) 3–0–9
For graduate students in the physical and communication sciences. Neuroelectric activity in relation to sensory information processing. Evoked responses at various levels of the nervous system in different biological species. Time and the central nervous system. Models for the behavior of sensory systems. Simulation experiments on neuroidal nets. *Rosenblith*

6.592 ***Analytical Models for Human Processing of Sensory Inputs*** **(A)**
Prereq.: 6.37 or 6.372
Year: G (2) 2–0–7
Evaluation and design of research procedures for the simulation of human perceptual processes. Review of relevant literature from psychophysics and theory of perception, considering both human perception and the evidence from the study of lower organisms. Application of this information to a critical evaluation of recent work in machine simulation of human perceptual processes, emphasizing studies of pattern recognition, abstracting, self-organizing systems as perceptual models, etc. Design of experimental research projects utilizing the technique of machine simulation with the goal of providing a perceptual model that satisfies the known constraints of human physiology and psychology. (*Not offered 1964–65.*) *Eden*

6.595J ***Biological and Neurological Control Systems*** **(A)**
(Same subject as 7.595J)
Prereq.: 6.213 or 7.06 or 18.04
Year: G (1, 2) 2–4–6
Experimental analysis of biological systems. Introductory seminars followed by detailed laboratory sessions on human neurological servomechanisms. Utilization of specialized equipment and approaches to illustrate general concepts of linear and nonlinear operators, prediction mechanisms, and noise as evidenced in biology. Each student prepares a seminar and, in addition to eight prepared laboratory exercises, engages in a special experimental topic. Attendance limited. *Stark*

6.601 ***Feedback Control Theory*** **(A)**
Prereq.: 6.05; *6.571 or 6.573;* 18.05
Year: G (1) 3–0–9
Introduction to the basic theoretical tools for the analysis and design of feedback control systems. Theory of dynamic systems, transform techniques, phase space approach. Stability theory, Lyapunov's methods, Nyquist criterion. Trial-and-error design techniques for linear feedback control systems. Introduction to optimization theory for deterministic and random inputs. *Gould*

6.602 ***Nonlinear Control Systems*** **(A)**
Prereq.: 6.601
Year: G (2) 3–0–9
Unified treatment of system theory in terms of operators. Solution by inverses. Iteration techniques depending on the contraction principle and other fixed point theorems. Eigenfunction methods, including the describing function. Generalized state space. Adjoint operators. Properties of trajectories. Stability by the second method of Liapunov. Applications to feedback controllers, modulators, oscillators, and adaptive systems. *Seifert*

6.603 ***Seminar in Control Research*** **(A)**
Prereq.: 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, 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 Information Systems*** **(A)**
(Same subject as 1.16J, 2.191J, 16.362J)
Prereq.: 6.311 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 information systems associated with a large operational complex. 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. (Project for 1964: Preliminary design of an advanced orbiting astronomical observatory OAO.) Students selected by interview on basis of their potential to contribute actively and effectively.
Seifert, C. L. Miller, Baumann, Li

6.606 ***Control System Synthesis*** **(A)**
Prereq.: 6.601
Year: G (2) 3–0–9
Synthesis of control systems with emphasis on use of analysis of mathematical models to guide engineering designs. Mathematical optimization theory presented as theoretical basis for synthesis of stationary and time-varying linear control systems. Signal characteristics, mean-square, integral-square error and other system performance criteria together with component limitations considered in formulating optimization procedures. Effects of sampling, nonlinearities, and switching discussed. Selected topics in components used in control systems: sensing devices, electric and hydraulic servomotors, gearing, signal and power amplifiers, carrier and non-carrier compensating networks. Opportunities for case studies, laboratory and special project work provided. *Newton*

6.607 ***Feedback Control Laboratory*** **(A)**
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised investigation of special topics in feedback control system analysis and synthesis, laboratory investigations supported by library research and analytical work utilizing the facilities of the feedback control laboratory. Program and hours to be arranged with interested staff member, subject to approval of instructor. *Newton*

6.608 ***Process Control*** **(A)**
Prereq.: 6.601 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 model of chemical processing units. Partial differential equations of linear transport

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processes and methods of solution. Perturbation theory for typical nonlinearities. Conventional regulation loops. Non-interacting control of multi-variable systems. Qualitative theory of nonlinear distributed systems. Stability of chemical reactors and other distributed systems through Lyapunov's methods. Introduction to dynamic optimization. *L. A. Gould*

6.609 *Theory of Optimal Control* (A)
Prereq.: 6.601
Year: G (1) 3–0–9
Review of linear algebra, vector differential equations, calculus of variations, dynamic programming. The optimal control problem. The maximum principle of Pontryagin, Hamilton-Jacobi equation, canonical equations, minimum time problems, minimum-fuel problems, minimum energy problems. Design of optimal and sub-optimal systems. *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.: 6.07
Year: G (1) 3–2–7
Analysis of electromagnetic wave propagation in uniform cylindrical waveguides; reduction of waveguide and discontinuity problems to equivalent transmission line and network problems; obstacles as matching elements. Cavity resonators; perturbation theory. Multiple waveguide junctions; matrix algebra techniques. Laboratory experiments. *Bers*

6.622 *Antennas* (A)
Prereq.: 6.07
Year: G (2) 3–0–9
General theory of radiation and its application to the analysis of representative types of antennas; emphasis placed on the design of antenna arrays, microwave reflectors, and lenses. *Chu*

6.623 *Principles of Pulse Circuits* (A)
Prereq.: 6.05
Year: G (1) 3–0–9
Analysis and design of high-speed circuits used for waveform generation and waveshaping inpulsed and digital systems. Methods of nonlinear circuit analysis based on piecewise-linear approximations, numerical methods and graphical methods, including phase-plane interpretation of relaxation oscillators and trigger circuits. Applications to system design problems. *Zimmermann*

6.624 *Detection and Measurement of Radio Astronomical Signals* (A)
Prereq.: 6.05, 6.07
Year: G (1) 3–0–9
Detection and measurement of radiation typical of signals encountered in radio astronomy. Spectral analysis of thermal-like radiation. Spatial correlation and angular filtering properties of antennas developed from the fundamentals of electromagnetic radiation. Antenna temperature and its relationship to gain and cross section of arbitrary receiving antennas. Sources and characterization of receiver noise. Intensive study of radiometric and autocorrelation methods of spectral analysis. Interferometry and related methods of aperture synthesis employing fixed and variable baseline antennas. *Graham*

6.625T *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*

6.626 *Modulation Theory and Systems* (A)
Prereq.: 6.311 or 6.573
Year: G (2) 3–0–9
Detailed study of the joint application of coding and modulation theory to the design and instrumentation of communication systems. Propagation characterization: dispersion and random fading. Space, time, and coding diversity-combining. Effects of input and output quantization: algebraic and probabalistic decoding. *Wozencraft*

6.631 *Plasma Dynamics* (A)
Prereq.: 6.03, 8.05
Year: G (1) 3–0–9
Foundations for the production and manipulation of ionized gases. Particle interactions with electromagnetic fields. Discussion of collision theory, ionization, and breakdown. Development of macroscopic transport parameters from the Boltzmann equation. Properties of plasmas and sheaths with and without magnetic fields. Methods of heating, containing, and accelerating plasmas. Plasma oscillations, wave propagation, and other topics as time permits. *Whitehouse*

6.632 *Electronic Instrumentation and Control* (A)
Prereq.: 6.05
Year: G (1, 2) 3–0–9
Transistors, other solid-state devices, and electron tubes in electronic instrumentation for control and measurement. Electronic conversion transducers; direct-coupled, pulse, and signal-processing amplifiers; modulators and demodulators; monostable and bistable switching circuits; gates; coincidence circuits; random-event counting and count-rate circuits. Illustrations from such applications as time-interval and frequency measurements, high-speed counting and recording instruments, computer components, strain gages, tachometers, and nuclear-reactor control. *T. S. Gray*

6.634J *Plasma Laboratory* (A)
(Same subject as 22.65J)
Prereq.: *2.274* or *6.631* 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, high voltage techniques, and other topics of current interest; brief lectures and literature references to elucidate the physical bases of the laboratory work. *Whitehouse, Lidsky*

6.635 *Transistors* (A)
Prereq.: 6.05; 6.08 or 8.07
Year: G (1) 3–0–9
Primarily for graduate students in electrical engineering. Physical foundations of transistor action, developing the terminal properties of the transistor as an electronic device. Brief qualitative introduction to the concepts of free electrons and holes in semiconductors; elementary quantitative treatment of electrical conductivity as a function of impurity concentration and temperature; drift, diffusion and continuity relations governing carrier flow out of thermal equilibrium; derivation of the d-c and incremental a-c electrical characteristics of the planar junction diode and junction transistor; equivalent circuits; implications of the model for device performance and limitations. *Adler*

6.636 *Semiconductor Electronics* (A)
Prereq.: 6.635
Year: G (2) 3–0–9
Principles and application of some of the electronic properties of semiconductors important for devices: avalanche and tunneling, breakdown in p-n junctions, avalanche diodes and transistors, tunnel diodes, statistics of recombination and trapping, PNPN switches, mobility in high electric fields, field effect transistor. Surface phenomena. Some details of band structure in Ge, Si, and related semiconductors. *Adler*

6.637 *Beam-Type Microwave Tubes* (A)
Prereq.: 6.07, 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*

6.64 *Insulators, Semiconductors, and Metals* (A)
Prereq.: 5.63 or 8.05 or 8.051
Year: G (2) 3–1–8
Study of atoms and molecules and their behavior in gases, liquids, and solids from the unifying standpoint of the interaction of matter with electric and magnetic fields (polarization, magnetization and conduction). Short survey of the macroscopic theory; effects of electric and magnetic moments from their initial individual appearance in spectroscopy to their final concerted action in ferroelectrics and ferromagnetics; the laws of motion of electrons and ions from insulators to semiconductors to metals. Interdepartmental subject for graduate students of science and engineering, designed to lead to an understanding of present-day research problems in the field of molecular science and molecular engineering. *Newnham*

6.641 *Laboratory Seminar in Molecular Engineering* (A)
Prereq.: 6.08
Year: G (1, 2) 0–8–4
Experimental investigations of the properties of materials; brief lectures on the basic theory of material properties and references to the literature; experiments closely related to current research in this area in the Department and expected to lead to thesis topics in the area; emphasis on the capabilities and limitations of modern methods of solid state experimentation. *A. C. Smith*

6.644 *Microwave Magnetics* (A)
Prereq.: 6.08
Year: G (2) 3–0–9
Fundamentals and engineering applications of microwave resonance in magnetically ordered solids. 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 nonreciprocal microwave circuit elements such as rotators, isolators, circulators, and gyrators; magnetostatic modes and spinwave analysis. Second part devoted to nonlinear effects associated with ferromagnetic resonance, including: nonlinear resonances, harmonic generation and frequency mixing, saturation of the main resonance, spinwave instabilities, subsidiary absorption, spinwave spectroscopy involving longitudinal pumping, parametric amplification; elastic waves in continuous and discrete media, magnetoelastic energy, magnon-phonon interactions in ordered magnetics, phonon spectroscopy; resonance loss mechanisms in magnetically ordered insulators. *Miles, Morgenthaler*

6.645 *Optical Masers* (A)
Prereq.: 8.361 or 8.731
Year: G (1) 3–0–9
Theory of interaction between electromagnetic radiation and atoms in gases and condensed phases. Coherent and incoherent processes in atoms and fields. Properties of stimulated emission devices. Density matrix and rate equation analysis of maser emission. Saturation and nonlinearities in intense optical fields. Use of optical masers as a focus of interest for discussion of the macroscopic and atomic electric and magnetic properties of matter. *Miles*

6.646 *Conduction Processes in Solids* (A)
Prereq.: 6.08 or 8.07; 6.635 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 nonequilibrium 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
Study of semiconductors centered about the significant experimental measurements made on Germanium and the use of these results to evolve a complete theoretical model. Measurements of conductivity, magnetoresistance, Hall effect, magnetic susceptibility, cyclotron resonance, optical and magneto optical properties, and transport properties are discussed for Ge, III-V, and II-VI semiconductors. The experiments are interpreted in terms of energy bands, effective mass theory, role of

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spin orbit coupling, excitons, impurity levels, interaction between electrons and phonons. Seminar aimed at relating a formal background in solid state to the planning and interpretation of experiments in materials research. Guest lecturers to speak on their specialties. (*Not offered 1964–65.*) *Pratt*

6.65 *Quantum Theory of Magnetism* (A)
Prereq.: 8.361
Year: G (2) 3–0–9
Magnetic properties of isolated atoms and ions. Crystal field theory. The spin Hamiltonian. Optical properties of paramagnetic crystals. Spin paramagnetism of metals. Diamagnetism of solids. The de Haas-van Alphen effect. Cyclotron resonance and magneto-optic effects in semiconductors. Ferromagnetic exchange interactions. The Weiss and Heisenberg theories of ferromagnetism. The Bethe-Peierls-Weiss theory. Energy band theory of ferromagnetism. Superexchange coupling in antiferromagnetism. Ferrimagnetism. *Pratt*

6.66 *Engineering Applications of Tensors* (A)
Prereq.: 8.041
Year: G (1) 3–0–9
Exploration of the value of matrices and tensors in the solution of engineering problems. Applications to networks, electromagnetic theory, inhomogeneous and anisotropic media, elasticity, optics, and color. *Moon*

6.671J *Flight Transportation* (A)
(Same subject as 1.221J, 15.483J, 16.751J)
Prereq.: 6.05 or 6.07 or 6.213
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, Cootner, 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, Cootner, Browne*

6.681, 6.682 *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. *Epstein*

6.692 *Advanced Engineering Acoustics* (A)
Prereq.: 6.35
Year: G (2) 3–0–9
Special seminar in engineering acoustics covering some twenty topics whose precise titles are tailored to the composition of the class. Subjects ranging from musical acoustics to underwater sound. Class presentations by students with guidance in library and bibliographic work involved. *Baruch*

6.70 *Experimental Electronics*
Prereq.: 6.02 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*

6.72 *Electromagnetic Laboratory*
Prereq.: 6.03
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.: *6.06* or *6.07* or *6.08*, 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.: 6.06
Year: G (1 or 2) *Arr.*
Graduate subject planned for the individual student; special problems on electrical energy converters and modulators. *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, 6.832 *Teaching Electrical Engineering* (A)
Prereq.: ——
Year: G (1, 2) 0–12–0
For qualified full-time 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. (*Not open to Teaching Assistants or Instructors.*) *C. E. Tucker, Epstein*

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*

6.885 ***Industrial Project at AVCO Corporation***
Year: U (2) 0–9–0
Project to satisfy requirements of S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

6.891-6.893 ***Industrial Practice at Radio Corporation of America***
Year: U (1, 2, S) 0–9–0
6.894 ***Industrial Practice at Radio Corporation of America***
Year: G (S) 0–9–0
Work at Research Center and Astro-Electronics Division of R.C.A. Laboratories in Princeton, New Jersey. Exploration of electronically-active solid materials; application of new principles in solid-state devices; creation of new or improved equipment for communications and broadcasting; research in energy conversion; development of new computing techniques, devices, and systems; studies in electron-tube and plasma devices; applied research, development, and design of space-vehicle systems; antennas; thermodynamics; optical systems; systems synthesis and analysis; data processing for operations research analysts and programming analysts. *Reintjes*

6.895 ***Industrial Project at Radio Corporation of America***
Year: U (2) 0–9–0
Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

6.90 ***Industrial Project at the General Electric Company***
Year: U (2) 0–9–0
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*

6.909 ***Industrial Project at the International Business Machines Corporation***
Year: U (2) 0–9–0
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*

6.939 ***Industrial Project at the Raytheon Company***
Year: U (2) 0–9–0
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*

6.949 ***Industrial Project at the Bell Telephone Laboratories, Inc.***
Year: U (2) 0–9–0
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*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

6.959 ***Industrial Project at the General Radio Company***
Year: U (2) 0–9–0
Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

6.961–6.963 ***Industrial Practice at the Philco Corporation***
Year: U (1, 2, S) 0–9–0
6.964 ***Industrial Practice at the Philco Corporation***
Year: G (S) 0–9–0
Work for the Philco Corporation in Philadelphia. Work in transistor circuitry, television development, microwave systems, government communication and detection systems, computer techniques, solid-state physics, and analytical studies. (*Not offered 1964–65.*) *Reintjes*

6.969 ***Industrial Project at the Philco Corporation***
Year: U (2) 0–9–0
Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. (*Not offered 1964–65.*) *Reintjes*

6.971–6.973 ***Industrial Practice at the American Electric Power Service Corporation***
Year: U (1, 2, S) 0–9–0
6.974 ***Industrial Practice at the American Electric Power Service Corporation***
Year: G (S) 0–9–0
Work at a plant of the American Electric Power Service Corporation (Canton, Fort Wayne, New York City, or Roanoke). Work associated with the operation and planning of a large multi-state power generation and distribution system. Challenging assignments in computer solutions (analog and digital) of power flow, stability, regulation, and economy loading in a large network. Microwave communication systems, electronic relaying, research in corona and extra-high voltages. Opportunities for outside experience during earlier terms. *Reintjes*

6.979 ***Industrial Project at the American Electric Power Service Corporation***
Year: U (2) 0–9–0
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*

6.989 ***Industrial Project at the Naval Ordnance Laboratory***
Year: U (2) 0–9–0
Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

6.991–6.993 ***Research and Development at the Air Force Cambridge Research Laboratories***
Year: U (1, 2, S) 0–9–0

6.994 ***Research and Development at the Air Force Cambridge Research Laboratories***
Year: G (S) 0–9–0
The Electronics Research Directorate of the Air Force Cambridge Research Laboratories conducts fundamental research in those physical and allied sciences likely to enhance Air Force capability in electronic and electromagnetic technology. Assignments available in areas of computer principles and techniques (including related mathematical sciences, data processing and simulation); solid-state electronics, nucleonics, and physical electronics (to discover, create, or improve electronics materials); electromagnetic radiation and microwave physics (leading to improved antenna systems); recognition and detection techniques including data processing (for collection of data on objects and phenomena above surface of earth); studies of terrestrial and extraterrestrial emission and propagation of electromagnetic waves (in order to obtain fundamental knowledge required for design of electronic equipment in terrestrial, aeronautical, and astronautical environments); communications systems and techniques (in terrestrial and extraterrestrial environments). *Reintjes*

6.999 ***Industrial Project at the Air Force Cambridge Research Laboratories***
Year: U (2) 0–9–0
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

7.00T ***Perspectives in Life Science***
Prereq.: ——
Year: 1 (2) 2–0–4
Lectures and demonstrations presenting the place of man in the world of living organisms; factors important in man's successful adaptation to his external environment, animate and inanimate; and the processes which make possible the various functions of man's body in health and disease including major concepts of genetics, growth, development, and physiology. Concluding lectures on the growing importance of biophysics and biochemistry in the shaping of modern biological concepts — (biology at the molecular level) and the outlook for theoretical biology. *B. S. Gould*

7.01 *General Biology*
Prereq.: 5.02, 8.02
Year: U (1) 4–1–6
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. *Levinthal, Wall*

7.02 *General Biology Laboratory*
Prereq.: 7.01
Year: U (2) 1–6–2
Experiments, exercises, and projects to explore the nature of animals and to understand some problems and methods of research in biology. *Lettvin*

7.03T *Genetics*
Prereq.: 7.21
Year: U (2) 3–0–6
Continuity and variation in the multiplication of living organisms. Mutation and selection as a mechanism for biological change. Principles of formal genetics. Physical and chemical basis of heredity. Structure and function of the hereditary material. Molecular basis for mutation, genetic function and recombination in microorganisms. *Fox*

7.031 *Genetics and Microbiology Laboratory*
Prereq.: 7.21
Year: U (2) 1–6–2
Laboratory designed to illustrate principles and methods of genetics and microbiology. *Dowben*

7.04 *Developmental Biology*
Prereq.: 7.01, 7.02, 7.05T
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.: 7.01, 7.02, 7.05T
Year: U (1) 0–6–0
Introduction to some classical and modern experimental methods for the analysis of development. Individual projects. *Humphreys*

7.05T *General Biochemistry*
Prereq.: 5.41, 5.61
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.: 7.05T
Year: U (1) 0–8–0
Laboratory exercises to illustrate principles discussed in 7.05. *B. S. Gould, G. M. Brown*

7.06 *General Physiology*
Prereq.: 7.02, 7.05T
Year: U (2) 3–0–6
Physical and chemical basis for molecular structure and relationship between structure and function in living systems. General principles of cell maintenance, transport, irritability, contraction, and cellular interaction. Relation of form and function. Mechanisms by which the animal interrelates with its internal and external environment. *Wall, D. F. Waugh*

7.061 *General Physiology Laboratory*
Prereq.: 7.06
Year: U (2) 0–6–0
Laboratory investigation of physiological processes.
Lettvin

7.08 *Introduction to Biophysics*
Prereq.: 7.00 or 7.02; 8.04
Year: U (2) 2–0–4
Application of the analytical methods of the physical sciences to biology. Emphasis on the molecular aspects of the control systems governing the growth, development and functioning of living organisms. *Levinthal*

7.13 *Genetics*
Prereq.: 7.02
Year: U (2) 2–0–4
Facts and theories of heredity; their relation to the present state of biological theory in general. *Fox*

7.21 *General Microbiology*
Prereq.: 7.01, 7.05T
Year: U (1) 3–0–6
Properties of unicellular organisms, especially bacteria: composition, metabolic activities, and structural organization. Microorganisms as model systems for the study of cellular growth and its physiological basis. Variation, heredity, and the organization of the genetic system in bacteria. Comparative discussion of cellular organization in bacteria, in other microbes, and in multicellular organisms. *Luria, Magasanik*

7.23T *Microbial Physiology* (A)
Prereq.: 7.05T, 7.21
Year: G (2) 2–1–6
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.: 7.05T
Year: G (1) 2–0–4

7.32 *Biology Seminar* (A)
Prereq.: 7.05T
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*

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7.50 *Physical Chemistry of Macromolecules* (A)
Prereq.: 7.05T
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 *Quantitative Chemical Physiology* (A)
Prereq.: 7.01, 7.05T
Year: G (1) 3–0–6
Discussion of the biochemical and physical processes which enable complex organisms, vertebrates and invertebrates, to function as units and regulate their cellular functions in the face of a changing environment; regulation of metabolism, performance of work, excretion and detoxication, hormone action, mechanism of drug action and other topics. *Dowben*

7.595J *Biological and Neurological Control Systems* (A)
(Same subject as 6.595J)
Prereq.: 6.213 or 7.06 or 18.04
Year: G (1, 2) 2–4–6
Experimental analysis of biological systems. Introductory seminars followed by detailed laboratory sessions on human neurological servomechanisms. Utilization of specialized equipment and approaches to illustrate general concepts of linear and nonlinear operators, prediction mechanisms, and noise as evidenced in biology. Each student prepares a seminar and, in addition to eight prepared laboratory exercises, engages in a special experimental topic. Attendance limited. *Stark*

7.68 *Intermediary Metabolism* (A)
Prereq.: 7.05T
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.: 7.05T
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.: 7.05T
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*

7.77 *Biophysics Seminar* (A)
Prereq.: 7.05T
Year: G (1) 1–0–2

7.78 *Biophysics Seminar* (A)
Prereq.: 7.05T
Year: G (2) 1–0–2
Student presentation and discussion of reports on current literature in biophysics. *Levinthal*

7.81 *Enzymology* (A)
Prereq.: 7.05T
Year: G (1) 2–0–4
Quantitative study of enzymes emphasizing their general properties; kinetics of reactions catalyzed by them; conditions which control their activity. *Sizer*

7.811 *Enzymology Laboratory* (A)
Prereq.: 7.81
Year: G (1) 0–4–2
Methods of purification of enzymes; determination of their catalytic activity and chemical properties; effects of environmental factors on enzymes. *Robbins*

7.85 *Optical Methods in Biophysics* (A)
Prereq.: 7.06, 8.04
Year: G (1) 2–2–4
Principles and biological applications of emission and absorption spectroscopy in the ultraviolet, visible, and X-ray regions; microscopy in general; electron microscopy; X-ray diffraction; related instrumentation. *Hall*

7.86 *Molecular Genetics* (A)
Prereq.: 7.05T, 8.04
Year: G (2) 2–0–4
Recent experimental and theoretical developments in molecular genetics will be reviewed. Emphasis on the genetic, isotopic, and radiation experiments which yield information on the replication of nucleic acid, the mechanism of genetic recombination, and the translation of genetic information into molecular structure. *Levinthal*

7.90 *Seminar in Enzymology* (A)
Prereq.: 7.81
Year: G (2) 2–0–4
Discussion of recent advances in the field of enzymology, with emphasis on enzymes concerned with respiration, phosphorylation, and intermediary metabolism. *Sizer*

7.911 *Instrumentation and Research Methods* (A)
Prereq.: 8.04
Year: G (1) 2–0–4
Introductory subject in the analysis of physical research methods and instrumentation for the life sciences, including industrial biology and certain aspects of medical research. Principles of the basic instrumentation elements (primarily electrical elements). Preparation for synthesis and design of new research methods and systems for solution of biological problems. *Lion*

7.912 *Instrumentation and Research Methods Laboratory* (A)
Prereq.: 8.04
Year: G (1) 0–4–0
Laboratory subject, complementary to 7.911. *Lion*

7.92 *Electrical Instrumentation in Biology* (A)
Prereq.: 7.911, 7.912
Year: G (2) 0–4–0
Principles of electrical instrumentation in the biological sciences including research and industrial biology and certain aspects of medical science. Principles of electronics and electronic devices: amplifiers, oscillographs, photoelectric cells, X-ray tubes, and dosimeters. *Lion*

7.93 *Selected Topics in Biology* (A)
Prereq.: 7.05T
Year: G (1 or 2) *Arr.*
Class work in various fields of biology not covered by the regular subjects of instruction. *Staff*

7.941 *Research Problems* (A)
Prereq.: ——
Year: G (1) *Arr.*

7.942 *Research Problems* (A)
Prereq.: ——
Year: G (2) *Arr.*

Directed research in a field of biological science, but not contributory to graduate thesis. *Staff*

7.95 *Electron Microscopy* (A)
Prereq.: 7.85 or 8.04
Year: G (2) 2–0–4

Principles of electron optics, the electron microscope, interaction of electrons with matter, methods in electron microscopy, applications of electron microscopy. *Hall*

7.96 *Electron Microscopy Laboratory* (A)
Prereq: 7.95
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*

7.97 *Molecular Biology Seminar* (A)
Prereq.: 7.05T
Year: G (1) 2–0–4

7.98 *Molecular Biology Seminar* (A)
Prereq.: 7.97
Year: G (2) 2–0–4

Molecular organization of cells and their products as revealed by electron microscopy, polarization optics, X-ray diffraction, physical chemistry, and cytochemistry. Fundamental structural and interaction properties of organized systems at different hierarchies of complexity, with particular emphasis on macromolecular, fibrous, and lamellar systems and their role in the physiology of the cell. *Schmitt, Davison*

7.99 *Molecular Configuration in Biological Systems Seminar* (A)
Prereq.: 7.06
Year: G (1) 2–0–4

The properties conferred on biochemical substances by assumption of specific physical configurations. Optical methods (emphasizing X-ray diffraction) for determining configuration in macromolecular systems. Selected examples of the relationship between molecular order and function in tissues. *Rich*

8.
Physics

8.01T *Physics I*
Prereq.: ——
Year: 1 (1) 5–0–6

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*

8.02T *Physics II*
Prereq.: 8.01T
Year: 1 (2) 5–0–6

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 *Physics (Electricity and Magnetism)*
Prereq.: 8.02, 18.02
Year: U (1) 4–1–5

Fundamental laws of electricity and magnetism and some of their applications. Electrostatics, direct and alternating currents, magnetic fields, and induced electromotive forces. *J. G. King*

8.031 *Physics (Electromagnetism)*
Prereq.: 8.02, 18.02
Year: U (1) 4–1–5

Fundamental laws of electricity and magnetism presented from the standpoint of field theory. Static and dynamic properties of the electromagnetic field, interaction of the field with charges and currents, dielectric and magnetic media, Maxwell's equations. *Scherb*

8.04 *Physics (Optics and Atomic Physics)*
Prereq.: 8.03 or 8.031
Year: U (2) 4–1–5

Propagation, reflection, refraction, interference, and diffraction of electromagnetic radiation. Introduction to the quantum aspect of electromagnetic waves and the wave aspect of particles. The sequence 8.03–8.04 is intended for those students who will terminate their study of physics at the end of their second year. Students taking 8.031 followed by 8.04 will find it necessary to study certain topics not included in 8.031. *J. G. King*

8.041 *Physics (Electromagnetic Theory of Light and Physical Optics)*
Prereq.: 8.031
Year: U (2) 4–1–5

Continuation of 8.031. Classical electromagnetic theory of light and its interaction with matter, Huygens' principle, physical optics. The sequence 8.031–8.041 is intended for those students who intend to continue the study of physics for at least one more semester. *Scherb*

8.05 *Physics of Atoms and Molecules I*
Prereq.: 8.04 or 8.041
Year: U (1) 4–0–8

Survey of the experimental foundation of quantum physics with examples largely from atomic phenomena: optical, X-ray, radiofrequency, and infra-red 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. *Kendall*

8.051 *Introduction to Quantum Physics*
Prereq.: 8.04 or 8.041
Year: U (1, S) 4–0–5

Study of the experimental foundations of quantum physics and the quantum theoretical interpretation of atomic phenomena. *Enge*

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8.053 ***Introduction to Nuclear Physics***
Prereq.: 8.051 or *8.06*
Year: U (2) 4–0–5
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. *Kendall*

8.07 ***Statistical Mechanics and Thermodynamics***
Prereq.: 8.05 or 8.051
Year: U (2) 4–0–6
Elementary kinetic theory and statistical mechanics, foundations of quantum statistics. Application to transport phenomena, heat capacities, black body radiation, electric and magnetic susceptibilities. Laws of thermodynamics with specific applications to the properties of matter. *Ingard*

8.08 ***Electronics***
Prereq.: 8.04 or 8.041
Year: U (1) 4–0–6
Electron ballistics, mass spectroscopy, introduction to theory of special relativity, principles of high-energy accelerators; space charge theory; Fermi-Dirac statistics, thermionic emission, Schottky effect, high field and secondary emission, photoelectric effect in metals, elementary properties of semiconductors. *Harvey*

8.09 ***Experimental Atomic Physics I***
Prereq.: 8.041
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.) *Valley*

8.10T ***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. *Valley*

8.11T ***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. *Osborne*

8.12 ***Special Problems in Undergraduate Physics***
Prereq.: ——
Year: U (1, 2) *Arr.*
Opportunity for undergraduates to engage in experimental or theoretical research under the supervision of a staff member. *Staff*

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*

8.18 ***Special Problems in Optics*** **(A)**
Prereq.: 8.04
Year: G (1 or 2) *Arr.*
Experimental work in optics with assigned reading and consultation. *Staff*

8.19 ***Physical Optics*** **(A)**
Prereq.: 8.72
Year: G (2) 3–0–9
Selected topics, varying from year to year, in the general field of physical optics. *Staff*

8.21 ***Physical Electronics*** **(A)**
Prereq.: 8.08
Year: G (1) 3–0–6
Introduction to theoretical and experimental aspects of physical electronics, including electron emission from solids (thermionic emission, photoelectric emission, secondary emission and strong-field emission), excitation of electrons in luminescent materials and other solids, excitation and ionization of gases by electrons, and gas discharge phenomena. (*Not offered 1964–65.*) *Staff*

8.212 ***Physical Electronics Laboratory*** **(A)**
Prereq.: 8.21
Year: G (2) 2–3–3
Lectures and laboratory for the development of techniques useful for research in physical electronics and their application to experimental investigation of important phenomena of physical electronics. (*Not offered 1964–65.*) *Staff*

8.231 ***Electrical Discharges in Gases*** **(A)**
Prereq.: 8.05, 8.07
Year: G (1) 3–0–6
Study of the fundamental processes of plasma physics, experimental determination of the basic cross sections, the calculation of electron and ion mobility and diffusion coefficients, the Townsend avalanche and breakdown, ambipolar diffusion and the positive column, statistics of energy gained by free electrons and its transfer to the excitation and ionization of atoms, the passage of radiation through an excited gas, space charge sheaths, probe theory and plasma diodes, time lags in breakdown, and the formation of a spark. *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) 3–1–6
X-ray apparatus, production of X-rays, absorption, scattering, refraction, X-ray spectra. Theory and application of the diffraction of X-rays in matter to the determination of the structure of crystals, and the atomic and molecular arrangement in liquids and amorphous solids. General review of the structure of matter as determined by X-ray diffraction analysis. *Warren*

8.28 *X-ray Diffraction* (A)
Prereq.: 8.27
Year: G (2) 3–0–6
Selected advanced topics in the application of X-ray diffraction to problems of solid-state physics. The elastic spectrum of crystals from the temperature diffuse scattering of X-rays. Measurement of long-range and short-range order parameters in binary alloys. Measurement of randomness in structures and cold work distortion in metals by X-ray diffraction. Fourier analysis of imperfect crystals. Discussion of extinction effects in perfect crystals. *Warren*

8.30 *Special Problems in Crystal Physics* (A)
Prereq.: 8.27
Year: G (1 or 2) *Arr.*
Advanced problems in X-ray diffraction or crystal physics with assigned reading and consultation. *Staff*

8.311 *Introduction to Optical, Microwave, and Radiofrequency Physics* (A)
Prereq.: 8.361 or 8.731
Year: G (2) 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 *Selected Topics in Electromagnetic Wave Phenomena* (A)
Prereq.: 8.311
Year: G (1) 3–0–9
Topics in optical, microwave, and radio frequency physics, varying from year to year. *Staff*

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. *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.: 3.51 or 8.44; 8.051 or 8.06; 18.05
Year: G (2) 4–0–6
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) 4–0–6
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. *J. H. Wood*

8.362 *Theory of Molecular Structure* (A)
Prereq.: 8.361
Year: G (2) 4–0–6
Separation of nuclear and electronic motion. The hydrogen molecule-ion and molecule. Diatomic molecules. Group theory and molecular symmetry. Simple polyatomic molecules, with relation to the theory of the chemical bond. Relation of molecular theory to energy bands in solids. (*Not offered 1964–65.*)

8.363 *Theory of Solids* (A)
Prereq.: 8.361 or 8.731
Year: G (2) 3–0–6
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. *Benedek*

8.364 *Selected Topics in the Theory of Solids* (A)
Prereq.: 8.363
Year: G (1) 3–0–6
Topics in solid-state theory varying from year to year. *Staff*

8.37 *Neutron Diffraction* (A)
Prereq.: 3.50 or 8.27
Year: G (2) 3–1–6
Neutron properties, sources, and apparatus. Absorption and scattering of neutrons by isolated atoms. Transmission through and scattering by assemblages of atoms. Diffraction by single crystal and polycrystalline specimens. Crystallographic and magnetic structure analyses. Long wave-length methods and applications. Refractive index characteristics. Neutron polarization. Inelastic scattering. Laboratory experiments offered. (*Alternate years.*) *Shull*

8.38 *Special Problems in Neutron Diffraction* (A)
Prereq.: 8.37
Year: G (1 or 2) *Arr.*
Experimentation in solid-state or neutron physics utilizing neutron scattering techniques. *Staff*

8.411 *Statistical Thermodynamics I* (A)
Prereq.: 8.731
Year: G (1) 3–0–9
Principles of thermodynamics. Conditions of equilibrium and stability. The thermodynamic potentials. Derivation of the thermodynamic formulae. Phase transitions of the first and second kind. Nernst's law. Statistical foundations. Ensembles. Canonical and microcanonical distributions. Fluctuations. Elementary quantum statistics, Boltzmann gas, Debye theory of specific heat, entropy constants. (*Alternate years. Not offered 1964–65.*) *Tisza*

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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 1964–65.*) *Tisza*

8.421 *Statistical Mechanics I* (A)
Prereq.: 8.731
Year: G (1) 4–0–8
Review of thermodynamics: First and Second Law. Thermodynamic potentials. Conditions for equilibrium. Phase transitions and other applications. Third Law. Classical kinetic theory of gases: method of 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.*) *Low*

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.*) *Low*

8.44 *Introduction to Solid-State Physics*
Prereq.: 8.05, 18.05
Year: U (1) 3–0–6
Introduction to properties of solids, including classification, elastic constants, lattice vibrations, and thermal properties of solids: dielectric properties; paramagnetic, ferromagnetic, and antiferromagnetic states: superconductivity, conductivity, band theory of metals, properties of semiconductors, and imperfections in solids. Descriptive aspects of topics to be stressed since only elementary quantum mechanics to be used. *Strandberg*

8.45 *Special Problems in Solid-State Physics* (A)
Prereq.: 8.362 or 8.412
Year: G (1 or 2) *Arr.*
Advanced problems in the physics of the solid state, with assigned reading and consultation. *Staff*

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. *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.*) *Staff*

8.47 *Wave Propagation in Plasmas* (A)
Prereq.: 8.461, 8.72
Year: G (2) 3–0–6
Propagation of waves in homogeneous plasma in magnetic field. Electromagnetic, plasma-electron, plasmaion waves. Infinite plane waves; surface waves; guided waves. Sensitivity to velocity distribution, Landau damping, beam plasma instability and non-linear effects, shock waves. (*Alternate years.*) *Allis*

8.48 *Introduction to Physics of Space* (A)
Prereq.: 8.711, 8.72
Year: G (1) 3–0–6
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*

8.49, 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*

8.511 *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. *R. D. Evans*

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. *R. D. Evans*

8.541 ***Introduction to Fundamental Particle Physics*** **(A)**
Prereq.: 8.06, *8.731*
Year: G (1) 3–0–9
Observation and classification of elementary particles. Electromagnetic interactions of photons and charged particles. Classical and wave mechanics of collision and production processes. Conservation laws and invariance principles: charge, energy, momentum, angular momentum, parity, time reversal, isotopic spin, strangeness, baryonic and leptonic numbers. Strong interactions of mesons, nucleons, and hyperons. Weak interactions of leptons, mesons, nucleons, and hyperons. *Friedman*

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.*) *Osborne*

8.543 ***Strange Particle Physics*** **(A)**
Prereq.: 8.732
Year: G (2) 3–0–9
Review of current status of K-meson and hyperon physics. Intensive analysis of selected topics such as the magnetic moments of the hyperons, the anisotropies in their decay modes, and photoproduction of K-mesons and hyperons. (*Alternate years. Not offered 1964–65.*) *Feld*

8.551 ***Theory of Nuclear Structure I*** **(A)**
Prereq.: 8.732
Year: G (1) 3–0–9
Review of the current theories of the structure of atomic nuclei. Nature of internuclear forces as determined by two-body phenomena. Discussion of three- and four-body problems. Nuclear spectroscopy. (*Alternate years.*) *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. (*Alternate years. Not offered 1964–65.*) *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 (2), VIII)**
Prereq.: 18.05
Year: U, G (1) 4–0–8
Mechanics of particles, planetary motion, scattering, rigid bodies, small vibrations, strings, membranes, acoustical and elastic waves. Lagrange's equations and generalized coordinates. *Lemmer*

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. *Lemmer*

8.72 ***Electromagnetic Radiation*** **(A, except Courses V (2), VIII)**
Prereq.: 18.05
Year: U, G (2) 4–0–8
Electrostatics and magnetostatics. Maxwell's equations, the potentials, Poynting's theorem. Plane waves in empty space, reflection and refraction. Wave guides and resonant cavities. Spherical waves, field of oscillating dipole. Radiation from antennas and antenna arrays and from atoms and molecules. Interference, diffraction, scattering. Electron theory of dielectric constant, permeability, and polarization. *Huang*

8.721 ***Electromagnetic Theory I*** **(A)**
Prereq.: 8.041, 18.05
Year: G (1) 4–0–8

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

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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. *Lomon*

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. Non-stationary states; equations of motion. Heisenberg and Schroedinger picture; transitions; the classical limit. Central field problems; angular momentum; elementary scattering theory. *Federbush*

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. *Federbush*

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. *Huang*

8.74 *Applications of Group Theory to Theoretical Physics* (A)
Prereq.: 8.361 or 8.731
Year: G (2) 3–0–6
Theory of groups and their matrix representations. Application to physical problems drawn from quantum and classical mechanics. Permutation groups and the Dirac Vector Model. Rotation and double groups. Space groups. (*Alternate years.*) *Koster*

8.75 *Operations Research, Principles and Applications* (A)
Prereq: 18.11
Year: G (1) 3–3–6
Selected topics dealing with the application of experimental and theoretical techniques to the analysis of operational systems. Collection of operational data, use of machine simulation, determination of operating rules, and control criteria, illustrated by examples presented in the lectures and also by laboratory exercises. *Morse*

8.78 *Relativity* (A)
Prereq.: 8.722
Year: G (2) 3–0–9
Review of special relativity: Lorentz transformations, relativistic mechanics, and electromagnetism. The equivalence principle. Linear gravitational theories. General covariance. Elements of tensor analysis. The gravitational field equations and some special solutions. Gravitational waves, Mach's principle, and cosmological models. (*Alternate years. Not offered 1964–65.*) *Federbush*

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 1964–65.*) *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 1964–65.*) *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*

9.
Psychology

9.00 *Introductory Psychology*
Prereq.: 21.02
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.: 9.001
Year: G (2) 6–0–15

Intensive survey of psychology on the graduate level, covering in the first term historical origins, biological foundations, learning, and higher processes; and in the second term perception, child development, personality, and social interaction. Lectures, group discussions, and guided reading. (*Restricted to graduate students in Psychology.*) *Staff*

9.01 *Physiological Psychology*
Prereq.: 7.01, 9.00
Year: U (1) 3–0–5

Biophysical, biochemical, and morphological investigations of brain structure and function: methods and results. Evolution of sensory, motor, and neural mechanisms. Structural and functional organization of the vertebrate central nervous system. Neural correlates of behavior: the psychophysiology of motivation, feeling and emotion, sensation and perception, memory and learning, language and thought. *Altman*

9.011 *Seminar in Memory* (A)
Prereq.: 9.002
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. *Chorover*

9.012 *Seminar in Physiological Psychology* (A)
Prereq.: 9.002
Year: G (2) 3–0–6

Advanced treatment of topics in physiological psychology. (*Primarily for graduate students specializing in this field.*) *Altman*

9.013 *Practicum I in Physiological Psychology* (A)
Prereq.: 9.002
Year: G (1) 1–4–4

Gross and microscopic structure of the nervous system of vertebrates from fish to man. Brain dissection and examination of brain sections. Histological preparation of brains. Localization of experimentally produced brain lesions and study of anterograde and retrograde degeneration. Presentation by means of correlated lectures, demonstrations, and laboratory projects. *Staff*

9.014 *Practicum II in Physiological Psychology* (A)
Prereq.: 9.002
Year: G (2) 2–4–3

Opportunity to obtain a working familiarity with basic electrical and electronic circuits employed in neuropsychological research as well as with acute and chronic surgical procedures, electrical and chemical brain stimulation techniques, and the recording of bioelectric phenomena. Presentation by means of correlated lectures, demonstrations, and laboratory projects. *Chorover*

9.021 *Brain and Behavior* (A)
Prereq.: 9.002
Year: G (2) 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 micro-anatomy, by electrical stimulation and recording, and by chemical means. Analysis of function (behavior) proceeds by comparing effects of cerebral stimulation (or destruction) in the experimental animal, with corresponding effects of injury or disease in man. *Teuber*

9.03 *Neural Mechanisms of Learning and Motivation*
Prereq.: 9.001, 9.01
Year: U (2) 3–0–5

Consideration of the evidence for physiological mechanisms of learning and of motivated behavior (e.g. eating, drinking, sleep, maternal and reproductive behavior) derived from neuropsychological, neurophysiological and neurochemical experiments. Reports, lectures and discussion. *Gross*

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 9.01 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. *Gross*

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*

9.351 *Seminar on Sensation and Perception* (A)
Prereq.: 9.002
Year: G (1) 3–0–6

Reading, discussion, and criticism of selected topics. One or another of the following themes emphasized in a particular semester: psychophysics, signal detection theory, audition, vision, somesthesis, taste and smell, pain, perceptual organization, pattern recognition, relations with learning and motivation, neural correlates of perception. *Held*

9.40 *Learning*
Prereq.: 9.00
Year: U (1) 3–0–5

Experimental phenomena of conditioning and discrimination in various species. Analysis of complex learning, especially of verbal materials by human beings: memory and forgetting. Theories of learned behavior. *Wickelgren*

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9.401 ***Seminar in Learning*** **(A)**
Prereq.: 9.002
Year: G (1 or 2) 3–0–6
Reading, discussion and criticism of selected topics. One or another 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. *Staff*

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. *Wickelgren*

9.50 ***Research in Psychology***
Prereq.: 9.00 and any two subjects in psychology
Year: U (1) *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
Psychological theories of meaning and reference. Verification of statistical and descriptive linguistic models by psychological experimentation, study of language development and study of aphasia. Application of linguistic models to animal communication systems and other complexly structured behavior patterns. *T. G. Bever*

9.591 ***Seminar in Psychology of Language and Communication*** **(A)**
Prereq.: 9.002
Year: G (2) 3–0–6
Reading, discussion, and criticism of selected topics. One or another of the following themes will be emphasized in a particular semester: statistical theories of language, speech perception, communication in subhuman species, experimental semantics, aphasia, language acquisition, language and thought. *Fodor*

9.60 ***Theories of Personality***
Prereq.: 9.00
Year: U (1) 3–0–5
The structure and development of personality, with an emphasis on a detailed study of the most basic phenomena and concepts, experimental and nonexperimental methods and research findings. Phenomena discussed: effects of motivation on memory, beliefs and cognitive processes; anxiety, conflict and defense; and moral development. *Saltzstein*

9.70 ***Social Psychology***
Prereq.: 9.00
Year: U (2) 3–0–5
Analysis of social structure in terms of roles, stratification, and institutions; and of such social processes as value internalization, acquisition of cognitive cultural systems, dyadic and small group interaction, attitude change, and mass phenomena. *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. *Saltzstein*

9.801 ***Social Behavior in Animals and Man*** **(A)**
Prereq.: 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. *Hein, Saltzstein*

9.89 ***Developmental Psychology***
Prereq.: 9.00
Year: U (2) 3–0–5
Review of major issues, methods, and results in studies of child development. Origins of sensorimotor coordination; early stages in development of perception; acquisition of language and logical structures. *Schiller*

9.891 ***Seminar in Developmental Psychology*** **(A)**
Prereq.: 9.002
Year: G (2) 3–0–6
Advanced treatment of topics in developmental psychology. *Staff*

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.: 9.002
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.: 9.002
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.: 5.02
Year: U (1) 3–0–5
Techniques of industrial chemical calculations. First law of thermodynamics and its application to chemical changes and to processes occurring in closed and open systems. *Merrill*

10.13 ***Chemical Engineering Thermodynamics***
Prereq.: 10.12, *18.04*
Year: U (2) 4–0–6
Second law of thermodynamics and its applications to compressors, pumps, refrigeration equipment, and to separation and other chemical engineering processes. Free energy and applications to chemical and phase equilibria. *Sherwood*

10.15 *Thesis Reports*
Prereq.: ——
Year: U (1, 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, infra-red spectroscopy, and potentiometric measurements. Study of some of the following topics: flame photometry, ultra-violet and visible spectrophotometry, hot-wire anemometry, viscometry, microscopy, transient temperature measurements, pyrometry, pH measurements, and radiation counting techniques. ——

10.25 *Industrial Chemistry* (A)
Prereq.: 5.42, 5.62
Year: G (1) 3–0–6
The technology of selected important chemical industries, with emphasis on applied physical chemistry and quantitative interrelationships; the economic significance of new developments. For new graduate students from other schools who have had insufficient training in the quantitative aspects of industrial chemistry. *Meissner*

10.26 *Industrial Chemistry Laboratory*
Prereq.: 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. *Sherman, M. E. Weber*

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.
Sherman, M. E. Weber

10.30 *Fluid Mechanics*
Prereq.: 10.12, 18.04
Year: U (1) 4–0–6
Introduction to fluid mechanics. Dynamics of fluids in motion; laminar and turbulent flow; 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 *Vivian*

10.33 *Analytical Treatment of Chemical Engineering Processes* (A)
Prereq.: 5.62, 18.04
Year: G(2) 3–0–6
Mathematical techniques for handling rate problems such as diffusion, heat transfer, and chemical reaction which are basic to most chemical engineering operations. Training in setting up ordinary and partial differential equations corresponding to specific physical situations, and in methods available for their solution, including various graphical constructions. *Mickley*

10.34 *Numerical Solution of Problems in Chemical Engineering* (A)
Prereq.: 10.33
Year: G (1) 2–2–4
Advanced seminar in the numerical analysis associated with the solution of ordinary and especially partial differential equations by numerical methods. Lectures and problem assignments on the analysis of the stability and convergence of finite-difference methods of solving differential equations. Lectures and student seminar reports to cover recent advances and new techniques in the field. Each student to program and solve on the

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IBM 7090 computer at least one problem from such fields as chemical reactor simulation, heat transfer, diffusion, and fluid mechanics, with the focus upon the relative effectiveness of various finite-difference methods of solving a particular type of problem. Some training in Fortran coding of the IBM 7090. (*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. *Sherwood*

10.362 *Process Design*
Prereq.: 10.31
Year: U (2) 3–0–6
Same as 10.36, but with new case studies. May be taken by students who have credit for 10.361. *Sherwood*

10.37 *Chemical Kinetics*
Prereq.: 5.62, 10.30
Year: U (1) 3–0–6
Reactions of simple order and mechanism, with application to processes of industrial importance. Interaction of heat and mass transport with chemical reaction and application to simple design problems. (*Not offered 1964–65.*) *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. *Vieth*

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. *Sarofim*

10.46 *Absorption and Extraction* (A)
Prereq.: 10.32
Year: G (1 or 2) 3–0–6
Basic principles of equilibria, mechanism, and rate of interaction. Quantitative applications including the absorption of single gases such as sulfur dioxide, ammonia, and hydrochloric acid and complex mixtures such as light oil, casing-head gasoline, refinery gases, etc. Graphical methods. Basic principles of extraction by liquids, solvent recovery by absorption and the leaching of various solids. *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 (1) 3–0–6
Application of fundamentals of conduction, radiation, and convection of heat to industrial problems. Numerical methods for comp' x 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. *G. C. Williams*

10.52 *Mechanics of Fluids* (A)
Prereq.: 10.32
Year: G (1) 3–0–6
Development of basic relationships governing fluid flow with emphasis on continuity, linear momentum, and angular momentum equations. Flow of incompressible fluids employing the continuum approach. Cartesian tensor and dyadic notations in the context of describing the state of stress and rate of strain. Perfect fluids, simple laminar motions, creeping motions, laminar boundary layers, concepts of turbulence. Prior knowledge of vector calculus required. (*Not offered 1964–65.*) *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 Biology and Medicine* (A)
Prereq.: 5.62, 10.32
Year: G (2) 2–0–4
Examination of phenomena and problems drawn from biology and medicine and selected for their relevance to either (1) broadening perspectives of the chemical engineer, or (2) requiring chemical engineering in providing analytical methods and in choosing among alternative engineering solutions. Consideration of subjects within four categories: (1) fluid mechanics and heat transfer; (2) mass transport and separation processes; (3) chemical processes; (4) molecular organization and structural properties of biological substances. Lectures, reading, short problems, and a term paper chosen from a list of topics of current interest. *Merrill*

APPLIED CHEMISTRY

10.60 *Catalysis*
Prereq.: 5.62
Year: U (1) 2–0–4
Methods of examining catalyst surface and structure. Physical adsorption, chemisorption; relationships between catalyst properties and activity. Catalysis mecha-

nisms, evidence and theory. Catalyst carriers, promoters and poisons. Role of diffusion in catalysis. Case studies of several industrial catalysts and associated catalytic processes. *Satterfield*

10.601 *Seminar in Catalysis* (A)
Prereq.: 10.60
Year: G (2) 2–0–4
Oral presentations on special topics in catalysis by participants and invited guests. *Satterfield, Baddour*

10.61J *Physics and Chemistry of Surfaces*
(Same subject as 38.9J)
Prereq.: 5.62
Year: U (1) 3–0–6
Thermodynamic, structural, and kinetic factors underlying surface and interfacial phenomena. Molecular aspects of phase boundaries, intermolecular forces, and origins of surface tension. Capillarity and related phenomena. Thermodynamics of surfaces: surface activity, adsorption, and orientation at interfaces. Spreading, wetting, adhesion, and related processes. Electrical phenomena at interfaces: origins of surface potential, structure of the diffuse double layer, electrocapillarity. Survey of the importance of surface phenomena in processes such as flotation, detergency, corrosion, and catalysis. *Michaels, de Bruyn*

10.62 *Advanced Thermodynamics* (A)
Prereq.: 10.40
Year: G (2) 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*

10.64 *Structure and Properties of Polymers* (A)
Prereq.: 5.42, 5.62
Year: G (2) 4–0–6
Effects of molecular structure (e.g., chain constitution, configuration, and conformation) of organic polymers on their mechanical, thermal, elastic, rheologic, and optical properties. Dependence of the properties of plastics, elastomers, and fibers on crystallinity, cross-linking, and the presence of fillers or plasticizers. Effect of polymer synthesis on structure, and of polymer structure on fabrication and utilization. *Michaels, Bixler*

10.65 *Applied Chemical Kinetics* (A)
Prereq.: 5.62, *10.31*
Year: G (2) 3–0–6
Application of kinetics to development and improvement of industrial chemical processes. Basic concepts of homogeneous and heterogeneous reactions and of chain reactions. Interpretation of experimental data, determination of controlling steps in over-all rate, and choice and design of reactors. *Satterfield*

10.66 *Colloid Chemistry* (A)
Prereq.: 10.61J
Year: G (1) 3–0–6
Fundamental properties of colloidal dispersions: diffusion, sedimentation, light-scattering, and color. Preparation of colloids, stabilization of emulsions and foams. Electrical aspects of colloid-stability: mechanisms of coagulation, sensitization, protection, deflocculation. Flocculation kinetics. Electrokinetic phenomena; electrophoresis, electroendosmosis. Lyophilic colloids: swelling, gelatin, syneresis. Applications of colloid chemistry to the manufacture of protective coatings, pharmaceuticals, ceramics, polymers, and other chemical products. *Michaels, Bixler*

10.67 *Applied Surface Chemistry* (A)
Prereq.: 10.21 or 10.211 or 10.66
Year: G (2) 3–0–6
Flow through porous media. Thermodynamics and kinetics of condensation processes with specific emphasis on crystal growth. Adsorption and chemical reactions at gas-solid and liquid-solid boundaries. Dispersion and flocculation mechanisms and their effects on sedimentation, filtration, and suspension rheology. Adhesion and adhesives. Application of surface phenomena to mass transfer in chemical processing. Corrosion as a surface chemical and physical process. *Bixler, Michaels*

10.68 *Polymer Chemistry* (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 applications 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 and recent methods such as "resinography" and non-Newtonian flow parameters. Synthesis of polymers by condensation, free radical processes (bulk, solution, emulsion), and ionic methods. Effect of method of synthesis on physical chemical properties. Brief survey of differences between biologically important polymers and synthetic polymers. *Merrill*

10.69 *High Polymer Technology* (A)
Prereq.: 5.42, 5.62
Year: G (1, 2) 3–0–6
Broad review of the chemical and engineering aspects of high polymer synthesis and manipulation. Physical methods of characterizing high polymers; basic chemistry and kinetics of polymerization reactions; industrial polymerization processes. Compounding and processing of resins and elastomers; molding, extrusion, and other polymer manipulation techniques. *Bixler, Vieth*

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*

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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

10.83 ***School of Chemical Engineering Practice — Bayway Station***
Prereq.: 10.32
Year: U (2) 0–18–0
Similar to 10.85. For seniors during the second period of the academic year. *Bixler*

10.84 ***School of Chemical Engineering Practice — Bound Brook Station***
Prereq.: 10.32
Year: U (2) 0–18–0
Similar to 10.87. For seniors during the second period of the academic year. *Bixler*

10.85 ***School of Chemical Engineering Practice — Bayway Station*** **(A)**
Prereq.: 10.32
Year: G (1 or 2) 0–12–0
Conducted in the refinery area of Humble Oil and Refining Company, Linden, New Jersey: large scale production of gasoline, heating oils, tars, petrochemicals, and other petroleum products. Operations in all phases of petroleum refining and purification, including the manufacture of many petrochemicals. Problems in all phases of mass and heat transfer, kinetics, instrumentation, and other engineering operations. *Bixler*

10.86 ***School of Chemical Engineering Practice — Bayway Station*** **(A)**
Prereq.: 10.85
Year: G (1 or 2) 0–12–0
Continuation of 10.85. *Bixler*

10.87 ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
Prereq.: 10.32
Year: G (1 or 2) 0–12–0
Conducted in the main plant of the Organic Chemicals Division of American Cyanamid Company at Bound Brook, New Jersey. Highly diversified operations, including process development and production of dyes, synthetic pharmaceuticals, organic pigments, rubber chemicals, intermediates, textile chemicals, plastics, resins, and related products. *Bixler*

10.88 ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
Prereq.: 10.87
Year: G (1 or 2) 0–12–0
Continuation of 10.87. *Bixler*

GENERAL

10.90 ***Experimental Research Problem*** **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
For special and graduate students who wish to carry out some minor investigation in a particular field. Subject and hours to fit individual requirements. *G. C. Williams*

10.91 ***Experimental Research Problem***
Prereq.: ——
Year: U (1, 2) *Arr.*
For undergraduate students who wish to carry out a special investigation in a particular field. Topic and hours to fit individual requirements. *Meissner*

10.991 ***Seminar in Chemical Engineering*** **(A)**
Prereq.: 10.32
Year: G (1) 2–0–4

10.992 ***Seminar in Chemical Engineering*** **(A)**
Prereq.: 10.32
Year: G (2) 2–0–4
For students working on doctoral theses. *Gilliland*

12.
Geology and Geophysics

12.00 ***Earth Science (Geology, Geophysics, Geochemistry)***
Prereq.: ——
Year: 1 (2) 2–0–4
Lectures and demonstrations on the more important aspects of the origin, history, physical behavior and chemical constitution of the earth and the methods of reasoning and investigation by which the major concepts, laws and hypotheses of earth science were formulated. General topics to be discussed: earth origin and methods of determining sequence of events in geologic history; development of continents, oceans and mountains; evolution of plants and animals through geologic time; formation, distribution, and methods for discovery of minerals, rocks, ores, coal, petroleum and natural gas; reshaping of the earth's surface features by water, ice and wind; activities associated with earthquakes, volcanoes and hot springs; and discussion of the kinds of work carried on by earth scientists as geologists, geophysicists and geochemists. Local field trips to collect minerals and study features of bed rocks and glaciation. *Pinson*

12.001 ***Astronomy I***
Prereq.: ——
Year: 1 (1) 3–0–3
Survey of the history of astronomy and its contributions in philosophy and science to our modern civilization. Emphasis on present theories of the age, origin, and evolution of the Universe. Lectures on the basic physical and chemical principles and the instruments used in modern astrophysics, followed by a study of the planets and their relation to the Universe. Discussion of concepts of stellar magnitudes, spectral classification, stellar energy production, galactic dynamics, Universe expansion, and element origin. Orientation of the Earth to the Universe. Several trips to Harvard Observatory and Agassiz Station. *Pinson*

12.002 ***Astronomy II***
Prereq.: 8.04, 12.001
Year: U (1) 2–0–4
Survey of the history and basic data of astrophysics; review of atomic and molecular spectra applied to astrophysical problems; the spectral classification of the stars; interpretation of normal stellar spectra; stars with

peculiar spectra; the physics of the stars: binary stars including eclipsing and spectrographic binaries; the intrinsic variable stars; the Fraunhofer spectrum; spectra of planetary atmospheres; interstellar matter. Opportunities for telescopic observations and visits to Harvard College Observatory and Agassiz Station. *Pinson*

12.003 *Astronomy III*
Prereq.: 12.002
Year: U (2) 2–0–4
Some statistical data of astronomy; methods of measuring astronomical distances, centering about the establishment and reliability of the period — luminosity relationship; galactic clusters; globular clusters and population types; introduction to stellar evolution; structure, composition, and dynamics of the Milky Way; the Magellanic Clouds; and the revised time and distance scales of the Universe. *Pinson*

12.011 *Mineralogy I*
Prereq.: 5.02
Year: U (1) 3–4–3
Introduction to the symmetry, crystal chemistry, structure, and classification of minerals. Dennen, *Principles of Mineralogy.* *Dennen*

12.012 *Mineralogy II*
Prereq.: 12.011
Year: U (2) 3–4–3
Intensive study of minerals with emphasis on determinative methods. Use and occurrence of minerals. Identification and classification of rocks. Dennen, *Principles of Mineralogy.* *Dennen*

12.05 *Mineralogical Seminar* (A)
Prereq.: 12.202
Year: G (1 or 2) 2–0–4
Presentation and discussion of literature bearing on certain phases of theoretical mineralogy. *Buerger*

12.14 *Petrology*
Prereq.: 12.011, 12.301
Year: U (2) 2–0–4
Occurrence and origin of igneous and metamorphic rocks, with emphasis on correlation with experimental work. Turner and Verhoogen, *Igneous and Metamorphic Petrology.* *Fairbairn*

12.15 *Petrology Laboratory*
Prereq.: 12.231
Year: U (2) 0–6–0
Use of the polarizing microscope on thin sections of igneous, metamorphic, and sedimentary rocks. Rogers and Kerr, *Optical Mineralogy;* Williams, Turner, Gilbert, *Petrography.* *Fairbairn*

12.161 *Mineral Deposits and Petrology Seminar* (A)
Prereq.: 12.14, 12.40
Year: G (1) 2–0–4

12.162 *Mineral Deposits and Petrology Seminar* (A)
Prereq.: 12.161
Year: G (2) 2–0–4
Discussion of igneous and metamorphic rocks, mineral deposits, and problems bearing on their genesis. (*Alternate years.*) *Fairbairn, Hurley (12.161); Hurley, Fairbairn (12.162)*

12.17 *Advanced Petrology Laboratory* (A)
Prereq.: 12.15
Year: G (1) 0–4–2
Techniques of petrological research with applications of the Universal stage to mineralogical and petrofabric problems. Arranged to suit the requirements of individual students. *Fairbairn*

12.201 *Crystallography*
Prereq.: ——
Year: U (1) 2–2–2
Geometrical fundamentals of crystallography important in the study of mineralogy, metallography, chemistry, and solid-state physics. Symmetry and its restriction in crystals; crystal classes; crystal systems; crystal forms; methods of determining crystal symmetry; space groups; equipoints. Buerger, *Elementary Crystallography.* *Buerger*

12.202 *Crystallography*
Prereq.: 12.201
Year: U (2) 2–0–4
Introduction to the theory of the structure of crystals, and application of crystal structure concepts to crystallography and mineralogy, including elementary crystal chemistry, structures of the silicates, polymorphism and transformations, disordered structures, solid solution and segregate phase formation, crystal growth and habit, crystal imperfection and lineage structure, and plastic deformation of crystals. *Buerger*

12.231 *Optical Crystallography*
Prereq.: 12.011 or 12.201
Year: U (1) 0–6–2
Discussion of principles of optical crystallography, illustrated in the laboratory by the immersion method of crystal identification. Larsen and Berman, *Microscopic Determination of the Non-opaque Minerals* (U. S. G. S. Bull. 848); Wahlstrom, *Optical Crystallography.* *Fairbairn*

12.27 *Crystallographic Research* (A)
Prereq.: 12.201
Year: G (1 or 2) *Arr.*
Supervised research on a crystallographic problem. *Buerger*

12.301 *Physical Geology*
Prereq.: ——
Year: U (1) 3–4–4
Objective study of the earth including geological agents and processes. Structural relations of rock masses. Laboratory and field exercises. *Dennen*

12.302 *Historical Geology*
Prereq.: 12.301
Year: U (2) 3–4–4
Development of the surface features of the earth from the time of its origin to the present, including the nature and distribution of lands and seas during the past. Evolution of plants and animals. Principles and methods used in interpreting the geologic record of the past. *Mencher*

12.308T *Marine Geology and Sedimentology* (A)
Prereq.: 12.302
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*

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12.40 *Mineral Deposits* (A)
Prereq.: 12.011, 12.301
Year: G (1) 3–3–5
Occurrence and origin of metallic and nonmetallic mineral deposits. Laboratory study of ore-mineral relationships in major deposits by use of metallographic microscope on polished sections. Lindgren, *Mineral Deposits;* Short, *Microscopic Determination of the Ore Minerals* (U.S.G.S. Bull. 914). *Hurley*

12.441 *Petroleum Geology I*
Prereq.: 12.302
Year: U (1) 3–0–5
Nature and origin of petroleum and natural gas. Factors responsible for accumulation of oil and gas. Principles underlying interpretation of oil field data. (*Alternate years.*) *Mencher*

12.442 *Petroleum Geology II*
Prereq.: 12.441
Year: U (2) 3–0–5
Illustration of principles discussed in 12.441 by a study of typical oil fields. Applications to the location and evaluation of new fields. (*Alternate years.*) *Mencher*

12.45 *Petroleum Geology Laboratory*
Prereq.: 12.441
Year: U (2) 0–6–2
Methods of illustration and interpretation of oil field data, in conjunction with principles discussed in 12.441. Study of well cuttings, cores, logs. *Mencher*

12.461 *Petroleum Geology Seminar* (A)
Prereq.: 12.441
Year: G (1) 2–0–6
12.462 *Petroleum Geology Seminar* (A)
Prereq.: 12.461
Year: G (2) 2–0–6
Discussion of latest information on origin, migration, and accumulation of petroleum. Evaluation of new methods of exploration for oil deposits. Stratigraphy and structure of principal oil-bearing areas of world. *Mencher*

12.51 *Paleontology*
Prereq.: 12.302
Year: U (1) 3–3–6
Study of the past plant and animal life of the earth through comparison of fossils with living plants and animals. Shrock and Twenhofel, *Principles of Invertebrate Paleontology.* (*Not offered 1964–65.*) ——

12.582 *Advanced Sedimentology* (A)
Prereq.: 12.308T
Year: G (1 or 2) *Arr.*
Laboratory and microscopic study of the important primary and secondary physical, chemical and structural characteristics of sedimentary rocks using hand specimens, polished specimens and thin sections. Work arranged to suit the preparation and requirements of individual students. *Mencher*

12.583 *Sedimentology Seminar* (A)
Prereq.: 12.308T
Year: G (2) 2–0–6
Discussion of latest literature on the origin, deposition, classification and significance of sediments and sedimentary rocks. *Shrock, Mencher*

12.60 *Oceanography I*
Prereq.: 5.02, 8.02, 18.02
Year: U (1 or 2) 3–0–6
Introduction to different aspects of the oceans and their relations to the atmosphere, solid earth, and marine life. Lectures varying from term to term and given by staff members from both M.I.T. and the Woods Hole Oceanographic Institution. *Staff*

12.611 *Chemical Oceanography I* (A)
Prereq.: 5.02, 8.04
Year: G (1) 3–0–6
Study of the chemical systems in the oceans; the composition of sea water; the density-chlorinity-salinity relationships; the carbon dioxide system; the nutrient systems; dissolved gases; the routes and rates of material and energy transfer between hydrosphere, biosphere, and geosphere. Discussion of the methods of measurement of the dissolved substances in sea water. (*Restricted to graduate students in Geology and Geophysics; others admitted only by permission of instructor.*) *Carritt*

12.612 *Seminar in Chemical Oceanography* (A)
Prereq.: 12.611
Year: G (2) 3–0–6
Readings in the contemporary literature and discussion of several topics chosen to fit the backgrounds, fields of study, and interests of the participants. Topics in which chemical data are used in the interpretation of natural processes in the sea, such as carbon 14 dating in marine sediments in sea water; exchange of carbon dioxide (and other gases) across the sea surface; rates of physical, biological and geological processes in the oceans as inferred from chemical data; discussion of chemical species in natural fresh and salt waters. *Carritt*

12.613 *Oceanographic Methods and Measurements* (A)
Prereq.: 5.02; 8.04; 12.60 or 19.83
Year: G (1) 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*

12.65 *Special Problems*
Prereq.: ——
Year: U (1 or 2) *Arr.*
For seniors desiring special laboratory or field work on geologic problems. *Staff*

12.661 *Special Problems* (A)
to *Prereq.:* ——
12.664 *Year:* G (1 or 2) *Arr.*
For graduate students desiring special investigation of some geological subject or special laboratory or field work on geological problems. *Staff*

12.70 *Structural Geology*
Prereq.: ——
Year: U (1) 3–2–6
Elementary survey of rock structures and mechanics of rock deformation. Development of elementary concepts of plastic flow and fracture of 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*

12.72 *Mechanics of Rock Deformation I* (A)
Prereq.: 12.70, 18.06
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*

12.74 *Seminar in Structural Geology* (A)
Prereq.: 12.72
Year: G (1, 2) 2–0–4
Discussion of current research or advanced topics in tectonics, rock mechanics or experimental structural geology. *Brace*

12.801 *Theoretical Geology I* (A)
Prereq.: 5.61 or 8.04; 18.04
Year: G (1) 4–0–8
Applications of thermodynamics to geological problems — melt and aqueous equilibria, metamorphic equilibria in open systems, phase transitions, effects of the geothermal and pressure gradients, convection. Denbigh, *Chemical Equilibrium.* (*Not offered 1964–65.*) *Staff*

12.802 *Theoretical Geology II* (A)
Prereq.: 12.801
Year: G (2) 4–0–8
Application of the kinetic theory of solids to the estimation of the physical constants of minerals in the absence of complete experimental data, e.g. at high pressures, over geological times, on newly synthesized phases, on solid solutions. (*Not offered 1964–65.*) *Staff*

12.811 *Geochemistry I* (A)
Prereq.: 5.61
Year: G (1) 3–0–6
Intensive review of thermodynamics and solution physical chemistry with application to phenomena in the earth sciences. *Winchester*

12.812 *Geochemistry II* (A)
Prereq.: 5.62, 12.811, 12.813
Year: G (2) 3–0–6
Selected topics in chemistry applied to current geochemical research. (*Alternate years.*) *Winchester*

12.813 *Nuclear Geochemistry* (A)
Prereq.: 12.811
Year: G (2) 3–0–6
Introduction to nuclear chemistry with application to experimental geochemistry and to radioactive processes in nature. (*Alternate years. Not offered 1964–65.*) *Winchester*

12.814T *Earth Science Laboratory* (A)
Prereq.: ——
Year: G (1) 1–4–4
Laboratory work offered by several departmental staff members as an introduction to their research specialties. *Winchester*

12.815 *Cosmochemistry*
Prereq.: 5.02, 8.02
Year: U (2) 2–0–4
Description of the chemical history of the solar system with discussion of current research methods, including isotope and physical chemistry techniques. *Winchester*

12.83 *Introduction to Geophysics*
Prereq.: 8.04, 18.04
Year: U (2) 3–0–6
Study of various properties of the earth and its crust through indirect measurement. The shape of the earth, its probable composition, and the nature and history of its magnetic field, as well as investigation of some of the methods which give information on the nature of the crust. Attention given to instrumentation and interpretation of data. *Greenewalt*

12.831 *Elements of Geophysics I*
Prereq.: 8.041, *18.05*
Year: U (1) 3–0–9
Applications of potential theory to problems in gravity, magnetism, and steady electric current flow. Examples drawn from earth problems and from exploration geophysics. Inclusion of such topics as shape of the earth; isostasy; data collection, reduction, and interpretation. *Madden*

12.832 *Elements of Geophysics II*
Prereq.: 12.831
Year: U (2) 3–0–9
Study of elastic and electromagnetic wave propagation with applications to geophysics. Discussion of such topics as interpretation of deep earth structure, analysis of earthquake data, seismic wave propagation, seismic and electromagnetic prospecting problems, and treatment of earth's natural electromagnetic field. *Madden*

12.833 *Geophysical Laboratory*
Prereq.: 12.831
Year: U (2) 2–4–2
Experimental work in various phases of geophysics, including hydrodynamics, elasticity, and electromagnetism. Problems such as modelling, measurement of physical properties of materials, equipment design and construction, and field studies. *Greenewalt*

12.851 *Geophysical Analysis and Computation* (A)
Prereq.: 12.874, 18.06
Year: G (1) 2–1–6
12.852 *Geophysical Analysis and Computation* (A)
Prereq.: 12.851
Year: G (2) 2–1–6
Study of specific current geophysical problems to indicate where analytical treatment is no longer adequate and numerical procedures are necessary. Development and study of computational methods from the standpoint of high-speed computers. Presentation of reports on case studies by the students, covering both analytical and numerical work. (*Not offered 1964–65.*) *S. M. Simpson*

12.873 *Advanced Geophysics* (A)
Prereq.: 12.832 or 18.15
Year: G (1) 3–0–6
12.874 *Advanced Geophysics* (A)
Prereq.: 12.873
Year: G (2) 3–0–6
Advanced topics in the analysis and interpretation of geophysical phenomena. Inclusion of such problems as potential fields and acoustic, elastic, and electromagnetic waves occurring in the earth and atmosphere. *Madden, S. M. Simpson*

12.875 *Geomagnetism* (A)
Prereq.: 8.041
Year: G (1) 3–0–6
Description and analysis of geomagnetic field and secular variation. Hydrodynamics of rotating fluids; thermal convection; simple magnetohydrodynamic flows, including Alfven waves, Hartmann flow, homogeneous dynamos. Internal constitution of Earth. Theories of geomagnetism. Magnetic fields of other astronomical bodies. *Hide*

12.88 *Geophysics Seminar* (A)
Prereq.: 12.874
Year: G (1 or 2) 2–0–4
Problems of current geophysical interest; subject matter varying from term to term. *Hide, Madden, S. M. Simpson*

12.89T *Isotope Geology* (A)
Prereq.: 8.04, 12.301
Year: G (2) 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*

(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.

12.91 ***Mineral Industry I***
Prereq.: ——
Year: U (1) 3–0–6
Exploration and development of mines. Prospecting procedures and fundamentals of mining practice. Methods of production, management, organization, mining laws, health and safety. Field trips to properties which are in operation. (*Not offered 1964–65.*) *Parks*

12.92 ***Mineral Industry II***
Prereq.: 12.91
Year: G (2) 3–0–6
Application of advanced techniques to mine planning, development and administration. Cost and productivity estimates. Case studies. Opportunity for mine inspection trips. (*Not offered 1964–65.*) *Parks*

12.94 ***Mineral Economics***
Prereq.: ——
Year: U (1) 3–0–6
World mineral resources, their economic importance and industrial potential. Effects of distribution, control, monopolies, cartels, and tariffs on availability of mineral raw materials. Current mineral problems, national and international. (*Not offered 1964–65.*) *Parks*

12.95 ***Valuation of Mineral Property*** **(A)**
Prereq.: 12.92
Year: G (2) 3–0–6
Methods of examination and principles of valuation to equip the student with the theory of valuation and its practical application to representative types of mineral and oil property. Sampling, sampling calculations, estimation of ore, costs, selling prices, profit spread, the interest rate, depletion, and taxation. Parks, *Examination and Valuation of Mineral Property.* (*Not offered 1964–65.*) *Parks*

12.96 ***Mineral Economics Seminar*** **(A)**
Prereq.: 12.94
Year: G (1 or 2) *Arr.*
Detailed study or report on a particular mineral, area, or condition developing in the mineral field. (*Not offered 1964–65.*) *Parks*

12.97 ***Mineral Valuation Seminar*** **(A)**
Prereq.: 12.95
Year: G (1 or 2) *Arr.*
Optional study; engineering report on valuation of a mineral or oil property, or detailed investigation of some phase of the problem, e.g., taxation. (*Not offered 1964–65*). *Parks*

13.

Naval Architecture and Marine Engineering

13.00 ***Principles of Naval Architecture***
Prereq.: 1.612 or 2.201
Year: U (1, 2) 4–1–7
Hydrostatics; buoyancy and stability of water-borne vehicles in intact, damaged, and partially water-borne conditions; dynamics and hydrodynamics applied to resistance, propulsion, and interaction effects of ships; equations of motion applied to controlled and uncontrolled motions of vessels in smooth and rough water. Laboratory exercises in the Ship Model Towing Tank and the Propeller Tunnel. *Abkowitz, Kerwin, 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 drawing room on fairing of naval ship lines, calculations for and drawing of displacement and other curves, cross curves of stability, curves of statical stability and floodable length curves for a naval ship from preliminary design data. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Nicholson*

13.02 ***Propulsion Hydrodynamics*** **(A)**
Prereq.: 1.612 or 2.201; *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. *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*

13.10 ***Ship Structural Analysis and Design***
Prereq.: 2.01
Year: U (1) 3–3–6
General and local structural reactions of marine vehicles to their environment including consideration of materials, structural configurations, modes of failure, elastic and plastic instability, continuous frames, and plate theory. Integration and optimization of primary longitudinal structure. *J. H. Evans*

13.12 ***Naval Structural Theory I*** **(A)**
Prereq.: 2.05, 2.08
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 II*** **(RA)**
Prereq.: 13.12
Year: G (2) 3–0–6
Selected topics of advanced structural analysis including sidesway in continuous frames, optimization of structural sections, web discontinuities, stiffened plates under lateral load, stiffened cylindrical shells, and ship oscillation loadings. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *J. H. Evans*

13.14 *Naval Structural Design I* (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 *Naval 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.: 13.12
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.: 2.01, *2.201*, 2.403
Year: U (2) 4–1–7
Energy conversion devices and systems of types applicable to ships, involving thermal, mechanical, hydraulic, and electrical machinery; interaction of coupled devices under steady state and transient conditions; optimization principles. *Powell*

13.21 *Ship Propulsion* (A)
Prereq.: 2.403, 2.54
Year: G (1) 3–2–6
Subject matter same as 13.22, except for substitution for certain classified material. Most lectures in common with 13.22. *Porter, Powell*

13.22 *Naval Ship Propulsion* (RA)
Prereq.: 2.402, 2.54
Year: G (1) 3–2–6
Critical examination of the effect of naval ship propulsion requirements on the design of systems and components. Optimization of propulsion system parameters on the basis of minimum weight. Design studies and calculations specially selected to stimulate professional discussion. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Porter*

13.23 *Propulsion System Reliability and Control* (A)
Prereq.: 6.27 or 13.96 or 18.10 or 18.18
Year: G (2) 2–0–4
Application of statistical and operational research methods to systems reliability with constant and time-varying failure rates. Complex systems reliability optimization under constraints. Interaction of components and subsystems affecting 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.*) *Porter*

13.25 *Advanced Naval Electrical Engineering* (RA)
Prereq.: 6.03
Year: G (S) 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.*) *Porter*

13.30 *Mechanical Vibration*
Prereq.: 2.02 or 2.05
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. *F. M. Lewis*

13.31 *Mechanical Vibration* (A)
Prereq.: 2.05
Year: G (1) 3–0–6
Free and forced vibration of systems of a single degree of freedom; complex variable and vector representation; Fourier series; harmonic analysis by tabular and mechanical methods; systems of several degrees of freedom; torsional systems; balance of rotating machinery and reciprocating engines; elements of torsional vibration problems in reciprocating engines. *Den Hartog*

13.40 *Introductory Ship Design*
Prereq.: 13.00, 13.10
Year: U (2) 1–6–2
Engineering and economic principles involved in the selection of dimensions and coefficients of commercial ships; design of hull form and internal arrangements and prediction of performance criteria in comprehensive design exercise. A condensation of material offered in 13.41 to satisfy departmental design requirement for undergraduate degree. *Mandel*

13.41 *Principles of Ship Design* (A)
Prereq.: 13.00; 13.10 or 13.12
Year: G (1) 2–4–5
Fundamental distinction among water-borne vehicles; engineering, economic, and military principles involved in the selection of dimensions and coefficients of displacement type commercial ships and warships; influence on dimension selection of rough water as well as smooth water considerations; design of hull form; internal arrangement design with emphasis on subdivision for survival after damage. Design exercises in application of principles. (*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*

(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.

13.43 ***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.*) *Nicholson*

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.*) *Nicholson*

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.*) *Nicholson*

13.46 ***Preliminary Design of Naval Ships*** **(RA)**
Prereq.: 13.41, 13.45
Year: G (2) 0–9–3
Work in the drawing room, including the preparation of the necessary plans and calculations for the preliminary design of a naval ship. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Nicholson*

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.*) *Staff*

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.*) *Staff*

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.: 6.27 or 13.96 or 18.10; 13.00; 13.10; 13.20; 14.01
Year: G (1) 2–0–4
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. Application of systems engineering and operations research for information flow and response prediction. Integration of the transportation system. *Frankel*

13.94 ***History of Naval Ships*** **(R)**
Prereq.: ——
Year: G (1) 3–0–4
A seminar-type subject supplemented by lectures by members of the faculty and other authorities. Designed to give a perspective view of the characteristics of warships, including the interrelationships of such characteristics and the naval policies of the several powers, particularly the United States. Warship developments of World War II and possible developments of the future. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Nicholson, MacIsaac*

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; cavity flows; jet and boundary layer noise. Radiation of sound by various types of sources. Transmission of sound in the ocean. Fundamentals of active and passive sonars. Vibrations in marine structures and machinery. Engineering applications to ship and submarine noise control.

13.96 ***Application of Operational Methods***
Prereq.: 18.04
Year: U (2) 4–0–8
Elementary probability theory, statistics, programming methods, and application to transportation, distribution, and marine design problems. Shipping system analysis, scheduling, flow procedures, decision strategies, and information search and analysis with particular reference to shipping and shipbuilding in the integrated transportation system. *Frankel*

14.
Economics and Social Science

GENERAL ECONOMICS AND THEORY

14.003 ***The Modern World and Social Science***
Prereq.: 21.02
Year: U (1, 2) 3–0–5
Study of the development of the business, economic, and parliamentary political systems in the Western world. Consideration of the nature of economic and political scientific theory. Limited registration. *Pool*

14.004 ***The Modern World and Social Science***
Prereq.: 14.003
Year: U (2) 3–0–5
Study of the changing nature of nationalism, international relations, diplomacy, and war in the twentieth century; study of the politics of mass society, the totalitarian state, and the developing non-Western world. Further consideration of the nature of social science. Limited registration. *Pool*

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, gov-

ernment 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. *Bishop*

14.04 *Industrial Organization and Public Policy*
Prereq.: 14.02
Year: U (2) 3–0–5
Case studies of the economic organization of particular American industries, with evaluations of their efficiency and technological progressiveness; anti-trust laws and other regulations of business. *MacAvoy*

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. *R. E. Freeman*

14.06 *Structure of the American Economy*
Prereq.: 14.03
Year: U (2) 3–0–5
Study of magnitudes and quantitative relationships in the American economy having special relevance to an evaluation of the performance of the economy (its efficiency, growth, etc.), and to the design of public policy. Two or three special topics selected for detailed exploration; e.g., government expenditure, capital formation, industrial concentration, war-potential, labor force, income distribution, productivity, foreign trade. *Eckaus*

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. *Domar*

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.) *Domar*

14.09 *Economic Problems Seminar*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
A seminar designed to complete a three-term humanities combination in economics and taking up selected problems of business and public policy, chosen because of their current interest or continuing significance for engineers and scientists. Development and application of the analytical techniques of 14.01 and 14.02. (*Sections limited to fifteen students.*)

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. *Fisher*

14.11 *Linear and Nonlinear Programming*
Prereq.: 14.03; 18.15 or 18.20
Year: U (1) 3–0–5
Origin of linear programming problems. Properties of solutions. Simplex and other methods of computation. Duality and interpretation of the dual problem. Applications to firm, industry, and aggregate planning. Nonlinear programming. Discrete programming. Relations to general economic theory. *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.*) *Rosenstein-Rodan*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

14.116 ***Economics and Finance: Principles and Policies III*** **(A)**
Prereq.: 14.115
Year: G (2) 3–0–6
Continuation of 14.115. (*Restricted to Sloan Fellows.*) *Adelman*

14.117 ***Economics and Industrial Management***
Prereq.: 14.01
Year: G (1) 3–0–6
Introduction to measurement and determination of national income and national product; economic fluctuations and effectiveness of stabilization policies, especially monetary and fiscal. (*Restricted to graduate students in Course* XV.) *Alexander*

14.121 ***Economic Analysis*** **(A)**
Prereq.: 14.03
Year: G (1) 3–0–6

14.122 ***Economic Analysis*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Interdependent growth of theory and fact, general theory of equilibrium under competition and monopoly. Findings revalued under conditions which more closely approach reality. *Bishop* (*14.121*), *Samuelson* (*14.122*)

14.123 ***Advanced Economic Theory*** **(A)**
Prereq.: 14.122
Year: G (1) 3–0–6
Continuation of 14.121 and 14.122 to cover more difficult aspects of material, together with still other branches of price and distribution theory and welfare economics. Content varying from year to year. *Solow*

14.132 ***Schools of Economic Thought*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Economic ideas developed by different groups of economists in recent times. *Rosenstein-Rodan*

14.151 ***Mathematical Approach to Economics*** **(A)**
Prereq.: 14.122
Year: G (1) 3–0–6
The use of mathematical methods in all the fields of economics. *Samuelson*

14.161 ***Economic History*** **(A)**
Prereq.: 14.121
Year: G (1) 3–0–6
Analysis of development of world economy and major national economies in terms of theory of economic growth, 1750–1873. *Travis*

14.162 ***Economic History*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Analysis of development of world economy and major national economies in terms of theory of economic growth, 1873 to present. *Letwin*

14.171 ***Theory of Economic Growth*** **(A)**
Prereq.: 14.122, 14.451
Year: G (1) 3–0–6
The interaction of economic variables in the long-run growth process. Theoretical models of the relationships among population and resource patterns, capital formation, monetization of the economy and growth of markets, technological change, sectoral patterns of investment, foreign trade, and the like. *Rosenstein-Rodan*

14.172 ***Research Seminar in Economic Development*** **(A)**
Prereq.: 14.171
Year: G (2) 3–0–6
Conceptual and empirical problems of conducting both library and field research on economic development. Discussion of formulation of relevant research topics, problems of quantification and measurement, interpretation of results, etc. Case materials from literature and from research in progress. *Millikan*

14.182 ***Capitalism, Socialism and Growth*** **(A)**
Prereq.: 14.121, 14.451
Year: G (2) 3–0–6
A comparative study of capitalist and socialist economies mainly from the point of view of development and growth, and with major emphasis on the economy of the Soviet Union. *Domar*

14.191 ***Economics Seminar*** **(A)**
Prereq.: 14.121
Year: G (1) 3–0–6

14.192 ***Economics Seminar*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Special economic problems. (*Open to graduate students only.*)

14.195 ***Reading Seminar in Economics*** **(A)**
Prereq.: 14.121
Year: G (1) *Arr.*

14.196 ***Reading Seminar in Economics*** **(A)**
Prereq.: 14.121
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, 2) 3–0–5
Analysis of key economic features of particular industries such as nature of production process, characteristics of demand for its output, financial problems, growth, stability, and location. Entire term ordinarily to be spent on two or three industries such as transportation, chemical, machinery, fuel and power, minerals, and retail. *MacAvoy*

14.23 ***Economics of Fuel and Power***
Prereq.: 14.02
Year: U (2) 3–0–6
Survey of the main trends in production, pricing, and investment costs of coal, electric power (hydro- and thermal electricity), crude oil, and refined oil products. Economics of nuclear power. An energy program for an underdeveloped country. Intended for students of either economics or engineering. *Rosenstein-Rodan*

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.: 14.02
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.: 18.04
Year: U (1) 3–0–6

Elementary but mathematical viewpoint. Random variables, elements of probability, mathematical expectation, generating functions, probability distributions, sampling theory, correlation and regression. *H. A. Freeman*

14.372 *Statistical Theory* (A)
Prereq.: 14.371
Year: G (2) 3–0–6

Elements of theories of estimation and testing hypotheses, maximum likelihood, the general linear hypothesis, Gauss-Markoff theorem. *H. A. Freeman*

14.374 *Design and Analysis of Scientific Experiments* (A)
Prereq.: 14.371 or 18.10
Year: G (2) 3–0–6

Application of modern statistical theory to the design and analysis of scientific experiments. Discussion ranging from simple comparative experiments to experiments involving many factors and many variables, and centering on designs using analysis of variance. *H. A. Freeman*

14.381 *Statistical Method*
Prereq.: 14.101
Year: G (2) 3–0–6

Elementary survey, designed to fill the minimum needs of students not prepared for 14.371. Elementary principles of probability and statistical inference, with emphasis on those topics most useful in the analysis of economic data. *Shell*

14.383 *Econometrics* (A)
Prereq.: 14.102 14.372
Year: G (1) 3–0–6

Principal statistical problems in the analysis of economic phenomena, including identification, least-squares bias, and autocorrelation, with emphasis on recent estimation procedures. Term project applying econometric techniques to economic phenomena required for each student. *Fisher*

14.384 *Advanced Topics in Econometrics* (A)
Prereq.: 14.383
Year: G (2) 3–0–6

Selected topics including specification error, non-linear estimation, simulation, aggregation, and the derivation of economic policy models. Term paper required. *Fisher*

14.39 *Economic Research Seminar*
Prereq.: 14.371
Year: U (1) 2–0–6

Introduction to research procedures in economics in preparation for thesis. Students to prepare reports on research topics. *Eckaus, R. Evans*

14.391 *Research Seminar in Economics* (A)
Prereq.: 14.122, 14.452
Year: G (1, 2) 2–0–7

Individual or team participation in a single substantial project involving empirical or theoretical research with required report. Discussion of technical and statistical problems, as they arise. Varying topics from year to year. *Staff*

NATIONAL INCOME AND FINANCE

14.40 *Monetary and Banking Policy*
Prereq.: 14.02
Year: U (2) 3–0–5

Monetary factors affecting the level of national income and relationships of financial institutions to these factors. Financial organization of society: the money-banking system, credit institutions, capital markets, fiscal policy, international financial relations. *R. E. Freeman*

14.43 *Public Finance*
Prereq.: 14.02
Year: U (1) 3–0–5

Effects of government revenue and expenditure programs on the level and distribution of economic activity; intergovernmental fiscal problems; relationship of fiscal to other economic policies. *E. C. Brown*

14.451 *Theory of Income and Employment* (A)
Prereq.: 14.05
Year: G (1) 3–0–6

Examination of principal determinants of aggregate levels of income and employment. *Domar*

14.452 *Economic Growth and Fluctuations* (A)
Prereq.: 14.451
Year: G (2) 3–0–6

Application of theory of income and employment to analysis and measurement of changes in level of economic activity over time, and to study of inflation. *Solow*

14.462 *Monetary Economics I* (A)
Prereq.: 14.121, 14.451
Year: G (2) 3–0–6

Examination of sources and determinants of supply of money with special attention to roles of commercial banks, Federal Reserve System, and Treasury. Discussion of nature of demand for money. Role of monetary policy in determination of level of economic activity. *Modigliani*

14.463 *Monetary Economics II* (A)
Prereq.: 14.122, 14.452
Year: G (1) 3–0–6

General equilibrium theory of money, interest, prices, and output; portfolio problems, cost of capital, and the effects of monetary phenomena on investment and accumulation of wealth with special reference to problems arising from uncertainty. *Samuelson*

14.471 *Fiscal Economics I* (A)
Prereq.: 14.03, 14.05
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 activ-

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ities. First term: particular fiscal devices and institutional arrangements examined by partial equilibrium techniques. Second term: the interrelationships of whole tax systems, stabilization problems, distributional and resource-allocation implications. Either term may be taken separately. *E. C. Brown*

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*

INTERNATIONAL ECONOMICS AND RELATIONS

14.51 *International Relations*
Prereq.: 14.003
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*

14.52 *Principles and Problems of American Foreign Policy*
Prereq.: 14.51
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. *Saloma*

14.521 *Development of General War Systems and Strategies* (A)
Prereq.: 14.53 or 14.531
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*

14.522 *Development of Limited War Systems and Strategies* (A)
Prereq.: 14.521
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*

14.523 *Introduction to Systems Analysis for Defense*
Prereq.: 14.522
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. *Kaufmann*

14.524 *Research Problems in Defense* (A)
Prereq.: 14.523
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*

14.526 *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*

14.53 *Seminar in International Politics*
Prereq.: 14.52
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. *Clemens*

14.531 *Theory and Practice of International Relations* (A)
Prereq.: 14.53 or 14.98
Year: G (1) 3–0–6
The conceptual framework of international relations; analysis of 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*

14.532 *Goals and Strategies in Foreign Affairs* (A)
Prereq.: 14.52 or 14.531 or 14.571
Year: G (2) 3–0–6
Identification of foreign policy goals and interests, and the development of short- and long-term political doctrines and strategies. Factors in policy formulation — political, military, psychological, and technological — and the process of decision-making for foreign affairs. Illustrative problems of policy-making, and consideration of political gaming as a test for strategy. (*Not offered 1964–65.*) *Bloomfield*

14.533 *Function of Law in the World Community* (A)
Prereq.: 14.53 or 14.901
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 1964–65.*) *Padelford*

14.534 ***The UN System and Problems of Political Development*** **(A)**
Prereq.: 14.53 or 14.531
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*

14.535 ***U.S. Foreign Policy and Problems of Technological Change*** **(A)**
Prereq.: 14.53
Year: G (1) 3–0–6
Analysis of selected issues confronting U.S. foreign policy, with special emphasis on questions arising out of scientific and technological change, such as the problem of arms control and disarmament. *Bloomfield*

14.54 ***International Trade***
Prereq.: 14.01; 14.02 or 14.51
Year: U (2) 3–0–5
Theory of international trade and finance, and application to current problems, such as exchange restrictions, economic development, and foreign aid. *Kindleberger*

14.55 ***Prediction of Social and Political Change***
Prereq.: 14.02 or 14.52 or 21.403 or 21.525
Year: U (2) 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*

14.57 ***Contemporary Ideas on Political and Economic Development***
Prereq.: 14.003
Year: U (1) 3–0–5
Evaluation of major political ideas from the 1890's to the present, with special attention to the problems that arise in their application to economic and political practice. Study of political ideas with regard to the actual performance by which they have been followed. ——

14.571 ***Major Problems in United States Foreign Policy***
Prereq.: 14.53
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. ——

14.58 ***Nationalism and National Development***
Prereq.: Any two 14 subjects
Year: G (2) 3–0–5
The interplay of political ideas and social institutions in the case of nationalism in the present era. Survey of ideas of nationality and contrast with the verifiable realities of peoples and countries. Effect of urbanization and industrialization on nationalism, and effect of nationalism on further political and economic development. Study of leaders and decisions against background of broad trends and particular movements. Survey of forces making for national sovereignty and contrast with trends toward federal government, economic unions, or international organization. ——

14.581 ***International Economics*** **(A)**
Prereq.: 14.03, 14.05
Year: G (1) 3–0–6

14.582 ***International Economics*** **(A)**
Prereq.: 14.581
Year: G (2) 3–0–6
The foreign exchange market, foreign trade and commercial policy, with emphasis on the relation of the items in the current account to national income: international finance and the achievement and maintenance of equilibrium in the balance of payments as a whole: current problems of international economics. *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.: 14.901
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. (*Not offered 1964–65.*) ——

14.586 ***Interregional Economics*** **(A)**
Prereq.: 14.03
Year: G (1) 3–0–6
Problems of economic analysis as affected by the geographical separation of resources and markets; factors leading to interregional trade; the role of transportation with particular reference to national transportation policy; problems of industrial location and regional competition; interregional adjustment of diverse economic activities; regional economic planning in the context of national economic policy. (*Not offered 1964–65.*) *Lefeber*

14.59 ***Reading Seminar in Social Science***
Prereq.: ——
Year: U (1, 2) *Arr.*
Reading and discussion of special topics in the fields of social science. Open to advanced undergraduates by arrangement with individual staff members. *Staff*

14.60 ***Arms Control, Disarmament, and Foreign Policy***
Prereq.: 14.51
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. (*Not offered 1964–65.*) *Bloomfield*

14.61 ***Postwar U.S. Defense Policies***
Prereq.: 14.52
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*

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14.62 ***Current U.S. Defense Problems***
Prereq.: 14.61
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*

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. *Myers*

14.64 ***Labor Economics and Public Policy***
Prereq.: 14.63
Year: U (1, 2) 3–0–5
Particular applications of the analytical tools developed in prerequisite subjects to two aspects of the industrial relations scene: (1) the economics of collective bargaining, problems presented by wage determination at firm, industry, and economy levels; and (2) the development of public policy on the rights and obligations of employers, unions, and workers. *R. Evans*

14.671 ***Problems in Labor Economics*** **(A)**
Prereq.: 14.64
Year: G (2) 3–0–6
Development of the labor movement, and detailed analysis of collective bargaining and union policies on wages, hours of work, entrance to the trade, hiring, layoffs and transfers, make-work and restriction of output, technological change, union-management cooperation, and industry-wide agreements. The economic aspects and effects of these policies. *Hildebrand*

14.672 ***Public Policy on Labor Relations*** **(A)**
Prereq.: 14.64
Year: G (1 or 2) 3–0–6
Major trends in labor legislation, the legality of union activities, protection of the right to organize and bargain collectively, regulation of wages and hours, governmental machinery for the adjustment of labor disputes, and social insurance. The broad economic and social questions raised by these trends. *D. V. Brown*

14.673 ***Labor-Management Relations and Public Policy*** **(A)**
Prereq.: 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, Hildebrand*

14.674 ***The Labor Movement: Theories and Histories*** **(A)**
Prereq.: 14.64
Year: G (1) 3–0–6
Comparative analysis of labor organization in different contexts. (1) A review of traditional theories of the labor movement. (2) Examination of key labor problems common to industrialized or industrializing countries. (3) Historical analysis of labor organization in selected countries. (*Not offered 1964–65.*) ——

14.681 ***Seminar in Personnel Administration*** **(A)**
Prereq.: 14.63, 15.30
Year: G (1) 3–0–6

14.682 ***Seminar in Personnel Administration*** **(A)**
Prereq.: 14.681
Year: G (2) 3–0–6
Theory and practice of case study as dynamic learning. Experimentation with the "Incident Process" of case analysis. Demonstrations, followed by delegation of responsibility to the class for preparing and presenting case material and discussing these cases. Other objectives: learning to distinguish between facts and opinions, summarizing key facts, formulating issues, making and testing practical decisions, and generalizing from case situations. *Pigors*

14.69 ***Labor Problems Seminar***
Prereq.: 14.64
Year: U (1 or 2) 3–0–5
Supplements the humanities combination in labor relations and labor economics. Selected labor problems chosen for their current interest or continuing significance. Development and application of problems and techniques of 14.63 and 14.64. (*Section limited to fifteen students.*) *R. Evans*

14.691 ***Research Seminar in Industrial Relations*** **(A)**
Prereq.: 14.671 or 14.672
Year: G (1) 3–0–6
Discussion of important areas for research in industrial relations, frameworks for research, research techniques, and methodological problems. Centered mainly on the thesis research of advanced graduate students. *Myers*

14.692 ***Research Seminar in Industrial Relations*** **(A)**
Prereq.: 14.691
Year: G (2) 3–0–6
Continuation of 14.691. *Myers*

14.693 ***Collective Bargaining and Union-Management Cooperation*** **(A)**
Prereq.: 14.63
Year: G (2) 3–0–6
Intensive discussion of collective bargaining problems in particular industries and introduction to plans for union-management cooperation in solving production problems and reducing costs. ——

POLITICAL SCIENCE
(see also international economics and relations)

14.901 ***Concept Formation and Research Technique in Political Behavior***
Prereq.: ——
Year: G (1) *Arr.*
Requirements for testable concepts and innovations in research technique relating to attitudes, institutions, decision-making. Case studies on key problems of national, international, and comparative processes. (*Not offered 1964–65.*) *Lerner*

14.902 ***Theory of Political Processes***
Prereq.: 14.901
Year: G (2) 3–0–6
Analysis of the theoretical assumptions underlying the political process at different levels and in different systems with a view to identifying structures and functions; representing these elements by suitable concepts or variables and examining their interrelationships in some scheme or model. Testing of different theoretical models by the insights they may yield about the same political practices or institutions as well as by their ability to bring out contrasts among different processes or types of government. *Pool*

14.903 ***Introduction to Mathematical Models in the Social Sciences***
Prereq.: 14.901
Year: G (1) 3–0–6
Consideration in detail of three or four models in various areas of social science. Some drilling in the mathematics involved. Specially intended for people with little mathematical background. *Lehrer*

14.91 ***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*

14.915 ***Soviet Communist System*** **(A)**
Prereq.: 14.92 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*

14.916 ***Research Methodology in Problems of International Communism***
Prereq.: 14.901 or 14.915
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. *Griffith*

14.918 ***Politics in the Transitional Middle East***
Prereq.: 14.901 or 14.92
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. *F. W. Frey*

14.92 ***Comparative Political Systems***
Prereq.: 14.003
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. *Fein*

14.921 ***Theories of Political Development*** **(A)**
Prereq.: 14.52 or 14.901
Year: G (1) *Arr.*
Study of various analytical models of the political process in transitional societies. Systematic examination of factors influencing political behavior in changing societies; functions of politics in such societies. *Pye*

14.922 ***Comparative Asian Politics*** **(A)**
Prereq.: 14.901 or 14.921
Year: G (2) *Arr.*
Comparative analysis of political systems of Asia. Special attention to the processes of social change and the problem of political stability. Study will cover the transition from traditional and colonial systems to the contemporary ones. *Pye*

14.923 ***The Development of Political Organizations*** **(A)**
Prereq.: 14.901
Year: G (1) *Arr.*
Examination of the factors involved in the origins, development, and maintenance of various types of political organizations. Emphasis on the creation of political parties and maintenance of local party organizations in underdeveloped areas. *Weiner*

14.924 ***Economic Development as Social Change*** **(A)**
Prereq.: 14.121 or 14.901
Year: G (2) 3–0–6
Theory of social change, with the transition from traditional to technologically progressive society as the case to be studied. Presents a general system of theory, with personality, social, political, cultural, and economic-technical variables. *(Not offered 1964–65.)*

14.925 ***Technological Progress and Political Behavior*** **(A)**
Prereq.: 14.924
Year: G (1) 3–0–6
Theoretical introduction, then case studies of causal interrelations between technological progress and political organization and behavior in the early stages of industrialization. Will deal both with political organization as a factor influencing technological progress and with technological change as a factor causing change in political organization and behavior.

14.927 ***Special Problems in Contemporary Political and Economic Development*** **(A)**
Prereq.: 14.901 or 14.902
Year: G (1, 2) *Arr.*
Analysis of principles of social organization, social stratification and social mobility as they affect various aspects of political development such as political participation, political leadership, political organization, legitimacy, and political integration. *Weiner*

14.928 ***Special Problems in Comparative Politics*** **(A)**
Prereq.: 14.902 or 14.922
Year: G (1, 2) *Arr.*
Reading, consultation, special lectures, and original investigation on selected problems of contemporary politics in Asia or Africa.

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14.93 ***Seminar: Issues in Contemporary American Politics***
Prereq.: 14.91 or 14.92
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*

14.94 ***Government, Politics and Technology***
Prereq.: 14.91
Year: U (2) 3–0–5
An examination of the impact of science on political ideologies and processes; the major public policy issues which technological advance poses for governments; the ways in which science modified patterns of political activity and institutions; the role of the scientist in political decision-making. Special emphasis on student projects which explore actual cases of political controversy involving technological change. *R. C. Wood*

14.941T ***Public Management of Science***
Prereq.: ——
Year: G (2) 3–0–6
Nature of public organizations and organizational behavior, with special emphasis on the role of the scientist and professional executive in the administrative process. Examination of major theories of bureaucracies and public administration, by reference to specific cases involving policy-making and execution, and the relation of elected and non-elected officials. *R. C. Wood*

14.942T ***American Federal System*** **(A)**
Prereq.: 14.91
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. *R. C. Wood*

14.943 ***Politics and Outer Space*** **(A)**
Prereq.: 14.51 or 14.91
Year: G (1) 3–0–6
Inquiry into some of the urgent problems posed by the opening of the Space Age for international relations, for government and society, and for the individual. Consideration of peaceful uses; economic impact; behavioral aspects; problems for public administration; and relevant issues of international politics, organization, and law. *Bloomfield*

14.944 ***Scientific Development and Government Policy*** **(A)**
Prereq.: 14.94 or 14.941T
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. *(Not offered 1964–65.)* *Killian*

14.945 ***Science and American Foreign Policy***
Prereq.: 14.944
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. *Skolnikoff*

14.946 ***American Science and Its Development: Current Issues and Problems***
Prereq.: 14.944
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. *R. C. Wood, Skolnikoff*

14.95 ***Politics, Society, and Policy-Making***
Prereq.: Any previous social science subject
Year: U (1) 3–0–5
Case material on decision-making examined with a view to seeing what types of persons are likely to take action and in what ways under a variety of conditions. Cases involve conflicts of parties, pressure groups and governmental policy makers in the U. S. Congress and in foreign decision-making bodies. *Pool*

14.951 ***Changing Outlooks and Identities in World Affairs***
Prereq.: ——
Year: G (1) *Arr.*
Changes in human relations resulting from changes in power relations, new conceptions of others and of self arising, e.g., out of the end of colonial rule and the emergence of new national sovereignties in Asia and Africa; changes in national identities and in patterns of race attitudes and behavior; the consequences of the recession of white supremacy systems in Asia, the world, including the United States; problems of psychological re-tooling in the new modes of interaction among Americans, Europeans, Asians, and Africans. *Isaacs*

14.953 ***Mass Media and Communication Systems***
Prereq.: ——
Year: G (2) *Arr.*
Examination of the pattern of communication in societies at different stages of development. Comparison of networks of oral communication with systems based on mass media. The role of opinion leaders, informal communication networks, literacy, the press, radio, film, and international communications. *Pool*

14.954 ***Methods of Communication Research*** **(A)**
Prereq.: 14.901
Year: G (1) 3–0–6
Survey analysis, content analysis, with some study of the institutional structure of communications and of communication flows. For students needing to secure or evaluate data about public opinion and attitude formation under the impact of communication. *F. W. Frey*

14.956 ***Public Opinion and Propaganda***
Prereq.: ——
Year: G (1) 3–0–6
History and development of public opinion as a factor in public policy: relationship of public opinion and private attitudes; organization of political parties and pressure groups; techniques used by them; conditions of effective and ineffective communications. *Pool*

14.957 ***Research Seminar in International Communications*** **(A)**
Prereq.: 14.901
Year: G (1) *Arr.*

14.958 *Research Seminar in International Communications* (A)
Prereq.: ——
Year: G (2) *Arr.*
Cooperative examination of key problems in this field. (*Not offered 1964–65.*) *Lerner*

14.96 *Power, Influence and Policy Decisions*
Prereq.: 14.95
Year: U (2) 3–0–5
Review of factors shaping such decisions as those examined in 14.95. Systematic analysis of communication flows, the values, motivations and personality traits of political activists, and the structure of power among them. Uses of game theory, operational codes, and elite analysis. *F. W. Frey*

14.961 *Personality, Society, and Politics*
Prereq.: 14.901
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 1964–65.*) ——

14.962 *Identity and Ideology*
Prereq.: 14.004
Year: G (2) 3–0–6
Psycho-social and psycho-sexual problems of youth. Identity crisis and identity diffusion. Ideology as a transient necessity for individual maturation and for the rejuvenation of society. Application to political problems. (*Not offered 1964–65.*) ——

14.97 *Asian Political Systems*
Prereq.: ——
Year: U (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. *Weiner*

14.98 *Political Science Seminar*
Prereq.: 14.97
Year: U (2) 3–0–5
Seminar for students in political science program with members of the faculty to explore various aspects of selected problems in political science. Coordination of thinking from the varying points of view of political science and development of ability to deal with issues of decision-making. *Weiner*

14.99 *Structure of Urban Life*
Prereq.: 14.91
Year: U (2) 2–4–10
Intensive survey of the political, economic and social systems in organized urban life today and the major public policy issues of urban regions, combining class and field work in a joint seminar with students from Dartmouth College. A weekly class meeting, in addition to an extensive coordinated field investigation of a highly urbanized area in Boston, employing the principal research techniques of social science. *R. C. Wood*

14.991 *Reading Seminar in Social Science* (A)
Prereq.: ——
Year: G (1) *Arr.*

14.992 *Reading Seminar in Social Science* (A)
Prereq.: ——
Year: G (2) *Arr.*
Reading and discussion of special topics in the fields of social science. Open to advanced graduate students by arrangement with individual staff members. ——

15.
Industrial Management

15.01 *Industrial Management I*
Prereq.: 14.01
Year: U (2) 3–0–6
Economics of the firm and of the industry. How the price-profit system works through operation of supply and demand. Market structures and market behavior in specific industries. *S. S. Alexander*

15.012 *Economics of the Firm*
Prereq.: ——
Year: G (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. (*Restricted to School of Industrial Management graduate students; others admitted only with permission of instructor.*) *S. S. Alexander*

15.02 *Industrial Statistics*
Prereq.: 18.03
Year: U (1) 3–0–6
Introduction to statistical methods with application to engineering and administrative problems. Basic statistical distributions including binomial, hypergeometric, Poisson, exponential, normal, and Chi-square. Introduction to acceptance sampling, quality control, and the analysis of variance. *Durand*

15.025 *Statistical Method*
Prereq.: ——
Year: G (2) 3–0–6
Essentially the same material as 15.02; but at a slower rate and without going as deeply into mathematical derivations. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Durand*

15.032 *Sampling of Human Populations* (A)
Prereq.: 15.025
Year: G (2) 3–0–6
This subject is designed specifically for students in advanced marketing and demand analysis. Cluster sampling; equal and unequal sized cluster; cluster sampling with and without sub-sampling; multi-stage sampling; combinations of cluster sampling and stratified sampling; disproportionate stratified sampling; two-phased and sequential sampling. *Durand*

15.04 *Psychology and Human Organization*
Prereq.: 15.01, 15.02, 15.50T
Year: U (1, 2) 3–0–6
Organization theory and behavior. Introduction to psychological theory and research relevant to the behavior of people in groups and organizations. *Berlew*

15.091 *Mathematics for Industrial Management*
Prereq.: ——
Year: G (1) 3–0–6
Designed to strengthen the mathematical background of entering graduate students. Topics include basic concepts of the calculus, set theory, combinatorial mathematics, probability, difference equations, and aspects of elementary statistical decision theory. (*Restricted to School of Industrial Management graduate students.*) *Kaufman*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

15.092 ***Mathematics for Industrial Management***
Prereq.: 15.091
Year: G (2) 3–0–6
Continuation of 15.091. Topics include vector spaces, matrix algebra, and methods of optimization, e.g. linear programming and dynamic programming. (*Restricted to School of Industrial Management graduate students.*) *Kaufman*

15.094J ***Probabilistic Systems Analysis***
(Same subject as 6.27J)
Prereq.: 18.04
Year: U (1) 3–0–6
A subject serving both as a self-contained development for students wishing to become familiar with the theory and application of probabilistic concepts and as a foundation for graduate subjects in engineering, science, and management. Theory of probability presented on an axiomatic basis. Topics ranging from algebra of events to stochastic processes and simulation. Heavy emphasis on sample space concept for both discrete and continuous random variables. Discussion of operations on random variables, discrete and continuous transform techniques, common distributions, limit theorems, statistics, renewal processes, and computer analysis. Consideration of implications of probability theory for decision making, data analysis, and system modeling. Applications presented concurrently with development of the theory.
R. A. Howard

15.095 ***Statistical Decision Theory*** **(A)**
Prereq.: 15.094J
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 experimental design for common random processes. The place of dynamic programming and game theory in statistical decision. Examples drawn from a variety of operational systems. *R. A. Howard*

15.11 ***Introduction to Industrial Management***
Prereq.: 14.01
Year: U (1, 2) 3–0–6
Over-all view of managerial activities to develop interest in industrial administration. Not open to Courses XIV and XV. Basic treatment of fundamental principles and general practices of industrial management. Brief but specific coverage of selected important facets of marketing, finance, production, personnel, and administration. Relationship of scientist and engineer to functions and decisions of management. *L. B. Moore*

15.17 ***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*

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*

15.183T ***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.*) *Morison*

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

15.185T ***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.*) *Goetz, Forrester*

15.186 ***Marketing*** **(A)**
Prereq.: 15.181, 15.182
Year: G (2) 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.*) ——

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 School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Letwin, Travis, Brower*

15.221 ***International Business Management I*** **(A)**
Prereq.: 14.117
Year: G (1) 3–0–6
Theoretical and institutional environment of international business, with special reference to the role of Western enterprise in development of non-Western societies; Western enterprise and political development; conflict of interest in international trade and investment; analytical tools or criteria for finding and measuring economic risk, monetary risk, political risk, legal-commercial risk; institutional assistance to international business; relevant U. S. tax and antitrust law. *Robinson*

15.222 ***International Business Management II*** **(A)**
Prereq.: 15.221
Year: G (2) 3–0–6
Operational problems arising from the international nature of business, with special reference to the relationship between a Western enterprise and an associated firm operating in a non-Western society; forms of international business relationship, internal organization of a firm conducting international business; problems of personnel relations, procurement, production, marketing, finance, and public policy. *Robinson*

15.231 ***Management of Economic Development*** **(A)**
Prereq.: 14.117, 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 ***Public and Private Enterprise in Developing Nations*** **(A)**
Prereq.: 15.231
Year: G (2) 3–0–6
Policies and operational problems of development banks and related institutions, with particular reference to tropical Africa. Functional and legal distinctions among development banks; ownership, financing, and control; relationship with government; delayed transfer of bank control to private sector; criteria for evaluating performance; establishment of groupings of developmental institutions; financial and legal structure of joint ventures; managing agency contracts; local participation; disinvestment policy; development of local entrepreneur-ship; development bank manpower and training. Some case studies, with role-playing in negotiation of joint venture projects. *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. *Pigors*

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 School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *D. V. Brown*

15.322 ***Problems in Labor Relations and Personnel Administration*** **(A)**
Prereq.: 15.312
Year: G (2) 3–0–6
The function of personnel administration and the role of the personnel administrator in the individual firm. Assumptions, objectives, and methodologies of the personnel function in several major problem and program areas. Field studies to examine company personnel programs. *Johnson*

15.331 ***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 School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Bennis*

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 School of Industrial Management; others admitted only by permission of the instructor.*) *Bennis*

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 the instructors.*) *Berlew*

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 the instructor.*) *Berlew*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

15.351 *Industrial Sociology* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Examination of some sociological problems of industrial organization: technological change and organizational structure; career patterns of business executives and staff specialists; professionalization of management; relation of industry to community. Field studies, secondary analysis of survey data, or 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 *Laboratory in Organizational Behavior* (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*

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 the instructor.*) *Bennis*

15.374 *Organization* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Descriptive studies of organizational behavior. Development of an analytical framework for the description and design of organizations, bringing together concepts from a number of social science disciplines. Discussion of organization research methods and selected empirical findings. (*Primarily for doctoral candidates; others admitted by permission of instructor.*) *Soelberg*

15.375 *Behavioral Theories of the Firm* (A)
Prereq.: 15.012, 15.374
Year: G (2) 3–0–6
Seminar in organization theory. Comparative analysis of key concepts of the major schools of organization research. Seminar discussion of the empirical and theoretical contents of traditional theories of the firm and selected simulation studies of organizational behavior. (*Primarily for doctoral candidates; others admitted by permission of instructor.*) *Soelberg*

15.376 *Laboratory Experiments on Organizations* (A)
Prereq.: 15.331
Year: G (2) 3–0–6
Analysis of the nature of organizational experiments, relations between laboratory and field experiments, and the interplay between laboratory experimentation and organization theory. Introduction to some problems of experimental design and techniques for analyzing data. Practice in designing and conducting experiments simulating organization structures and processes. (*Enrollment limited to 16 students; admission by permission of the instructors.*) *Evan, Stedry*

15.381 *Administrative Theory and Practice* (A)
Prereq.: 15.312, 15.412, 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, Marquis*

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 the instructor.*) *McGregor*

15.384 *Research Management* (A)
Prereq.: 14.117, 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.*) *Schein*

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. *Kuh*

15.412 *Financial Management* (A)
Prereq.: 15.501, *15.702*
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 School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Kuh*

15.42 *Investments*
Prereq.: 15.02, 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 analytical and techniques. *Cootner*

15.432 *Capital Markets and Financial Institutions* (A)
Prereq.: 15.412
Year: G (2) 3–0–6
The role and functioning of the capital and money markets as a device for the allocation of resources, the channeling of investable funds, and the 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.: 15.412
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. *W. L. White*

15.46 *Financial Administration of Industry* (A)
Prereq.: 15.412
Year: G (1) 3–0–6
Analysis of specific problems confronting business managers in internal financial management. Emphasis on 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. *Weingartner, Kuh*

15.472 *Risk and Uncertainty in Financial Decision-Making* (A)
Prereq.: 15.092 or 15.59; 15.412
Year: G (2) 3–0–6
The decision-making process under uncertainty from the point of view of both the industrial executive and the officers of financial institutions. The nature of financial markets with imperfect knowledge and the implications for investor behavior. The techniques available to the financial manager for the reduction and specialization of risk. The nature and formation of expectations about the future under conditions of uncertainty. Emphasis on principles and methods rather than results. *Cootner*

15.483J *Flight Transportation* (A)
(Same subject as 1.221J, 6.671J, 16.751J)
Prereq.: 15.412; 15.59 or 16.30
Year: G (1) 3–0–6
Intergrated 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.
Cootner, Bore, 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. 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. *Cootner, Bone, Reintjes, Browne*

15.50T *Managerial Information and Control*
Prereq.: 14.02 or 15.01
Year: U (1, 2) 3–0–6
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 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. *Poensgen*

15.501 *Managerial Information and Control*
Prereq.: ——
Year: G (1) 3–0–6
More intensive coverage of the topics embraced by 15.50. Nature of various types of costs, plans, and budgets, and techniques for their effective employment by management in improving its knowledge and ability to evaluate the results of operations, and thus promote organizational efficiency and implementation of the firm's goals. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Linn*

15.51 *Industrial Cost Controls and Project Analyses*
Prereq.: 15.01, 15.02, 15.50T
Year: U (1, 2) 3–0–6
Determinants of the organizational structure of the firm and the control system that is necessary for implementing objectives by means of communicating necessary information, motivating efficiency, evaluating performance and instigating remedial action. Analysis of information requirements of cost control systems. Study of cost and

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profit behavior within the firm. Critical evaluation of actual and standard cost systems. Problems of measuring costs and profits of individual products and activities of the firm. Methods of using data in evaluating alternative courses of action, future planning, and control of operations. Issues in centralization and decentralization of control and decision-making. Elements of future cost control systems. Case material from a variety of industrial situations supplemented by exercises and selected readings. *Hekimian*

15.511 *Managerial Planning and Control Processes* (A)
Prereq.: 15.012, 15.025, 15.501
Year: G (1, 2) 3–0–6
Study of the planning and control system as an effective management tool. Investigation into the objectives of the firm and the need for internal control systems. Characteristics of effective planning and control systems for communication, motivation, and performance evaluation. Study of standard cost systems. Problems of measuring costs and profits of segmented activities of the total firm (product lines or divisional activities). Characteristics of centralized versus decentralized systems and their impact on the firm's objectives. Cost analysis of alternative choice problems. Capital budgeting decisions. Internally and externally generated information and its impact on pricing decisions. Use of mathematical and statistical tools for control of operations and planning under uncertainty. Case material from a variety of industrial situations supplemented by exercises and selected readings. *Hekimian*

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.) *T. M. Hill*

15.542 *Management Information Systems* (A)
Prereq.: 15.50T or 15.501 or 15.53
Year: G (1, 2) 3–0–6
Study of the role of the information system in an organization, and the technology required to implement it. Emphasis on use of large-scale digital computers in integrated information and decision-making systems. The organization as a system, data collection, data classification, internal processing, data storage and retrieval, information display and dissemination, data transmission, sequential versus random processing, cost and value of information, integrated systems and their implementation, real-time system, and the role of the information system in planning and control. Lectures, library research, programming and other exercises.
Emery, Carroll, Linn

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, Emery, Greenberger*

15.58 *Industrial Dynamics*
Prereq.: 15.01 or 18.04
Year: U (1, 2) 3–0–6
Management decision-making treated from over-all system point of view; primary emphasis on interaction of separate elements of an enterprise. Study of behavior of firms and industries by computer simulation of feedback-models representing organizational structure of firm and its basic policies and decision criteria. Application of system-dynamics approach to study of various current problem areas in industry, including inventory policies, ordering rules, cash flows, consumer behavior, hiring and firing policies, and R and D management. Opportunity for students to run their own models on the IBM 7090 computer. *E. B. Roberts*

15.581 *Industrial Dynamics I* (A)
Prereq.: 15.012 or 18.04
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. Problems selected from various typical industrial phenomena relating to inventory policies, ordering rules, cash management, consumer behavior, hiring-firing procedures, and R and D management. Student projects using the DYNAMO system on the IBM 7090 computer.
E. B. Roberts

15.582 *Industrial Dynamics II* (A)
Prereq.: 15.58 or 15.581
Year: G (2) 3–0–6
Research seminar in business dynamics. Stress on the relationship of management policy and organizational structure to corporate performance. Growth dynamics in markets and companies. Discussion of objectives of industrial dynamics, steps in a study, selection of a subject and definition of the problem. Development of a verbal dynamic model of the selected problem based on the literature and student experience. Conversion of the verbal model to a formal mathematical model. Simulation of the model. Interpretation of simulation results and revision of objectives and model. Redesign and improvement of the business system. Discussion of problems involved in implementing recommendations of the study. *E. B. Roberts*

15.59 *Methods of Quantitative Analysis*
Prereq.: 15.091 or 18.04
Year: G (1, 2) 3–0–6
Mathematical basis for advanced subjects in quantitative analysis. Selected treatment of linear algebra, quadratic forms, characteristic values, Markov processes, convex sets, linear programming, duality, Lagrange multipliers, game theory, dynamic programming, difference and differential equations, complex variables, transform methods, and feedback control. Illustrations from management areas. *Greenberger*

15.591 *Case Studies in Quantitative Analysis* (A)
Prereq.: 15.092 or 15.59; 15.094J
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* (A)
Prereq.: 15.092 or 15.59
Year: G (2) 3–0–6
Graphs, network flows, selected topics in linear programming. Integer programming, nonlinear programming, dynamic programming. Applications. *Little*

15.593 *Stochastic Systems* (A)
Prereq.: 15.092 or 15.59; 15.094J
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.: 15.092 or 15.59; 15.094J
Year: G (2) 3–0–9
Analysis of linear probabilistic systems. Application of linear system theory to the study of finite- and infinite-state, discrete- and continuous-time, stationary and non-stationary, Markov and semi-Markov processes. Optimization of probabilistic systems over short and long time periods by means of dynamic programming. Concurrent presentation of examples in the areas of system reliability, congestion processes, automatic control, maintenance and replacement policies, search procedures, inventory control, and other operating problems of systems. Discussion of unsolved problems and promising areas of research. *R. A. Howard*

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. (*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.: 14.01
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*

15.661 *American Legal System* (A)
Prereq.: 15.201
Year: G (1) 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 School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Jacks*

15.702 *Managerial Models*
Prereq.: 15.091, 15.501
Year: G (2) 3–0–6
Models for managerial decision-making and for the analysis of business processes. Emphasis on subjects such as mathematical programming, simulation, and exponential smoothing, which have application in a variety of settings, and on topics such as capital budgeting, inventory control, and allocation of promotional effort, which arise in one functional area but have implications in others. *Little*

15.71 *Production Management*
Prereq.: 15.02
Year: U (2) 3–0–6
Quantitative approach to decision-making in production management. Incremental analysis, linear programming, stochastic models, waiting-line theory, and design of experiments applied to problems of economic quantities, production programming, statistical control, equipment purchase. *Bowman, Goetz*

15.712 *Operations Management* (A)
Prereq.: 15.012, 15.025, 15.092, 15.331
Year: G (1) 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*

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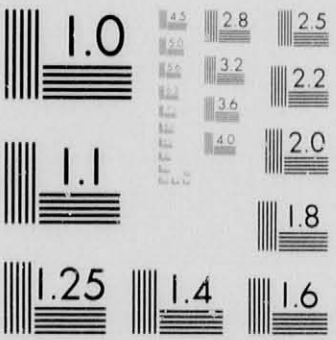

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15.72 ***Industrial Standardization***
Prereq.: 14.01
Year: U (1) 3–0–6
Techniques of measurement and standardization and their relevance to data-gathering or decision-making. Standards as the basic requisite of any plan of control. Historical and theoretical background of standardization movement in industry. Standards for material: engineering standards and standards programs. Standards for manufacturing and office labor: evaluation of work measurement techniques, uses of time standards, discussion of relationship of time standards to wage payment plans. Standards for managerial and administrative performance: discussion of qualitative and quantitative methods of evaluation. Consideration of managerial uses of standards; emphasis on understanding the general techniques and the uses of standards rather than upon facility in using any of the specific techniques or methods.

15.73 ***Management Laboratory***
Prereq.: 14.01
Year: U (1, 2) 3–3–3
Psychology and methodology of industrial improvement. Work simplification. Techniques of improvement including motion economy, work space and plant layout, process charts, flow diagrams, and other current practices as utilized in measurement and analysis of work cycles. Economic and psychological theory of the improvement process. Problems in management creativity. Laboratory experimentation. Participation in an actual company project situation. *Goodwin*

15.74 ***Advanced Management Laboratory***
Prereq.: 15.73
Year: U (2) 3–3–3
Organization and implementation of industrial improvement. Advanced treatment of work simplification. Managerial procedures employed in introducing and developing a company improvement program with administrators, executives, and employees. Appreciation, educational, and application phases of the company program. Coordination of all improvement activities within the company. Laboratory experimentation with and personal involvement in an actual company program situation. *Goodwin*

15.741 ***Advanced Management Laboratory*** **(A)**
Prereq.: 15.501
Year: G (1, 2) 3–3–3
Improvement as a management philosophy. Coordination of methods of analysis, design, measurement, and control of physical activity. Critical analysis and appraisal of various improvement techniques and methods of implementing production improvements in industry. Laboratory and field experimentation. Involvement in actual industrial situations, through a live case. *Goodwin*

15.75 ***Manufacturing Analysis***
Prereq.: 15.71
Year: U (1) 3–0–6
Field applications of methods of analysis developed in 15.71. Development of actual data required for operational use of decision-making models. *Goetz*

15.751 ***Manufacturing Analysis*** **(A)**
Prereq.: 15.712
Year: G (1) 3–0–6
Subject matter of 15.75 at advanced level. *Goetz*

15.78 ***Studies in Manufacturing Analysis***
Prereq.: 15.71
Year: U (1) 3–0–6
Examination of studies from current literature devoted to formal methods for analyzing production management problems. Applications of linear programming, other programming applications, waiting-line applications, applications of incremental analysis, and total cost and value models presented from the empirical literatures of management science, operations research, economics, and statistics. Student seminar responsibilities. *Bowman*

15.781 ***Studies in Manufacturing Analysis*** **(A)**
Prereq.: 15.712
Year: G (1) 4–0–5
Examination of studies from current literature devoted to formal methods for analyzing production management problems. General readings bearing on each method of analysis also included. Analysis of case studies as time permits. *Bowman*

15.791 ***Operational Models of the Firm*** **(A)**
Prereq.: 15.012, 15.501, 15.712, 18.04
Year: G (1) 3–0–6
Intensive analyses of selected kinds of management decision problems that involve interrelationships among functional areas. Study and solution of decision problems of rather broad scope by use of mathematical and statistical methods such as differential and difference equations, transform theory, calculus of variations, signal flow analysis, and Markov processes. Relation of theory and practice. Design of efficient operating techniques based upon theoretical findings. Student participation in field studies and special projects.

15.792 ***Manufacturing Decisions Seminar*** **(A)**
Prereq.: 15.712
Year: G (2) 3–0–6
Seminar based on literature of decision-making and one manufacturing problem area, such as inventory, scheduling, quality, or equipment, combined with field study in a local firm to observe, describe, and predict the decision-making behavior of individuals concerning that manufacturing problem. *Bowman*

15.81 ***Marketing***
Prereq.: 15.01
Year: U (1, 2) 3–0–6
Introduction to managerial problems in marketing operations, emphasizing possibilities of gaining insight into the underlying determinants and dynamics of consumer and industrial demand behavior through the medium of social and economic research. Basic policy considerations through which marketing management may adapt operations of firm to changing market environment: selection and control of channels of distribution, product line, pricing, and sales promotion policy. Theoretical concepts and quantitative techniques applied in study of marketing phenomena. *Claycamp*

15.812T ***Marketing*** **(A)**
Prereq.: 15.091, *15.702*
Year: G (2) 4–0–5
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 government 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 School of Industrial Management graduate students; others admitted only by permission of the 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. *Claycamp*

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. *Claycamp*

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.

15.832 *Demand Analysis and Marketing Research* (A)
Prereq.: 15.025, 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.

15.86 *Product Planning and Development* (A)
Prereq.: 15.812T
Year: G (2) 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.

15.901 *Study and Research in Management System Dynamics*
Prereq.: ——
Year: U (1, 2) *Arr.*
Integrated program for juniors and seniors in the School of Industrial 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 School of Industrial Management.*) *Forrester*

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.

15.93 *Business Practice and Policy Determination* (A)
Prereq.: 15.312, 15.412, 15.712, 15.812T
Year: G (2) 3–0–6
Subject matter of 15.91 at advanced level.

15.942 *Seminar in Business Practices* (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.*)

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.*) *Padelford*

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*

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16.
Aeronautics and Astronautics

16.01 *Dynamics*
Prereq.: 8.02, 18.03
Year: U (1, S) 4–2–6
Dynamics, with applications to aeronautical and astronautical problems. Kinematics and dynamics of particles and of groups of particles. Relative motion as seen by accelerating and rotating observers. Particles of variable mass. Mass properties of rigid bodies, the inertia tensor, geometric and mass symmetries. Kinematics and dynamics of a rigid body in general motion. Euler's dynamical equations, gyroscope equations. *Halfman*

16.02 *Aerodynamics*
Prereq.: 2.401, *16.01*
Year: U (1, 2) 4–2–6
Description of gaseous environment of vehicles in flight, considered as a continuous medium and from viewpoint of kinetic theory. Application of the conservation laws of mass, momentum and thermodynamic energy to real and perfect fluids in motion. One-dimensional flow of a perfect gas, with simple aeronautical and astronautical illustrations. Fundamentals of three-dimensional fluid motion; applications, with special reference to nonviscous incompressible flow; airfoil and wing theory. Elementary examples of viscous flow; boundary layer. *Ashley*

16.03 *Gasdynamics*
Prereq.: 2.401, *16.01, 18.05*
Year: U (1) 4–2–6
Fundamentals of fluid dynamics presented so as to meet the needs of students interested in research. Physics and thermodynamics of gases from the phenomenological and atomistic viewpoints. Conservation laws for a continuous fluid medium and their specialization to nonviscous perfect gas. One-dimensional flow. Constant-density flow, with emphasis on the two-dimensional case. Introduction to small-perturbation concepts and to methods for analyzing compressible fluid motion. *Ashley*

16.041 *Aerodynamics — Viscous Fluids* (A)
Prereq.: 16.02, *18.05*
Year: G (1) 3–0–9
Introduction to viscous flows. Basic flow equations; exact solutions; low Reynolds number cases; boundary layer flows; brief discussion of stability; transition; turbulent boundary layers. Lectures to be supplemented by occasional demonstrations. *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. 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, Abarbanel*

16.067 *Gas-Surface Interactions* (A)
Prereq.: 8.05 or 8.051
Year: G (1 or 2) 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*

16.081 *Advanced Gas Dynamics* (A)
Prereq.: 16.042 or 16.052 or 18.60; 18.06
Year: G (1) 3–0–9
16.082 *Advanced Gas Dynamics* (A)
Prereq.: 16.081
Year: G (2) 3–0–9
Two-semester subject for graduate students whose principal interest is in fluid mechanics. The equations of motion for continua and their relation to statistical mechanics. Approximations and perturbation methods. The statistical treatment of turbulence. Flow stability problems. Jet and wake flows. Conducted partly as student seminar. (*Not offered 1964–65.*) *Mollö-Christensen*

16.09 ***Fields in Continuous Media***
Prereq.: 2.401, 8.03, 18.03
Year: U (2) 3–1–5
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*

16.10 ***Space Flight Dynamics*** **(A)**
Prereq.: 16.01
Year: G (2) 3–0–6
Calculus of variations in flight engineering with applications to dynamic aircraft performance and interplanetary flight; classical minimum principles. Fundamentals of relativity and space flight. Satellite librations and general rotational motions. *Halfman*

16.105 ***Applied Aerodynamics*** **(A)**
Prereq.: 16.02, 16.11
Year: G (1) 3–0–6
Studies of flight vehicle performance including aerodynamics and characteristics of various types of power plant for a wide range of Mach numbers. *Larrabee*

16.11 ***Flight Vehicle Aerodynamics and Dynamics***
Prereq.: 16.01; 16.02 or 16.03
Year: U (2, S) 4–0–5
Motions of flight vehicles under the action of aerodynamic and gravitational loads. Discussion of methods of predicting aerodynamic loads with special consideration of their validity. Introduction to boundary layers and heat transfer. Small disturbance methods leading to classical dynamic stability of flight vehicles. *Bicknell*

16.15 ***Advanced Flight Vehicle Stability and Control*** **(A)**
Prereq.: 16.11
Year: G (1) 3–0–6
Analytic solutions for nonlinear problems in flight mechanics. Linear approximations to flight vehicle dynamics, including: classical airplane stability theory, stability derivative estimation, dynamic similarity laws, gust response, inertial cross coupling and spinning. Dynamics of simple aircraft-controller combinations. Analysis of flight test dynamic stability data. *Larrabee*

16.20 ***Solid Mechanics I***
Prereq.: 3.14
Year: U (2) 4–0–6
Fundamentals of solid mechanics presented to build upon the atomistic view as presented in an introductory subject in material science. Establishment of a connection between this viewpoint and the physics of solids on a phenomenological basis. Concepts of stress and strain. Equilibrium and compatibility of solids in three dimensions. Behavior and modes of failure of materials under extreme environmental conditions. Laboratory demonstrations. *Witmer*

16.201 ***Flight Vehicle Structures I***
Prereq.: 16.20
Year: U (1, 2) 4–0–6
Theories of elasticity and plasticity in three-dimensional orthogonal curvilinear coordinates. Thermoelasticity. Specialization to solid sections, simple shells and stiffened skin structures under shear, bending torsion and compression; both elastic and plastic effects. Elementary concepts of stability. Principles of minimum weight design. Laboratory demonstrations. *Pian*

16.202 ***Solid Mechanics II***
Prereq.: 16.20
Year: U (2) 4–0–6
Theories of elasticity and plasticity in three-dimensional orthogonal curvilinear coordinates. Tensor properties of stress and strain. Energy methods. Thermoelasticity. Elastic and plastic bending and twisting of beams. Concepts of stability. Elementary theory of plates including elastic and plastic buckling. *Mar*

16.21 ***Methods of Structural Mechanics*** **(A)**
Prereq.: 16.201 or 16.202; 18.05
Year: G (1) 3–0–6
Advanced energy methods in solid and structural mechanics. Approximate solutions of solid continuum by finite element idealizations and matrix structural methods. Influence coefficients. Thermal stresses. Structural problems involving physical and geometrical nonlinearities. *Witmer*

16.22T ***Shell Structures*** **(A)**
Prereq.: 16.201 or 16.202
Year: G (1) 3–0–6

16.23 ***Shell Structures*** **(A)**
Prereq.: 16.22T
Year: G (2) 3–0–6
Elements of tensor analysis. General formulation of elasticity in curvilinear coordinates. Introduction to differential geometry. Development of shell equations in tensor form. Membrane behavior of thin shells. Bending behavior of thin shells. Various topics such as shallow shells, shells of revolution, asymptotic integration, large deflections, buckling, and inflated shells. *Dugundji*

16.25 ***Advanced Theory of Structures*** **(A)**
Prereq.: 16.201 or 16.202
Year: G (1) 3–0–6
Varying content from year to year as new methods for analysis of all-metal aircraft become available for examination. Probable effects on structural analysis methods to be expected from new trends in design. (*Not offered 1964–65.*) *Mar*

16.26 ***Solid Mechanics Laboratory*** **(A)**
Prereq.: 16.62 or 16.63
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 concepts of system performance analysis based on frequency, transient, and polynomial coefficient

(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.

methods. Systematic system design procedures to meet a combination of specifications on input response, disturbance response, and adaptability. Design of control systems for elastic vehicles, for unstable plants, for processes involving transport delay, and for plants containing multiple integrations. Concept of performance indices and their use in the analytic design of systems and in adaptive control systems. System design with multiple inputs. Characterization of random processes and system design for random input and noise.
Li, Vander Velde

16.32 *Principles of Instrumentation and Control* (A)
Prereq.: 16.31
Year: G (2) 3–0–9
Continued treatment of the principles of analysis and design of feedback control systems with application to sampled-data and nonlinear systems. Performance characteristics of optimum switching and limit-cycling control systems. Control systems incorporating digital computers. State space characterization of dynamic systems and analysis of stability by the methods of Liapunov. *Li, Vander Velde*

16.33 *Automatic Control Systems 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 with the use of an analog computer. *Li*

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*

16.36T *Comparative Instrumentation* (A)
Prereq.: 16.30
Year: G (2) 3–0–6
Generalized fundamental treatment directed toward planning of measuring systems. Analysis of measurement concepts, components, system configurations and test methods with emphasis on comparison between different techniques. Detailed examination and error analysis of important classes of practical instruments stressing the general techniques used to improve accuracy. Students may also elect 16.361, an associated laboratory subject. *L. R. Young*

16.361 *Comparative Instrumentation Laboratory* (A)
Prereq.: 16.30
Year: G (2) 0–2–1
Individual laboratory projects for detailed investigation of one phase of instrument accuracy, emphasizing current research and development. (*Restricted to students taking 16.36T.*) *L. R. Young*

16.362J *Special Studies in Information Systems* (A)
(Same subject as 1.16J, 2.191J, 6.604J)
Prereq.: 16.30
Year: G (2) 2–4–6
Introduction to basic techniques in planning and design of information systems associated with a large operational complex. Detailed design of sub-systems by individual student groups with emphasis upon the 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 outstanding guest lecturers and faculty members. The particular operational complex chosen for each term to be announced before start of the term (Project for 1964: preliminary design of an advanced orbiting astronomical observatory OAO). Students selected by interview on basis of their potential to contribute actively and effectively to this subject.
Li, C. L. Miller, 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.: 6.18 or 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*

16.39 *Space Dynamics and Gyroscopic Instruments* (A)
Prereq.: 16.01
Year: G (1) 3–1–6
Consideration of origins of inertial space concepts and application to interpretation of measured data. Generalized theory of accelerations and velocities of bodies in spaces which are moving with respect to inertial space. Application of general theory and of Newtonian mechanics to theory of gyroscopic instruments. Space integrators and stabilization. Development of treatment from standpoint of engineer, using methods of vectors and of conventional analysis. Application to gyroscopic devices in airborne and marine navigation.
Wrigley, Hollister

16.392 *Inertial Guidance* (A)
Prereq.: 16.30, 16.39
Year: G (2) 3–0–9
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*

16.42 *Weapons Systems* (RA)
Prereq.: 16.30, 16.39
Year: G (1) 3–0–6
Generalized treatment of weapons systems problem and methods available for its solution by physical concepts and vectors. Application of gyroscopic and other equipment for interference isolation, tracking, and computing in weapons systems. Fire control principles for airborne and marine weapons systems. Fundamentals of inertial

guidance and its application to ships, aircraft, missiles, and spacecraft. Examples taken from service systems. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *Wrigley, Markey*

16.43 *Weapons Systems Laboratory* (RA)
Prereq.: 16.42
Year: G (1) 1–3–5
Demonstration of principles treated in 16.42. Various experiments on characteristics of fire control instrument components, including gyroscopic elements, data transmission systems, and integrating units. Experiments on service fire control equipment and special demonstration units to study static and dynamic performance characteristics of typical airborne and anti-aircraft equipment. Problems of solution time, smoothing, and tracking. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *R. K. Mueller*

16.44 *Automatic Control of Flight Vehicles* (A)
Prereq.: 16.30
Year: G (1) 3–0–6
Application of design techniques and principles to advanced automatic control systems for air and space vehicles. Synthesis of control systems from standpoint of meeting mission specifications. Analysis of adaptive control systems; their use in meeting performance requirements over widely changing environments encountered by high-speed aircraft and manned spacecraft. Typical engineering problems associated with design of control equipment, considering limitations and uncertainties of components, random input effects, mass cross-coupling effects, etc. *Whitaker*

16.46 *Astronautical Guidance* (A)
Prereq.: 16.37, 18.05
Year: G (1) 3–0–6
Fundamentals of space vehicle navigation, guidance and control with particular emphasis on the self-contained type. Extra-terrestrial trajectory determination; orbital injection problems; interplanetary celestial navigation; ballistic guidance for one-way and round-trip missions to the moon and planets; guidance of continuous low-thrust vehicles; guidance for satellite rendezvous; atmospheric reentry guidance. Effect of component inaccuracies on performance of missions. *Battin*

16.49 *Special Problems in Weapons Systems* (RA)
Prereq.: 16.42
Year: G (1 or 2) *Arr.*
Problems of interest to qualified students in consultation with the instructor. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *Wrigley*

16.50 *Vertical Take-Off Aircraft* (A)
Prereq.: 16.11
Year: G (1) 3–0–6
Analysis of performance and inherent stability and control characteristics of vertical take-off and landing aircraft, VTOL, including helicopters, convertiplanes, tilt wing, vectored lift and jet vertical risers. *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, thermodynamics, and automatic control to problems encountered in the design of aircraft capable of vertical take-off and landing, VTOL. Problems of control and stability during conversion to horizontal flight, design of aircraft stabilization systems, dynamics of wing-rotor combinations and of rigid or articulated rotors, and analysis of specialized power plant requirements for direct jet lift. *Ham*

16.53 *Rocket Propulsion*
Prereq.: 2.201 or 16.02 or 16.03; 2.401
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 magneto-hydrodynamic accelerators. *E. S. Taylor*

16.54 *Aircraft Engines*
Prereq.: 2.201 or 16.02 or 16.03; 2.401
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*

16.57 *Physical Mechanics* (A)
Prereq.: 8.051 or 8.06; 18.06
Year: G (1 or 2) 3–0–9
Engineering calculation of bulk properties of matter from microscopic data. Application of quantum mechanics and statistical mechanics to calculation of thermodynamic properties of gases under conditions not accessible experimentally. Study of Boltzmann equation and methods of obtaining transport properties, including viscosity, thermal conductivity, electrical conductivity. Radiative transport in gases. *Finston, Kerrebrock*

16.60 *Advanced Aeronautical Problems* (A)
Prereq.: 16.11 or 16.20
Year: G (1 or 2) *Arr.*
Individual advanced work by properly qualified graduate students. Problems selected in consultation with the instructor. *Staff*

16.605 *Aeronautical Problems*
Prereq.: ——
Year: U (1 or 2) *Arr.*
Individual or group work by properly qualified students. Problems chosen in consultation with instructor. *Staff*

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16.62 ***Experimental Projects I***
Prereq.: 16.81
Year: U (2) 2–4–4
Experimental projects in the field of aeronautics and astronautics. Emphasis on the role of the experimental method in relation to analysis, and on the student's responsibility in project leadership. *Staff*

16.63 ***Experimental Projects II***
Prereq.: 16.62
Year: U (1) 2–6–4
Philosophy of 16.62 applied to more complex problems. *Staff*

16.70 ***Aircraft Detail Design***
Prereq.: ——
Year: U (1) 3–5–0
Aircraft drafting room practice and the preparation of airplane assembly, subassembly, and detail part drawings. Lectures and drafting room exercises covering air frame detail design, landing gear and landing gear control system mechanisms, fuel systems, airplane graphics, and the preparation of a weight estimate and balance diagram for a complete airplane. *Bentley*

16.71 ***Flight Vehicle Engineering***
Prereq.: 16.11; 16.201 or 16.202
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. *Koppen*

16.72 ***Aircraft Design***
Prereq.: 16.71
Year: U (2) 2–3–7
Structural design of a major aircraft component including determination of critical flight loads. *Koppen*

16.73 ***Space Systems Engineering***
Prereq.: 16.11; 16.201 or 16.202
Year: U (1) 2–3–7
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.: 16.73 or 16.761
Year: G (2) 2–3–7
Continuation of 16.73 with greater emphasis on overall system and mission optimization. Analysis and preliminary design of flight vehicles and sub-systems and their relation to the overall mission concept. Methods of analyzing and predicting performance of propulsion system, structural design in the presence of heating, guidance and navigation equipment, ground handling requirements, communications, and life-support equipment. *R. H. Miller*

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, Cootner

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 domestic and international route allocation. 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, Cootner

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.
M. A. Hoffman

16.762 ***Orbital and Ballistic Flight*** **(A)**
Prereq.: 16.761
Year: G (2) 3–0–6
Continuation of 16.761 strongly oriented toward the effects of subsystem and component technologies on the vehicle system design. *M. A. Hoffman*

16.77 ***Atmospheric Entry*** **(A)**
Prereq.: 16.71 or 16.73 or 16.761
Year: G (2) 3–0–6
Study of planetary atmospheres, aerodynamic heating, entry dynamics and stability, and thermal protection. Variational methods for modulated entry. *Landahl*

16.78 ***Control and Guidance in Flight Transportation*** **(A)**
Prereq.: 16.11, 16.30
Year: G (1) 3–0–6
Study of the functional and technical aspects of the overall air transportation problems associated with enroute navigation, landing and take-off, and traffic control. Consideration of the interrelationships between the characteristics of the airplane as a whole and the facilities, equipment, and environment, with the view of evolving a comprehensive solution to the air navigation and control problem that meets the desired system performance. Study of existing navigation, traffic control, and automatic control systems. *Whitaker*

16.81 ***Flight Vehicles***
Prereq.: 8.01
Year: U (1) 3–0–6
The role of science and engineering in the development of aircraft and space craft. Examination of the fundamental problems and solutions of these problems in the light of current technology. *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 or 16.202
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. *Mollö-Christensen*

16.92 ***Advanced Aeroelasticity*** **(A)**
Prereq.: 16.91
Year: G (2) 3–0–9
Presentation of field of aeroelasticity from unified viewpoint applicable to all types of flight vehicles throughout range of airspeeds. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Forced response, static and dynamic eigenvalues of simplified systems, one-dimensional structures and two-dimensional structures. Special topics of interest to the aeroelastician, with emphasis on aerodynamic operators. *Ashley*

16.94 ***Dynamics of Structures*** **(A)**
Prereq.: 16.91
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. *Pian*

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. *Ankeny*

18.01 ***Calculus***
Prereq.: ——
Year: 1 (1) 3–0–6
Study of functions of one variable. Graphical representation, properties of continuous functions. Differentiation, with applications to curve sketching, maximum-minimum problems. Mean-value theorem. Indefinite and definite integration, fundamental theorem; applications to finding areas, simple volumes, arc length, simple surface areas. Logarithm and exponential functions. Technique of indefinite integration. Approximation methods, Taylor series, applications to calculation of the elementary functions. Thomas, *Calculus and Analytic Geometry, 3d edition.* *Mattuck*

18.02 ***Calculus***
Prereq.: 18.01
Year: 1 (2) 3–0–6
Study of functions of several variables. Vector algebra in three-space. Vector functions of one variable, analysis of space motion; Kepler's laws. Scalar functions of two and three variables; partial differentiation, gradient, exact differentials, line integrals, multiple integrals, areas, volumes, surface areas. Surface integrals, Green's theorem, and Stokes' theorem. Thomas, *Calculus and Analytic Geometry, 3d edition.* *Mattuck*

18.03 ***Calculus***
Prereq.: 18.02
Year: U (1, 2) 3–0–6
Infinite series. Complex numbers. Linear algebra. Probability. Thomas, *Calculus and Analytic Geometry, 3d edition.* Freund, *Mathematical Statistics.* *H. Rogers*

18.04 ***Differential Equations***
Prereq.: 18.03
Year: U (1, 2) 3–0–6
Treatment of ordinary differential equations. Series solutions. Kaplan, *Ordinary Differential Equations.* *H. Rogers*

18.05 ***Advanced Calculus for Engineers (A, except Courses II, V(2), VI, VIII, XIII, XVI, XVIII, XXII)***
Prereq.: 18.04
Year: G (1); U (1, 2, S) 3–0–6
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, V(2), XVI, XVIII, XXII)***
Prereq.: 18.05
Year: G (1, 2, S) 3–0–6
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. (Primarily for selected officers of the U. S. Army, Air Force, Navy and Coast Guard.) Douglass and Zeldin, *Calculus and Its Applications;* Kaplan, *Ordinary Differential Equations.* *Staff*

18.10 ***Introduction to Probability and Random Variables***
Prereq.: 18.03
Year: U (2) 3–0–6
Elementary subject in theory of probability and random variables. In latter part of material, specialization of techniques in development of statistical methodology. Beta and Gamma functions, probability, discrete and continuous random variables, joint distributions, derived distributions, mathematical expectation, hypothesis testing, estimation and standard tests. Illustrations of practical applications. *Wadsworth*

18.11 ***Operations Research*** **(A)**
Prereq.: 18.05 or 18.21; 18.10
Year: G (1) 3–0–9
Theory of probability and random variables; emphasis on mathematical models having important applications in the field of operations research. Problems involving maximization with limited total effort, search theory,

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queueing theory, time series, stochastic processes, difference equations, and generating functions. Examples of physical and laboratory operations; illustrations from the fields of production, inventory control, reliability, maintenance, and military operations research. *Wadsworth*

18.13 ***Numerical Analysis* (A)**
Prereq.: 18.05 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 solution of linear difference equations. Formulation and treatment of integral equations; Green's function; analytical and numerical methods of solution. Hildebrand, *Methods of Applied Mathematics.* *Hildebrand*

18.16J ***Heuristic Programming and Artificial Intelligence* (A)**
(Same subject as 6.544J)
Prereq.: 6.41 or 6.539 or *18.18* or 18.89; 18.04
Year: G (1) 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*

18.17 ***Combinatorial Analysis* (A)**
Prereq.: 18.03, *18.04*
Year: G (1) 3–0–9

Survey of combinatorial problems of current research interest. Methods of enumeration; generating functions, partitions, permutations with restricted position, the Polya-de Bruijn counting theory. Theorems on choice and matching, matrices of zeros and ones, flows in networks; elements of graph theory; applications to logic, communication theory, and genetics. *Rota*

18.18 ***Probability***
Prereq.: 18.04
Year: U (2) 3–0–6

Elements of combinatorial analysis. Random variables and expectations. Laws of large numbers. The central limit theorem and its applications. Recurrent events and Markov chains. W. Feller, *An Introduction to Probability Theory and Its Applications.* *Rota*

18.182 ***Introduction to Stochastic Processes***
Prereq.: 18.18
Year: U (1) 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. Stationary chains and prediction. Boltzmann's equation. M. Rosenblatt, *Random Processes.* *McKean*

18.20 ***Linear Algebra***
Prereq.: 18.04
Year: U (1, 2) 3–0–6

Vector spaces, euclidean spaces, linear transformations, linear equations, matrices, determinants, quadratic forms, canonical forms of matrices. 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.* *K. M. Hoffman*

18.21 ***Analysis***
Prereq.: 18.03
Year: U (1) 3–0–9

18.22 ***Analysis***
Prereq.: 18.20 or *18.26*; 18.21
Year: U (2) 3–0–9

Real numbers and euclidean n-space; 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*

18.23 ***Senior Seminar in Mathematics***
Prereq.: 18.21
Year: U (1, 2) 3–0–9

Seminars for senior mathematics majors in several topics, each under the direction of a faculty member whose special interest is in the field of the seminar. Reports and discussion by students on topics taken from current journals or from texts not regularly used in other mathematics subjects. Certain topics may require an additional prerequisite. *Staff*

18.24 ***Elementary Differential Geometry***
Prereq.: 18.22
Year: U (2) 3–0–6

Plane and space curves. First and second differential form of a surface. Theorems of Meusnier and Euler. Lines of curvature, asymptotic lines, conjugate lines, geodesics. Theorems of Gauss and Codazzi. Developable surfaces, surfaces of rotation, Liouville surfaces. Differential parameters. Problems of mapping. *Thorpe*

18.241 ***Introduction to Topology***
Prereq.: 18.20 or *18.25;* 18.22
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. *I. M. Singer*

18.242 ***Riemannian Geometry***
Prereq.: 18.22, 18.241
Year: U (2) 3–0–9

First and second fundamental forms, geodesics, curvature, spaces of constant curvature, rigidity, Gauss-Bonnet theorem (with emphasis on one- and two-dimensional cases). Riemann surfaces. Algebraic curves. *I. M. Singer*

18.25 ***Modern Algebra***
Prereq.: 18.04
Year: U (1) 3–0–9

18.26 ***Modern Algebra***
Prereq.: 18.25
Year: U (2) 3–0–9

Groups, subgroups, factor groups, homomorphism theorems; rings and ideals, factorization theory for Euclidean

rings; vector spaces and elementary field theory. Modules over a ring of operators. Applications to vector spaces and linear algebra. Normal forms for matrices. Quadratic forms. Tensor and Grassman algebras. *Artin*

18.27 ***Introduction to Functions of a Complex Variable*** **(A, except XVIII)**
Prereq.: 18.04
Year: G (1) 3–0–9

18.28 ***Introduction to Functions of a Complex Variable*** **(A, except XVIII)**
Prereq.: 18.27 or 18.31
Year: G (2) 3–0–9

Complex numbers, analytic functions, Riemann surfaces for certain functions, Cauchy's theorem, singularities, residues, contour integral, conformal mapping, Schwarz-Christoffel transformation, series and sequences, analytic continuation, harmonic functions, conjugate functions, the gamma function, second order linear differential equations and special functions, Laplace transforms, asymptotic series, saddlepoint method, Hilbert transforms. Singular integral equations. *Levinson*

18.29 ***Intermediate Differential Equations***
Prereq.: 18.21
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 1964–65.*) *Glimm*

18.292 ***Intermediate Differential Equations***
Prereq.: 18.21 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 1964–65.*) *Glimm*

18.31 ***Theory of Functions*** **(A)**
Prereq.: 18.21
Year: G (1) 3–0–9

Complex numbers, Riemann sphere, plane topology, fractional linear transformations. Complex integration, Cauchy's theorem, Cauchy's integral formula, power series, winding numbers, rational functions. Singularities, simple Riemann surfaces, local mapping theorem. Evaluation of definite integrals. Integral and meromorphic functions, special functions. Riemann mapping theorem. *McKean*

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, integral and metomorphic functions, Fourier and Laplace transforms, Wiener-Hopf equations, special functions, prime number theorem, elliptic and automorphic functions. *Strang*

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. (*Not offered 1964–65.*) *K. M. Hoffman*

18.35 ***Functions of Real Variable*** **(A)**
Prereq.: 18.22
Year: G (1) 3–0–9

18.36 ***Functions of Real Variable*** **(A)**
Prereq.: 18.35
Year: G (2) 3–0–9

Elements of the theory of metric spaces, category and Baire theorem. Lebesgue integration, absolute continuity and differentiation of functions of bounded variation. Abstract measure theory, Radon-Nikodym and Fubini theorems, L^p spaces. Elements of Banach spaces, Hahn-Banach and closed graph theorems. Topics on linear transformations on L^p spaces. *Goodman*

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 1964–65.*) *Segal*

18.365 ***Mathematical Analysis of Fundamental Physics*** **(A)**
Prereq.: 18.36
Year: G (2) 3–0–9

An introductory synthesis of contemporary mathematics and fundamental physics, with particular attention to compactness and precision. Models and methods for the treatment of classical and quantum, discrete and continuum mechanics; relativistic quantum fields and particles; selected non-linear problems. (*Not offered 1964–65.*) *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 1964–65.*) *Segal*

18.37 ***Functional Analysis*** **(A)**
Prereq.: 18.27 or 18.31; 18.35
Year: G (1) 3–0–9

Differentiable functions on Euclidean spaces. Distributions, Fourier transforms of distributions. Applications to differential equations, fundamental solutions, transmutation operators. Emphasis on analytic continuation techniques and geometric problems. *K. M. Hoffman*

18.38 ***Functional Analysis*** **(A)**
Prereq.: 18.37
Year: G (2) 3–0–9

Continuous functions. Stone-Weierstrass theorem. Topological linear spaces. Krein-Milman theorem. Banach spaces. Hahn-Banach theorem. Uniform boundedness principle. Closed graph theorem. Weak-star compactness. Hilbert spaces. Orthonormal bases and projec-

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tions. Banach algebras. The Gelfand theory. L^1 algebra of the real line. Gelfand-Naimark theorem. Spectral theorem for normal operators. Compact operators. *K. M. Hoffman*

18.41 ***Differential Equations*** **(A)**
Prereq.: 18.15 or 18.20; 18.31
Year: G (1) 3–0–9

18.42 ***Differential Equations*** **(A)**
Prereq.: 18.41
Year: G (2) 3–0–9

Existence theorems in real and complex cases. Linear systems. Regular singular points. Irregular singular points and asymptotic series. Boundary value problems including the non-self adjoint case and the case of infinite intervals. Stability theory and perturbation theory for non-linear differential equations. Periodic orbits. Limit cycles. Differential equation on a torus. (*Not offered 1964–65.*) *Levinson*

18.43 ***Partial Differential Equations*** **(A)**
Prereq.: 18.22
Year: G (1) 3–0–9

18.44 ***Partial Differential Equations*** **(A)**
Prereq.: 18.43
Year: G (2) 3–0–9

The Cauchy-Kowalewski theorem, existence and regularity of solutions of the Dirichlet problem for linear elliptic equations, existence and regularity of solutions of the Cauchy problem for hyperbolic linear equations, fundamental solutions for linear equations with constant coefficients. *Ambrose*

18.441 ***Advanced Partial Differential Equations*** **(A)**
Prereq.: 18.36
Year: G (1) 3–0–9

18.442 ***Advanced Partial Differential Equations*** **(A)**
Prereq.: 18.441
Year: G (2) 3–0–9

Regularity properties of solutions of elliptic boundary value problems; spectral theory of elliptic and hypoelliptic differential operators; applications to initial value problems for parabolic and hyperbolic equations. (*Not offered 1964–65.*)

18.47 ***Fourier Series and Integrals*** **(A)**
Prereq.: 18.21 or 18.31
Year: G (2) 3–0–9

Elementary theory of Fourier series and integrals as developed along modern lines. Stress on practical applications and development of the necessary analysis from the beginning. (*Not offered 1964–65.*)

18.48 ***Fourier Series and Integrals*** **(A)**
Prereq.: 18.47
Year: G (2) 3–0–9

Generalized harmonic analysis. Random functions. Hermitian developments in random function theory. Random functions in classical dynamics and in Schrödinger theory. General representation of nonlinear operators. (*Not offered 1964–65.*)

18.53 ***Theory of Probability*** **(A)**
Prereq.: 18.22 or 18.35
Year: G (1) 3–0–9

18.54 ***Theory of Probability*** **(A)**
Prereq.: 18.53
Year: G (2) 3–0–9

Probability measures, Borel fields, conditional probabilities, sums of independent random variables, limit theorems, zero-one laws, martingales, and topics selected by the instructor, for example, information theory, Markov processes, stationary processes and their connections with other parts of mathematics, especially with differential and integral equations.
Ray (18.53), McKean (18.54)

18.57 ***Theory of Approximation Methods*** **(A)**
Prereq.: 18.13; 18.15 or 18.20
Year: G (2) 3–0–9

18.58 ***Theory of Approximation Methods*** **(A)**
Prereq.: 18.57 or 18.651
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. Second term: finite difference methods for partial differential equations: equivalence of convergence and stability for linear initial-value problems; von Neumann's method in stability analysis; Lax theory of non-linear conservation laws. (*18.57 not offered 1964–65.*) *Strang*

18.60 ***Introduction to Fluid Mechanics***
Prereq.: 18.05 or *18.651*
Year: U (1) 3–0–6

Elements of the theory of perfect fluids; fundamental concepts and basic relations. Theory of potential motions. Motion of rectilinear vortices. Gravity waves and related free surface problems. Application of the theory of complex variables. Elements of the theory of viscous fluids. Some exact solutions. Low-speed flow. Boundary layer theory. *L. N. Howard*

18.61 ***Theoretical Fluid Mechanics*** **(A)**
Prereq.: 18.60
Year: G (1) 3–0–9

Topics selected for their physical interest and in illustration of the application of various mathematical theories and techniques to fluid mechanical problems. Review of basic principles. Hyperbolic partial differential equations, characteristics, and compressible flow. Singular perturbation theory, viscous boundary layers, rapidly rotating fluids, stratified flow. General theory of waves. (*Not offered 1964–65.*) *L. N. Howard*

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 1964–65.*) *Lin*

18.63 ***Mathematical Theory of Magneto-Fluid Mechanics*** **(A)**
Prereq.: 18.60
Year: G (2) 3–0–9

Maxwell equations, Lorentz transformation, discussion of the nature of approximation in hydromagnetics. Stress tensor, conservation theorems, scalar and tensor virial theorems. Equilibria, curl-free and force-free fields, incompressible "stars," pinches, steady flows. Hydromagnetic waves, stability, organized oscillations. (*Not offered 1964–65.*)

18.634 ***Topics in Applied Mathematics*** **(A)**
Prereq.: 18.06 or 18.652
Year: G (2) 3–0–9

Varying content from year to year so that students may take subject in successive years. Topics including the general stability theory of inviscid flow. *Pedlosky*

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. *Toomre*

18.65 *Integral Equations* (A)
Prereq.: 18.04
Year: G (2) 3–0–9
Objectives: (1) to show how to express physical problems in the form of integral equations, (2) to provide a treatment of the theory of integral equations, and (3) to describe the methods available for solving such equations. Applications to problems arising in several branches of physics and engineering. *(Not offered 1964–65.)* *Crout*

18.651 *Introduction of Applied Mathematics*
Prereq.: 18.20 or 18.25 & 18.26; *18.21*
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
Mathematical formulation of physical problems, approximations, models, linearized theories; general mathematical theory of partial differential equations, characteristics, classification of equations, existence, uniqueness, stability; linear problems, Fourier series and separation of variables, integral transforms, asymptotic methods, Green's functions, applications. Integral equations, Fredholm and Hilbert-Schmidt theory, singular integral equations, Wiener-Hopf method, dual integral equations, Riemann problem; calculus of variations, Galerkin procedure, approximation methods. *Hunter*

18.655 *Methods of Applied Mathematics III* (A)
Prereq.: 18.652 or 18.653
Year: G (1) 3–0–9
Nonlinear problems, perturbation theory, boundary layer theory, expansion methods; similarity solutions, dimensional analysis, nonlinear ordinary and partial differential equations; theory of characteristics, wave motion, group velocity; special topics. *Greenspan*

18.66 *Introduction to Elasticity*
Prereq.: 18.05 or 18.651
Year: U (2) 3–0–6
Elements of stress and strain in two and three dimensions. Hooke's Law, including thermal effects. St. Venant torsion theory. Problems of the elastic half space. *Reissner*

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 1964–65.)* *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. *Reissner*

18.69 *Tensor Calculus* (A)
Prereq.: 18.15 or 18.20
Year: G (2) 3–0–9
Classical theory of tensors and Riemannian geometry. Applications to mechanics and general relativity. *(Not offered 1964–65.)* *L. N. Howard*

18.721 *Algebraic Geometry* (A)
Prereq.: 18.25
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. *(18.721 not offered 1964–65.)* *Mattuck*

18.731 *Algebra* (A)
Prereq.: 18.20 or 18.26; 18.25
Year: G (1) 3–0–9
18.732 *Algebra* (A)
Prereq.: 18.731
Year: G (2) 3–0–9
Theory of fields and their extensions: algebraic and transcendental extensions, Galois extensions, algebraic closures. Structure of groups and rings. Additional topics varying yearly. *Iwasawa*

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18.74 *Topics in Algebra* (A)
Prereq.: 18.731
Year: G (1) 3–0–9
Content varies yearly so that graduate students may take the subject in successive years. Topics in the past few years have included algebraic groups, noncommutative rings and algebras, Lie algebras, local rings, nonassociative algebras. *Kostant*

18.763 *Algebraic Number Theory* (A)
Prereq.: 18.731
Year: G (2) 3–0–9

18.764 *Algebraic Number Theory* (A)
Prereq.: 18.763
Year: G (2) 3–0–9
Study of algebraic number fields and function fields, local and global, with emphasis on the sheaf-like viewpoints which generalize to algebraic groups and on cohomological methods. Ideals, ideles, and adeles; valuation theory. Splitting laws, group of units, class numbers, brief discussion of analytic methods. Cohomology of groups and class field theory for number fields and algebraic curves. (*Not offered 1964–65.*) *Ankeny*

18.77 *Theory of Numbers*
Prereq.: 18.20 or *18.25; 18.21*
Year: U (2) 3–0–9
Study of primes, congruences, and arithmetic functions and proofs of their asymptotic formulae. Approximations of the real numbers by rationals, Kronecker's theorem, and the introduction of geometry of numbers. Quadratic forms and quadratic number fields. Elementary proof of the prime number theorem. (*Not offered 1964–65.*) *Iwasawa*

18.78 *Topics in the Theory of Numbers* (A)
Prereq.: 18.31
Year: G (2) 3–0–9

18.79 *Topics in the Theory of Numbers* (A)
Prereq.: 18.78
Year: G (2) 3–0–9
Discussion of the Riemann Zeta function. Proof of the prime number theorem through contour integration, the method of contour integration applied to the divisor problem, the solution of Waring's problem via the circle method of Hardy-Littlewood and Vinogradoff's improvements, other applications of the circle method, the general sieve method of Selberg with application to primes, twin primes, Goldbach's problem. Proofs of certain best possible results of the sieve. Content varying from year to year, so that graduate students may take the subject in successive years. (*18.79 not offered 1964–65.*) *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. *Curtis*

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 sheaf theory, combinatorial topology, and/or differential topology. *G. W. Whitehead, Munkres*

18.84 *Locally Compact Groups* (A)
Prereq.: 18.35 or 18.37
Year: G (2) 3–0–9
Haar measure, group algebras, unitary representations, harmonic analysis on compact and abelian groups, Plancherel theorem, duality theorem. (*Not offered 1964–65.*) *Iwasawa*

18.85 *Continuous Groups* (A)
Prereq.: 18.35
Year: G (1) 3–0–9

18.86 *Continuous Groups* (A)
Prereq.: 18.85
Year: G (2) 3–0–9
The classical groups. Correspondences of Lie groups and Lie algebras. Structure theory of Lie algebras. Classification of semisimple Lie algebras and their representations. Topology of Lie groups. Discussion of symmetric spaces. (*Not offered 1964–65.*) *Kostant*

18.87 *Geometry of Manifolds* (A)
Prereq.: 18.22, *18.81*
Year: G (1) 3–0–9

18.88 *Geometry of Manifolds* (A)
Prereq.: 18.87
Year: G (2) 3–0–9
Real and complex manifolds, 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 1964–65.*) *I. M. Singer*

18.886 *Introduction to Mathematical Logic*
Prereq.: 18.20 or 18.25
Year: U (2) 3–0–6
Rigorous treatment of formal systems of mathematical logic. Formal languages, semantics and syntax. Propositional calculus and Boolean algebra. Quantification theory. Models, validity, and semantic implication. Formal derivability, completeness theorem, Skolem-Löwenheim theory, proof procedures. Axiomatic theories, e.g. set theory. Brief treatment of undecidability and incompleteness of axiomatic theories. Combinatorial systems. *H. Rogers*

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. (*Not offered 1964–65.*) *H. Rogers*

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. (*Not offered 1964–65.*) *H. Rogers*

18.893 *Set Theory* (A)
Prereq.: 18.886 or *18.89* or 21.641
Year: G (2) 3–0–9
Formalization of mathematics in axiomatic set theory. Cardinal and ordinal numbers. Consistency results of Godel. Independence results of Cohen. *Putnam*

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 1964–65.)* *Putnam*

18.90 *Mathematical Reading* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Reading of advanced mathematical treatises under the supervision of some member of the department. Choice of treatise and allotment of time according to individual cases. For graduate students finding it desirable to do advanced work not provided for in the regular subjects. Open to undergraduates only under exceptional circumstances. *W. T. Martin*

18.91 *Seminar in Mathematics* (A)
Prereq.: 18.06 or 18.22 or 18.31
Year: G (1 or 2) *Arr.*
Reading, consultation and discussion of current mathematical research. *(Not offered 1964–65.)* *Levinson*

19.
Meteorology

19.003 *Elementary Meteorology I*
Prereq.: ——
Year: 1 (2) 2–0–4
Introduction to meteorological science through examples from all scales of atmospheric motions; radiation balance and the global circulation; air masses and fronts; cyclones and weather forecasting; hurricanes; sea breeze; thunderstorms; micrometeorology; cloud physics; climatology. Laboratory exercises with weather maps. *J. M. Austin*

19.02 *Descriptive Meteorology*
Prereq.: ——
Year: U (2) 3–0–6
The general circulation of the earth's atmosphere; the secondary circulations, both tropical and extratropical, including the role of air masses and fronts; the tertiary (local) circulations, including drainage winds, local convection, whirlwinds, showers, thunderstorms, land and sea breeze, large scale turbulence eddies, föhn winds, etc. Willett and Sanders, *Descriptive Meteorology*, 2nd ed. *Willett*

19.14 *Long-Range Weather Forecasting* (A)
Prereq.: 19.44
Year: G (1) 3–8–6
Physical and statistical analysis of large-scale changes of the general circulation, with emphasis on the variable solar influences and climatic trends. Review of extended and long-range forecasting techniques. Laboratory exercises on the application of the Weather Bureau five-day prognostic technique. *Willett*

19.15 *Long-Range Forecasting* (A)
Prereq.: 19.44
Year: G (1) 3–0–6
Lecture part of 19.14. *Willett*

19.22 *Meteorological Instruments* (A)
Prereq.: 19.02
Year: G (2) 3–2–6
Laboratory study of the design and response characteristics of current surface and upper air instruments, with reference to the meteorologist's requirements. *Keily*

19.23 *Micrometeorological Instrumentation* (A)
Prereq.: 19.02
Year: G (1) 2–2–4
Design and evaluation of measuring systems for use in the lowest levels of the atmosphere. For graduate students specializing in micrometeorology. *Keily*

19.34 *Statistical Methods in Meteorology*
Prereq.: 18.04, *19.51*
Year: G (1) 2–0–4
Designed to examine recent developments in statistical weather forecasting and to provide a background for performing and evaluating statistical studies with meteorological data. Statistical forecasting by linear regression, nonlinear statistical forecasting, significance of empirical relations, and hypothesis testing. *Lorenz*

19.35 *Statistical Problems in Meteorology* (A)
Prereq.: 19.34
Year: G (2) 2–0–4
Seminar in statistical problems in meteorology, including such topics as power spectrum analysis, properties of stationary time series, and evaluation of linear and nonlinear methods of statistical weather forecasting. *Lorenz*

19.43 *Synoptic Meteorology I*
Prereq.: 19.601
Year: U (1) 3–0–6
Historical development of weather prediction. Application of elementary kinematics and dynamics to patterns of atmospheric flow. Description of structure and behavior of cyclonic and anticyclonic circulation. Simple dynamical prediction models. Petterssen, *Weather Analysis and Forecasting*, Vol. I, 2nd ed. *Sanders*

19.44 *Synoptic Meteorology II*
Prereq.: 19.43, 19.601
Year: U (2) 3–0–6
Further study of dynamical prediction models, with emphasis on large-scale vertical motion, clouds, and precipitation. Stability and instability and their relation to weather phenomena. Structure and behavior of severe convective systems. Petterssen, *Weather Analysis and Forecasting*, Vol. II, 2nd ed. *Sanders*

19.45 *Synoptic Meteorology III* (A)
Prereq.: 19.44
Year: G (1) 3–0–6
Analysis of methods and results of investigations of cyclonic and anticyclonic behavior. Synthesis of this information into models and theories of pressure change. Review of recent research in synoptic meteorology. Interrelationships between surface and upper-air changes, their application to the forecast problem. *J. M. Austin*

19.46 *Numerical Weather Prediction* (A)
Prereq.: 18.05
Year: G (2) 3–0–6
Scale analysis of atmospheric motions and the problem of meteorological noise. The quasi-geostrophic forecast system. Finite difference methods and the analysis of computational stability. Derivation and study of some simple atmospheric models for numerical forecasting. *Phillips*

19.51 *Synoptic Laboratory I*
Prereq.: 19.02
Year: U (1) 0–15–0
Techniques of analysis and prognosis of the daily circulation pattern. Dynamical and empirical methods for prediction of the circulation pattern and associated weather phenomena. *Sanders*

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19.53 *Synoptic Laboratory II* (A)
Prereq.: 19.44, 19.51
Year: G (2) 0–12–0
Theory and practice of modern weather prediction; development of quantitative prognostic procedures. *Sanders*

19.601 *Introduction to Theoretical Meteorology*
Prereq.: 8.02, 18.02
Year: U (1) 3–0–6
Simplified treatment of atmospheric statics, dynamics and thermodynamics designed to provide the theoretical background for synoptic meteorology and to prepare the student for more advanced subjects in dynamic meteorology. *Phillips*

19.62 *Dynamic Meteorology I*
Prereq.: 19.601
Year: U (2) 3–0–6
Hydrodynamic equations of motion. Streamlines and trajectories, circulation and vorticity, theory of atmospheric turbulence, its effects on the vertical distribution of wind and other meteorological elements. Energy transformations in the atmosphere. *Lorenz*

19.64 *Dynamic Meteorology II* (A)
Prereq.: 19.62
Year: G (1) 3–0–9
Large-scale atmospheric motions. Examination of recent theories of the general circulation. Research in the application of fluid mechanics to meteorology and oceanography. *Starr*

19.67 *Planetary Fluid Dynamics* (A)
Prereq.: 18.60
Year: G (2) 3–0–9
Discussion of fluid dynamical problems on the planetary scale with examples drawn from the atmosphere, the oceans and the interior of the earth. Convectively driven circulations in rotating systems and high-speed computational methods for the solution of the governing equations. *Charney*

19.70 *Elementary Physics of the Atmosphere*
Prereq.: 8.03, *18.02*
Year: U (1) 3–0–6
Treatment of atmospheric radiation, the ozone layer and the upper atmosphere, atmospheric electricity, atmospheric optics, propagation of sound in the atmosphere, and icing of aircraft. *Keily*

19.71 *Radar Meteorology* (A)
Prereq.: 8.03, 19.02
Year: G (2) 2–1–4
Elementary principles of radar and the techniques of storm detection. Brief discussion of microwave propagation. Analysis of the radar echo from precipitation. The potentialities of radar for the examination and measurement of precipitation processes. Lectures and laboratory work with operating radar systems. *P. M. Austin*

19.72 *Physical Meteorology* (A)
Prereq.: 8.04, 18.03
Year: G (2) 3–0–6
Advanced treatment of solar and thermal radiation, the atmospheric heat balance, the physics of condensation and precipitation and certain aspects of the physics of the high atmosphere. Extensive use of the current literature. *Houghton*

19.74 *Physics of the Upper Atmosphere* (A)
Prereq.: 8.04, 18.04
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, 18.04
Year: U (1) 3–0–6
Structure and physical properties of the oceans. Methods of measurement and an outline of the observational information. Dynamics of oceanic current systems. Wind currents, waves and tides. *Houghton*

19.84 *Dynamic Oceanography* (A)
Prereq.: 18.05, 19.83
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.: 19.44, 19.62
Year: G (1) 2–0–4
Weekly reviews and discussions by staff members and students of recent meteorological contributions in current periodicals and of original research. *Houghton*

19.911 *Meteorological Seminar I* (A)
Prereq.: 19.44, 19.62
Year: G (1) 1–0–2

19.912 *Meteorological Seminar II* (A)
Prereq.: 19.911
Year: G (2) 1–0–2
Same as 19.91. *Houghton*

19.94 *Special Problems in Meteorology*
Prereq.: 19.02
Year: G (1 or 2) *Arr.*
Reading, consultation, and original investigation on meteorological problems. *Staff*

19.95 ***Special Problems in Meteorology*** **(A)**
Prereq.: 19.44, 19.62
Year: G (1 or 2) *Arr.*
Reading, consultation and original investigation on meteorological problems of more advanced nature than those in 19.94. *Staff*

20.
Nutrition and Food Science

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.
J. T. R. Nickerson

20.111 ***Food Science and Technology Laboratory***
Prereq.: 5.142
Year: U (1) 1–4–1
Laboratory exercises involving canning, refrigeration, freezing, and drying of foods; the manufacture of bakery and associated products. Methods of detecting changes in foods due to the growth of microorganisms; chemical or physical changes. *Tannenbaum*

20.15 ***Food Engineering*** **(A)**
Prereq.: 2.041
Year: G (2) 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. *Charm*

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*

20.30T ***Basic Nutrition***
Prereq.: 7.05T
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.
Harper, Q. R. Rogers

20.301 ***Experimental Nutrition*** **(A)**
Prereq.: *20.30T*
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 ***Chemical and Biochemical Techniques in Food and Nutrition Research*** **(A)**
Prereq.: 5.14, 5.41, 7.05T
Year: G (1) 2–6–4
Lectures and experiments in the principles and use of gravimetric, colorimetric, fluorometric, flame photometric and spectrophotometric analyses; chromatography (ion exchange, gas, paper, thin layer); microbiological and isotope techniques in analysis of nutrients and metabolic intermediates. *Wolf, Wick, Issenberg*

20.36 ***Human Nutrition*** **(A)**
Prereq.: 20.30T
Year: G (2) 3–0–6
Measurement of nutrient requirements and evaluation of nutritional status of man; effects of dietary and conditioned nutrient deficiencies; nutrition in disease; effects of disease on nutritional status and nutrient requirements; aging and nutrition; military nutrition; institutional nutrition; economic and social aspects of nutrition; philosophy, methodology and techniques of clinical investigation. *Watkin*

20.37 ***Endocrinology*** **(A)**
Prereq.: 20.30T, *20.63T*
Year: G (2) 3–0–6
Introduction to those nutritional problems requiring an understanding of endocrinology. Review of basic principles of endocrinology as well as recent advances, with emphasis on the multi-disciplinary approach in research.
Fillios

20.38 ***Factors Influencing the Nutritional Values of Foods*** **(A)**
Prereq.: 20.11, 20.30T
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.
R. S. Harris

20.391 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05T, 20.301
Year: G (1 or 2) 2–0–4

20.392 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05T, 20.301
Year: G (1) 2–0–4

20.393 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05T, 20.301
Year: G (2) 2–0–4

20.394 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05T, 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

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of advances in energy, carbohydrate, lipid, protein, and nucleic acid metabolism. The sequence of topics beginning first semester, 1964–65: physiological aspects of protein metabolism; mineral metabolism; physiological aspects of lipid metabolism. (*20.391 and 20.394 not offered 1964–65.*) *Wolf* (*20.391*), *Q. R. Rogers*, *Harper* (*20.392*), *R. S. Harris* (*20.393*), *Fillios* (*20.394*).

20.40 *Selected Topics in Nutrition and Food Science* (A)
Prereq.: 20.11, 20.30T
Year: G (1 or 2) 3–0–4
Detailed discussion of selected topics of current interest. Class work in various fields of nutrition, food science and technology not covered by regular subjects of instruction. *Staff*

20.41 *Microbiology Laboratory*
Prereq.: 7.05T, 7.21
Year: U (1) 1–4–3
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.: 7.05T, 7.21
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. *J. T. R. Nickerson*

20.47 *Biochemical Engineering* (A)
Prereq.: 5.62 or 10.31; 7.05T or 7.21
Year: G (1 or 2) 3–3–4
Interactions of chemical engineering, biochemistry and microbiology. Mathematical representation of microbial systems. Kinetics of growth, death and metabolism. Sterilization of air and liquids. Mass transfer and mixing as they affect fermentations. Product recovery. Laboratory experiments dealing with fermentation kinetics, centrifugation, product recovery, biochemical fuel cells, and computer simulation of microbial systems. *Mateles*

20.51 *Advanced Food Science* (A)
Prereq.: 5.62, 20.11, 20.30T
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*

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. (*Alternate years. Not offered 1964–65.*) *Goldblith*

20.59T *Food Toxicology* (A)
Prereq.: 20.11, 20.30T
Year: G (2) 3–0–4
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, *20.59T*, 20.63T
Year: G (1 or 2) 1–6–2
Studies of acute and subacute toxicity; techniques of biological assay; and parameters of biological response. *L. Friedman*

20.61 *Seminar in Nutrition and Food Science* (A)
Prereq.: ——
Year: G (1) 2–0–2
20.62 *Seminar in Nutrition and Food Science* (A)
Prereq.: ——
Year: G (2) 2–0–2
Presentation of recent advances in nutrition, food science and technology. *Staff*

20.63T *Systemic Physiology* (A)
Prereq.: 20.30T
Year: G (1) 3–4–6
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*

20.64T *Comparative Histology and Organology* (A)
Prereq.: *20.63T*
Year: G (1) 4–6–6
Microscopic study of form and structure, and recognition of basic tissues and organs of animals. Basic concepts of general pathology. *Carlton*

20.65 *Nutritional Pathology* (A)
Prereq.: 20.64T
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 1964–65.*) *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*

20.66T ***Tissue Culture and Cell Toxicology*** **(A)**
Prereq.: 7.21, 20.32, *20.59T*
Year: G (1 or 2) 2–4–2

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.: 20.30T
Year: G (S) 4–0–4

Project visits and seminar discussions of the incorporation of nutrition into public health programs at international and local levels. Bilateral and international technical assistance programs involving nutrition. Application of supplementary feeding and food enrichment techniques. Nutritional factors in relation to growth and development, pregnancy and lactation, and cardiovascular diseases. Interrelationship between infection and nutrition. Dietary requirements for differing environmental and cultural situations. (*Restricted to suitably qualified physicians and dentists.*) *Scrimshaw*

20.82 ***Clinical Nutrition*** **(A)**
Prereq.: 20.30T
Year: G (S) 4–2–4

Four hours of round table discussions and two hours of hospital and clinic visits per week covering the characteristics, epidemiology, and prevention of nutritional diseases with special attention to protein malnutrition, kwashiorkor and marasmus, nutritional anemia, endemic goiter and vitamin deficiencies, and the relation of nutrition to morbidity and mortality from infectious diseases, cirrhosis of the liver, cardiovascular diseases, and cancer. (*Restricted to suitably qualified physicians and dentists.*) *Scrimshaw*

20.83T ***Evaluation of Nutritional Status*** **(A)**
Prereq.: 20.30T
Year: G (S) 2–10–4

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*

20.85 ***Research Management in the Food and Drug Industries*** **(A)**
Prereq.: ——
Year: G (1) 2–0–2

20.86 ***Research Management in the Food and Drug Industries*** **(A)**
Prereq.: ——
Year: G (2) 2–0–2

Lectures devoted to laboratory management problems peculiar to the food and drug industries and to 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. *C. N. Frey*

20.87 ***Oral Science*** **(A)**
Prereq.: 20.65
Year: G (2) 3–0–6

Comprehensive study of organs, tissues, and fluids of the oral and paraoral region from the point of view of each of the scientific and clinical disciplines, presented by faculty and guest lecturers. *R. S. Harris*

20.88 ***Seminar in Oral Science*** **(A)**
Prereq.: 20.30T
Year: G (1) 2–0–4

20.89 ***Seminar in Oral Science*** **(A)**
Prereq.: 20.30T
Year: G (2) 2–0–4

Presentations of recent advances in oral science by staff, guest lecturers and students. *R. S. Harris*

20.91 ***Experimental Statistics for the Biological Sciences I*** **(A)**
Prereq.: 18.02
Year: G (1) 2–2–4

Designed to give investigators in life sciences a working knowledge of statistical procedures for interpretation of experimental data. Topics including: variation and statistical measures. Probability, frequency distributions and moments; sampling distributions, point and interval estimation, tests of significance. Basic concepts of statistical models and use of samples. Regression and correlation. Analysis of variance and covariance. (*Restricted to graduate students in Nutrition and Food Science; others admitted only by permission of instructor.*) *Guzman*

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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. (*Restricted to graduate students in Nutrition and Food Science; others admitted only by permission of instructor.*) *Guzman*

21.
Humanities

21.01[1] ***The Greek Tradition***
Prereq.: ——
Year: 1 (1) 3–0–5
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[1] ***The European Tradition***
Prereq.: 21.01
Year: 1 (2) 3–0–5
Continuation of 21.01. Representative works selected by the Instructor from such later periods of the Western Tradition as Christian Antiquity, the Middle Ages, the Renaissance, and the Enlightenment.

21.03T[1] ***The Nature of Literature***
Prereq.: 21.02
Year: U (1, 2) 3–0–5
The experience, analysis, and evaluation of poems, plays, and fiction, particularly from the modern period, with emphasis on increasing the student's capacity to respond to various types of literary expression by fuller attention to structural aspects, historical and psychological background, and the interrelationship of form and idea in the works read. Readings from such authors as Conrad, Faulkner, Genet, Hemingway, Joyce, Kafka, Lawrence, Mann and Williams. (*21.03T and 21.11 may not both be taken for credit.*) *Staff*

21.04T ***Philosophy: Classic and Contemporary***
Prereq.: 21.02
Year: U (1, 2) 3–0–5
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) 3–0–5
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) 3–0–5
Studies in historical perspective of characteristic forms of twentieth-century thought and consciousness, emphasizing 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 Senior Seminar***
Prereq.: ——
Year: U (1) 2–0–6
Seminar on selected topic involving history, literature, philosophy. Open only to members of Courses XXI-A and XXI-B. *Lamson*

21.08T ***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

21.091T ***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*

21.092T ***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 1964–65.*) ——

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. *I. Singer*

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. *MacIsaac*

[1] Special sections with lectures and readings in French are conducted by the Department of Modern Languages. These are restricted to students with an adequate background in French.

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. *MacIsaac*

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. (*Limited to 12 students having instructor's approval.*) *Spacks*

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.*) *Staff*

21.12 *Literary Criticism*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Exploration of the characteristics of art and the criteria by which it may be judged. Reading of examples to illustrate problems of choice and samples of literary theory; social and philosophic implications of the arts. *W. C. Greene*

21.13 *The Epic*
Prereq.: 21.03T 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*

21.14T *The Bible*
Prereq.: 21.03T 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. *Reiche*

21.15T *Shakespeare*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
Reading and discussion of eleven major plays of Shakespeare. *N. N. Holland*

21.16T *Chaucer*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Reading and discussion of *The Canterbury Tales* and *Troilus and Criseyde.* (*Not offered 1964–65.*) *Lamson*

21.17 *Joyce*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
Close reading and discussion of James Joyce's major work prior to *Finnegan's Wake.* *Fassett*

21.19 *Major Writers of the English Renaissance*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
Study of selected works by Marlowe, Spenser, Shakespeare, Jonson, Bacon, Donne, Browne, and Milton in relation to literary traditions and to philosophical and scientific ideas in the Renaissance. *Lamson*

21.21T *Dissolution of Classicism*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
Concentration on the special way this process took place in English literature, with incidental references to French and German literature and to English philosophy as well. The main authors read: Swift, Pope, Johnson, Reynolds, Blake, Wordsworth, Coleridge, Byron. *Youngren*

21.22T *Nineteenth-Century: The Romantics*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Romanticism in England and the Continent studied through reading and discussion of selected works of the English Romantic Poets and of Goethe and Stendhal. (*Not offered 1964–65.*) *Lamson*

21.24T *The Birth of Modernism*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Attempt to create a modern sensibility in response to the nineteenth-century breakdown of cultural and literary values. Authors to be read and discussed: Nietzsche, Arnold, Baudelaire, Hopkins, James, Verga, Freud. *Kampf*

21.25 *The Modern Novel*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Discussion of works by such novelists as Kafka, Hesse, Joyce, Mann, Faulkner, and Camus. (*Limited enrollment.*) *C. Collins*

21.26T *Modern Drama*
Prereq.: 21.03T 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*

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21.27T *Modern Poets: Yeats, Eliot, Stevens and Williams*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
Emphasis on the analysis of major poems in the light of the poets' critical writings and sources. *Spacks*

21.28T *Modern American Literature*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Discussion of works by such writers as Eliot, Pound, Hemingway, Fitzgerald, Faulkner, Stevens, Williams, Cummings, Nathanael West, Capote, Salinger, and Robert Lowell. (*Limited enrollment.*) *C. Collins*

21.29T *Dostoevski, Tolstoi and Modern Russian Literature*
Prereq.: 21.03T 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. *MacMaster*

21.30T *Non-Western Literature*
Prereq.: 21.03T 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. *W. C. Greene*

21.302 *Chinese Literature*
Prereq.: At least one subject in literature
Year: U (2) 3–0–5
Principal characteristics of Chinese culture reflected in prose and poetry from earliest times to the present. Linguistic, metaphysical, social and political contexts. The writer as a historical figure. The evolution of forms and styles. Problems of translation. Study with intent to provide a more objective view of Western literary traditions. 21.30T desirable preparation, but not required. *Sivin*

21.31T *Narrative Fiction*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
Varieties and possibilities of fiction from the Renaissance to the present. Authors to be read and discussed: Boccaccio, Laclos, Hawthorne, Gogol, Tolstoy, Dostoevski, Svevo, Ford, Kafka, Bellow. *Kampf*

21.32T *The Nature of Poetry*
Prereq.: 21.03T 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*

21.33T *The Drama as Theatre*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
Close reading and discussion of a number of those plays presented in the Boston area during the term by professional, community, and academic organizations. Emphasis on the play *as it works on stage.* Class discussions assisted by visiting writers, directors, designers, or actors involved in the production of the play. *Gurney*

21.34T *The Short Story*
Prereq.: 21.03T 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. *Spacks*

21.35T *Theatre Arts: Elementary Stagecraft and Production Studies*
Prereq.: 21.03T 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*

21.36T *The Nature of the Comic*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Close reading of comic works by such writers as Apuleius, Cervantes, Chaucer, Chekhov, Carroll, Molière, and Shaw, with discussion of theories of the comic, including Bergson's, Freud's, and Kierkegaard's. *Gurney*

21.37T *Tragedy*
Prereq.: 21.03T 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*

21.38T *Myth and Symbol in Western Literature*
Prereq.: 21.03T or 21.11
Year: U (2) 3–0–5
Examination of selected works from Western literature in order to show that man lives not merely in a physical universe but in a symbolic universe as well. Readings from the Bible and Shakespeare, together with selections from contemporary works. (*Not offered 1964-65.*) *Pettit*

21.382 *The Psychology of Literature*
Prereq.: 21.03T or 21.11
Year: U (2) 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, Herrick, Hopkins, Kafka, Lawrence, Marvell, Molière, Shakespeare, Swift, Twain, Wordsworth. (*Limited enrollment.*)
N. N. Holland

21.39 *American Folklore*
Prereq.: 21.03T or 21.11
Year: U (1) 3–0–5
American folklore as historical documentation dramatically illustrating personal beliefs and experiences of our people. Extensive survey of our lore by geographical area and historical era with an examination of diaries and letters, histories such as Parkman's *Oregon Trail*, DeVoto's *Across the Wide Missouri*, and fiction such as A. B. Guthrie's *The Way West.* Use of folk material in cultivated music, drama, literature, and art. *T. Wood*

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. *Kaledin*

21.402 ***The United States in European Civilization: Colonial Times to the Present***
Prereq.: 21.02
Year: U (2) 3–0–5
An interpretative assessment of selected major currents in American history from the perspective of their place in the larger context of the general development of European civilization. Changing relation of American security to the policies of the European powers and the changing American awareness of and attitudes toward Europe and the world. Examination of the interaction of American and European civilization. Attempt to formulate some conclusions as to the effect of the long experience of attraction and repulsion, of separation and involvement, in American relations with Europe in shaping the course of American history and the development of the American "national style," or characteristic habits of thought and action. *Jensen*

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 1964–65: the factory town, the westward movement, the railroad, the automobile, and the New Deal. *L. S. 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 1965: Puritanism, Transcendentalism, civil liberties, the Mormons, and Pragmatism. *L. S. Bryant*

21.501 ***The Development of Market Economies in Europe***
Prereq.: 21.02
Year: U (1) 3–0–5
The dynamics of change and growth involved in the shift from agricultural to commercial economies, from agrarian to urban societies, from local to regional and interregional orientations. Principles, mechanisms, and consequences of the commercial revolution studied through relative examples in pre-industrial Europe, 1100–1650. *Watson*

21.502 ***The Development of European Economic Institutions***
Prereq.: 21.02
Year: U (2) 3–0–5
Study of the development of European economy and its transformation from a pre-industrial to a modern industrial society. Analysis of the economic institutions of Europe and of the main components of economic growth having special relevance to the history of capitalism since early modern times. Emphasis on the rise and growth of modern industrial economies and on comparative patterns of industrialization. Stress on long-run factors (aggregative and structural) in economic history, and historical problems arising from rapid economic change — widening economic inequality among nations, rapidity of shifts in economic and political power in the modern world, the ideological element in economic change, tensions in social structure and value systems arising from shifting distributions of income and wealth. *Glazier*

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. *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 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 stress on process and evolution; the increase in awareness of the self; the rise of historicism; the changing nature of scientific concepts; and the nature of imperialism, revolution and totalitarianism. Presentation focused, wherever possible, upon important individuals who epitomize a way of thinking and feeling. *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*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

21.507 ***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 1964–65.*) *Larkin*

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*

21.51T ***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*

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. *MacMaster*

21.513 ***Science and Natural Philosophy in the Chinese Tradition***
Prereq.: 21.02
Year: U (1) 2–0–6

21.514 ***Science and Natural Philosophy in the Chinese Tradition***
Prereq.: 21.513
Year: U (2) 2–0–6
Growth and structure of Chinese proto-scientific and scientific ideas. The origins, growth, and decay of particular disciplines and their integration. The role played by the classical language in forming concepts and terminology. The influence of the social and political milieu on the nature of scientific inquiry and the personality of the scientist. The transmission of, and the reaction to, foreign ideas. Emphasis on distinguishing the essential character of science from its culturally-conditioned style. Readings in primary sources, including unpublished translations. *Sivin*

21.517 ***The 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." *Mintz*

21.519 ***The 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. *Mintz*

21.521 ***History of Materials***
Prereq.: 21.02
Year: U (1) 2–0–6
Extensive study of the discovery and use of artificial materials with particular emphasis on metals. Relation of the development of empirical knowledge of materials to their use in engineering and art, and to the growth of scientific understanding. Some original early printed sources and archeological artifacts available to the students. *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, Economic Growth, and Social Change***
Prereq.: 21.02
Year: U (1) 3–0–5
Growth of technology in the modern world in its relationship to economic and social change. Crafts tech-

nology; industrialization-invention, origins of mass production and interchangeable parts, power sources, transportation, mechanization of agriculture; technology and large-scale enterprise, new industries. *T. P. Hughes*

21.526 *Engineers in History*
Prereq.: 21.02
Year: U (2) 3–0–5
Changing nature of engineering as shaped by the character of leading engineers and by tasks given them by different societies. Special emphasis on contrast of the architect-engineer of the Renaissance with the scientist-engineer of the 20th Century. *T. P. Hughes*

21.531 *Innovation and Continuity in the History of Science*
Prereq.: 21.02
Year: U (1) 3–0–5
Examination of certain generalizations about the process of scientific discovery and of the way in which scientists accept (or reject) and apply novel discoveries and theories. Readings beginning with general views of these processes derived from a study of the past. Study of the Copernican and the chemical revolution of the 18th century to evaluate the extent to which such general patterns fit concrete and complex historical situations. Student papers applying generalizations discussed to topics of choice in history of science. (*Not offered 1964–65.*) *Holmes*

21.532 *Scientists and Society*
Prereq.: 21.02
Year: U (2) 3–0–5
Historical development of science as a human activity, including respective contributions of scholars and technologists to the origins of scientific endeavour, organization of scientific investigation, interactions between the pursuit of scientific goals and contemporary social conditions, changing views of the role of scientists in relation to their profession and to their societies. (*Not offered 1964–65.*) *Holmes*

21.533 *History of Biology*
Prereq.: 21.02
Year: U (1) 3–0–5
Problems in the history of biology from antiquity to 1900. Emphasis on the development of concepts of physiology and the interactions of biological thought with that of other physical sciences. The influence of ancient Greek biological ideas upon later thought; early interpretations of biological processes as physical motions; introduction of the view that chemical reactions underlie biological processes; influences of the principle of conservation of energy on biological thought; the origins of the cell theory; evolution; and the development of experimental biology. (*Not offered 1964–65.*) *Holmes*

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. *Sivin*

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 1964–65.*) ——

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 1964–65.*) ——

21.613 *Classical Philosophy*
Prereq.: 21.02
Year: U (1) 3–0–5
Selected readings in the pre-Socratics; in Plato and Aristotle; or in Hellenistic and later thought: Stoicism — Lucretius, Epictetus, and Marcus Aurelius; Epicureanism — Epicurus and Lucretius; Neo-Platonism — Plotinus and the critical encounter with early Christianity in theologians like Origen and Augustine; the development of the Logos-concept. (*Not offered 1964–65.*) *Reiche*

21.614 *Aristotle*
Prereq.: 21.02
Year: U (2) 3–0–5
Aristotle's theory of knowledge and metaphysics. Some attention given to Aristotle's views on psychology, ethics and aesthetics, and to the relation of Aristotle's theories to later philosophical developments. *Zweig*

21.615 *Kant* (A)
Prereq.: ——
Year: G (1) 3–0–5
An examination of Kant's *Critique of Pure Reason*, along with some shorter writings on the theory of knowledge and ethics. The relation of Kant's views to those of his contemporaries and to current philosophical tendencies. (*Restricted to graduate students in philosophy; others admitted only by permission of instructor.*) *Zweig*

21.616 *Hegel and Kierkegaard*
Prereq.: 21.02
Year: U (2) 3–0–5
Examination of the validity of Kierkegaard's critique of Hegel through a close study of Hegel's *Phenomenology of Spirit* and Kierkegaard's *Concluding Unscientific Postscript* and *Sickness Unto Death*. *Todes*

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. *J. Thomson*

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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.
J. F. Thomson

21.634 *Phenomenology and Existentialism*
Prereq.: 21.02
Year: U (2) 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.*
Todes

21.641 *Symbolic Logic*
Prereq.: 21.02
Year: U (1) 3–0–5
Introduction to the principles of deductive logic. The major results concerning the structure of mathematics. The place of modern logic in philosophy; its influence on the formulation of philosophical problems and on the search for methods for their solution. *J. F. Thomson*

21.642 *Philosophy of Logic* (A)
Prereq. ——
Year: G (2) 3–0–5
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. (*Restricted to graduate students in philosophy; others admitted only by permission of instructor.*) *J. 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. *I. Singer*

21.652 *Moral Philosophy* (A)
Prereq.: ——
Year: G (2) 3–0–5
Systematic study of some problems of moral philosophy. Special attention to the concept of good action and its connection with intention, motive, and conscience; also to the definition of moral virtue. Readings from Aristotle, Aquinas, and Kant. (*Restricted to graduate students in philosophy; others admitted only by permission of instructor.*)
J. J. Thomson

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 1964–65.*) *Mazlish*

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.
I. Singer

21.672 *Philosophy in Literature*
Prereq.: 21.02
Year: U (2) 3–0–5
Study of philosophical ideas in great works of literature. Particular emphasis upon philosophical problems related to the concept of love and the nature of feeling. The views of Plato, St. Paul, St. Augustine, Stendhal, Freud, etc. studied both in themselves and as means of understanding books such as *Tristan and Iseult*, *Swann's Way*, *The Kreutzer Sonata*, *Lady Chatterley's Lover*, etc.
I. Singer

21.682 *Metaphysics*
Prereq.: 21.02
Year: U (2) 3–0–5
Nature of the metaphysical quest in the light of recent criticisms thereof, leading into an examination of six classic world views: realism, mechanism, pragmatism, Whitehead's philosophy of organism, idealism and mysticism. (*Not offered 1964–65.*) *H. C. Smith*

21.691 *Philosophies and Religions of the East*
Prereq.: 21.02
Year: U (1) 3–0–5
Exploration of the distinctive perspectives of India and the Orient on the nature of the universe, the goal of human life, and the means by which this goal is to be achieved. Reading and discussion on the basic texts of Hinduism, Buddhism, Confucianism, Taoism and Japanese Zen; lectures on historical background. (*Not offered 1964–65.*) *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. *P. Lee*

21.693 *Philosophy of Religion*
Prereq.: 21.02
Year: U (1) 3–0–5
The problem and method of a philosophy of religion. Relation to theology and phenomenology, psychology, sociology, and history of religion. The problem of human mortality as expressed in classic myths and related to awareness of one's life-history and destiny. Readings from classic texts of the Western tradition: Homer, Plato, the Bible, Dante, Shakespeare, Kierkegaard, Heidegger, Tillich, and Ricoeur. *P. Lee*

21.701 *Science and Philosophy from Antiquity to Copernicus*
Prereq.: 21.02
Year: U (1) 3–0–5
The course of civilization around the growth of scientific ideas. Philosophical ideas accompanying the formation of scientific concepts, from the Pre-Socratics and later Greek developments through the medieval view to its breakup in the Renaissance under the influence of Copernicus and the age of discoveries. *de Santillana*

21.702 *Science and Philosophy from Copernicus to the Present*
Prereq.: 21.701
Year: U (2) 3–0–5
Continuation of 21.701 to modern times. The period from the Scientific Revolution and the founding of modern scientific thought to the present. The formation of the main scientific ideas, their philosophical implications, and the interactions of science and society. *de Santillana*

21.703 *Cosmology — Old and New Problems*
Prereq.: 21.02
Year: U (1) 3–0–5
Cosmology in early times as the one total science. Its foundations in archaic astronomy. Its transformation under the influence of physics. The cosmological crisis in the eighteenth century. Modern cosmology as the convergence of all the sciences. Unsolved problems. (*Not offered 1964–65.*) *de Santillana*

21.705 *Biological Bases of Perception and Knowledge*
Prereq.: 21.02
Year: U (1) 3–0–5
An inquiry into assumptions underlying physiological and psychological experiments in perception as these reraise the question of whether the study of brain function can avoid metaphysical commitment. The mind-body problem in contemporary guise. *de Santillana, Lettvin*

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. *Shimony*

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 1964–65.*) *Putnam*

21.715 *Philosophy of Physics* (A)
Prereq.: ——
Year: G (1) 3–0–5
Consideration of philosophical problems concerning space, time, matter, cause, and chance in the light of some of the discoveries of modern physics. (*It is strongly suggested that students have taken 8.05 and 8.06 or their equivalents.*) (*For graduate students, and for undergraduates having permission of instructor.*) *Shimony*

21.716 *Philosophy of Mind*
Prereq.: 21.02
Year: U (2) 3–0–5
Some concepts in the philosophy of Mind, such as Mind and Matter, Sensation and Feeling, Thinking, Wishes and Motives, and Intention, discussed with references to classical psychology and modern analytical philosophy. (*Not offered 1964–65.*) *J. F. Thomson*

21.721 *Philosophy of Language* (A)
Prereq.: ——
Year: G (1) 3–0–5
Current philosophical approaches to questions about language in general and meaning in particular. Study of authors representative of the Positivist movement and of Ordinary Language Philosophy. Particular attention to such topics as the "performative" analysis of speech and the implications of the philosophy of language for philosophical psychology. (*Restricted to graduate students in philosophy; others admitted only by permission of instructor.*) *Putnam*

21.722 *Semantics*
Prereq.: 21.02
Year: U (2) 3–0–5
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) 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. Special attention to the role of a semantic theory in the solution of philosophical problems. (Additional requirement: thorough knowledge of material in Chomsky's *Syntactic Structures.*) (*Not offered 1964–65.*) *Fodor, Katz*

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 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 who wish to pursue special studies or projects with members of the Philosophy Section. *Staff*

MUSIC

21.91 *Introduction to Music*
Prereq.: ——
Year: U (1, 2) 3–0–5
A subject to familiarize students who have little or no knowledge of music with the language of music and its universal literature. Rudiments of harmony and ear training, and terminology of music. Analysis of representative masterworks through lectures and demonstrations. Listening to recordings, weekly exercises, and readings required. *Staff*

21.92T *Theory of Music*
Prereq.: 21.91
Year: U (1, 2) 3–0–5
The theory of music in its historical perspective, including harmonic, contrapuntal, and other formal organizations. Written exercises, reading, and ear training. (*Permission of instructor required.*) *Ferretti, Lay*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

21.926 ***Analysis of Musical Sound***
Prereq.: ——
Year: U (2) 1–2–5
Recording of sounds, waveform analysis, and an evaluation of listening to musical sounds. Lectures and laboratory projects. (*Permission of instructor required.*) *Ferretti*

21.93T ***Western Music in the Middle Ages and the Renaissance***
Prereq.: 21.91
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. *Mattfeld*

21.94T ***Western Music in the Baroque Era***
Prereq.: 21.91
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. *G. Tucker*

21.95T ***Western Music in the Classic Era***
Prereq.: 21.91
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.*) *G. Tucker*

21.96T ***Western Music in the Romantic Era***
Prereq.: 21.91
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.*) *G. Tucker*

21.97 ***Twentieth-Century Music***
Prereq.: 21.91
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.*) *G. Tucker*

21.98 ***The Opera***
Prereq.: 21.91
Year: U (2) 3–0–5
Study of the nature and development of the music drama. Illustrations at the piano as well as from recordings. (*Not offered 1964–65.*) *Mattfeld*

21.991 ***Seminar in Music***
Prereq.: 21.91
Year: U(1) 3–0–5
Varying topics from year to year, including Bach's cantatas, or passions and B minor Mass; Haydn's oratorios or string quartets; Mozart's piano concertos or operas; Beethoven's string quartets or symphonies; principles of music history; musical esthetics. Topic for Fall 1964: The String Quartets of Beethoven. (*Permission of instructor required.*) *Liepmann*

21.992 ***Seminar in Music***
Prereq.: 21.91
Year: U (2) 3–0–5
Varying topics from year to year. Topic for Spring 1965: The Operas of Mozart. (*Permission of instructor required.*) *Liepmann*

22.
Nuclear Engineering

22.10 ***Elementary Nuclear Physics***
Prereq.: 8.04 or 8.041; 18.04
Year: G (1) 2–0–4
Introduction to aspects of modern physics important in nuclear engineering; atomic structure, atomic radiations and X-rays; nuclear structure, radioactivity, nuclear reactions, and the fission process. Primarily for students without prior knowledge of nuclear physics who wish background as preparation for 22.21. Students planning to take graduate work in nuclear engineering should take 8.051. *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. (*Alternate years. Not offered 1964–65.*) *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. *Kaplan*

22.22 ***Nuclear Reactor Physics II*** **(A)**
Prereq.: 22.21
Year: G (2) 3–0–9
Problems relating to the operation of a nuclear reactor at power; poisoning effects of fission products; effect of temperature on reactor design parameters; excess reactivity; elements of reactor kinetics, perturbation theory, transport theory and control rod theory. Emphasis on applying reactor theory to actual reactor systems. *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; fuel cycle analysis; power reactor economics; 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, 18.04
Year: G (1) 3–0–6
Problem of control of dynamical systems and its implications, Fourier and Laplace transforms, transfer functions, feedback systems, flow graphs, block diagrams, transient and steady state response of feedback systems, stability criteria. Correlation techniques used in linear systems. Discussion of nonlinear problems. (*Not offered 1964–65.*) *Gyftopoulos*

22.242 ***Nuclear Plant Dynamics*** **(A)**
Prereq.: 6.213 or 6.601 or 22.241; 22.21
Year: G (2) 3–0–9
Nuclear reactor kinetics, thermal dynamics, inherent feedback loops, external control loops, transient and steady state performance of nuclear reactors. Pile statistics, pile oscillation tests. Dynamics of nuclear plants, analog and digital methods of analysis of nuclear systems. Analysis of nonlinear nuclear plant dynamics, development of boundedness and stability criteria for nonlinear systems. Synthesis of control systems. (*Not offered 1964–65.*) *Gyftopoulos*

22.25 ***Selected Topics in Reactor Physics*** **(A)**
Prereq.: 22.22
Year: G (1) 3–0–9
Status of power reactor design with emphasis on developments in reactor physics and engineering needed to achieve competitive nuclear power in both high and low fuel cost areas; physical aspects of reactor safety.
Gyftopoulos

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. *Benedict*

22.31 ***Nuclear Chemical Engineering*** **(A)**
Prereq.: 10.32
Year: G (1) 3–0–9
Applications of chemical engineering to the processing of materials for and from nuclear reactors. Fuel cycles for nuclear reactors; chemistry of uranium, plutonium and fission products; refining of uranium; production of materials for nuclear reactors; separation of products of nuclear reactors; inorganic solvent extraction as applied to nuclear reactor materials; disposal of radioactive wastes; processes for isotope separation; and theory of isotope separation. *E. A. Mason*

22.41 ***Nuclear Reactor Physics Laboratory*** **(A)**
Prereq.: 22.21
Year: G (1, 2) 2–6–4
Properties of the particles and radiations resulting from the fission process. Use of scintillation counters, ionization chambers, proportional counters, Geiger counters, health physics instruments, and other detection devices employed in reactor technology. Experimental methods for determining the macroscopic properties of nuclear reactors, including cross section measurements, cadmium ratios, diffusion lengths, albedoes, Fermi age, and neutron multiplication of the subcritical assembly. Radioactive chemical separation methods. *Clikeman, Lanning*

22.42 ***Nuclear Reactor Laboratory*** **(A)**
Prereq.: 22.41
Year: G (1, 2) 2–6–4
Techniques of nuclear reactor operation, reactivity evaluation, critical mass determination, shielding surveys, reactivity effect measurements, power measurements, hazards evaluation. Techniques and experiments utilizing the M.I.T. reactor as a neutron and gamma ray source including selections from experiments on shielding, neutron flux, neutron spectrum, reactor parameters, neutron temperature measurements, gamma ray spectrum, pile neutron temperatures and cross sections. Building and use of such equipment as shielding test facilities, pile oscillators, a neutron spectrometer, time of flight equipment, and mechanical velocity selector.
T. J. 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. *Dupree*

22.53T ***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*

22.531T ***Digital Computers in Nuclear Engineering*** **(A)**
Prereq.: 22.21
Year: G (1) 1–0–2
Programming aspects of 22.53T. *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. *K. F. Hansen, Rasmussen*

22.61 ***Plasmas and Controlled Fusion*** **(A)**
Prereq.: 8.041; 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 ***Thermonuclear Processes*** **(A)**
Prereq.: 8.72; 8.231 or 22.61
Year: G (2) 3–0–9
Topics in plasma dynamics of current interest in thermonuclear research, such as: conductivity of highly ionized plasma; radiation losses; wave propagation; magnetic field structures; instabilities; dynamics of a thermonuclear system; critical review of confinement schemes; advanced diagnostic techniques; recent experiments. *D. J. Rose*

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 *6.631* 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, high voltage techniques, and other topics of current interest; brief lectures and literature references to elucidate the physical bases of the laboratory work. *Lidsky, Whitehouse*

22.71 ***Materials for Nuclear Reactors*** **(A)**
Prereq.: 22.21
Year: G (2) 3–0–9
Selection of materials for fuel, cladding, coolant, moderator, controls, and structures in different reactor types. Limitations on material use in reactors based on mechanical and thermal properties, corrosion and radiation effects. Economic and engineering considerations in selection and fabrication of materials, with specific example of uranium dioxide fuel. *Ziebold*

22.81 ***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, shielding and radiation chemistry. Design of reactors as radiation sources. Applications include radioisotope tracer techniques, activation analysis, radioautography, thickness and level gauging, absorption and scattering analysis, industrial radiography, radioisotope power and light sources, radiation effects on chemicals, food preservation, and pharmaceutical sterilization. (*Alternate years.*) *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. *E. A. Mason*

22.91 ***Seminar in Nuclear Engineering*** **(A)**
Prereq.: ——
Year: G (1) 2–0–1

22.92 ***Seminar in Nuclear Engineering*** **(A)**
Prereq.: ——
Year: G (2) 2–0–1
For graduate students engaged on doctoral theses. *Benedict*

23
Modern Languages

23.11 ***Elementary German***
Prereq.: ——
Year: U (1) 3–0–5

23.12 ***Elementary German***
Prereq.: 23.11
Year: U (2) 3–0–5
Necessary foundation in German language for conversational and literary purposes Training in pronunciation, elementary grammar, acquisition of useful vocabulary, reading of varied matter. *Bon*

23.13 ***Intermediate German***
Prereq.: 23.12 or 2 years high school German
Year: U (1) 3–0–5
Continuation of practice in spoken and written German. Training in pronunciation and grammar, acquisition of useful vocabulary and idiomatic expressions. Conducted primarily in German. *Bon*

23.14 ***Intermediate German***
Prereq.: 23.13
Year: U (2) 3–0–5
Introduction to German literature. Reading, translation and discussion of works of nineteenth and twentieth century German authors. Introduction to the vocabulary of literary and cultural criticism. Conducted in German. *Bon*

23.15 ***The Romantic Era and Nineteenth Century Realism***
Prereq.: 23.14
Year: U (1) 3–0–5
The evolution of German opinion and life as seen in the works of romantic and realistic German writers. Conducted in German. *Bon*

23.16 ***Naturalism, Expressionism — Era of the Great Novel***
Prereq.: 23.14
Year: U (2) 3–0–5
Selected writings of authors who enjoy a European reputation, and others who occupy a niche as innovators or recorders of social trends (Mann, Kafka, Fallada, Frank, Toller, Kaiser, Brecht, and others). Conducted in German. *Bon*

23.17 *Scientific German*
Prereq.: ——
Year: G (1) 3–0–6
Intensive preparation for graduate language requirement in German. No previous study of German required. Group meetings for discussion of ways to facilitate comprehension of grammatical and syntactical difficulties. Section meetings by Courses for reading material in the field of the student. (*Open to graduate students only. No credit given.*) *Bon*

23.18 *Goethe: Faust*
Prereq.: 23.14
Year: U (2) 3–0–5
Intensive literary and philosophical analysis of *Faust* with emphasis on the development of Goethe as a poet and philosopher through a comparative study of his first and final versions of *Faust* against the background of the Faust legend. Conducted in German. *Koch*

23.20 *Great Books and Authors in German Literature*
Prereq.: 23.14
Year: U (2) 3–0–5
Reading and discussion of outstanding works in the drama, poetry and prose fiction of German literature. Period 1750–1830. Goethe, Schiller, Grillparzer, and Kleist. Selections from the poetry of Goethe and Schiller. Selections from the prose of Goethe and Kleist. Conducted in German. (*Not offered 1964–65.*) *Bon*

23.21 *Contemporary German Literature*
Prereq.: 23.14
Year: U (1) 3–0–5
A survey of German literature after 1945. The impact of military defeat on literature. The problems of the post-war generation. Selected writings in prose, poetry, and drama. Conducted in German. (*Not offered 1964–65.*) *Bon*

23.22 *Spoken German*
Prereq.: 23.13 or 3 years high school German
Year: U (2) 3–0–5
For students with little or no experience in using the spoken language. Recently developed techniques used to convert reading knowledge into ability to comprehend the spoken language. Full use made of mechanical devices for improving intonation and pronunciation. Emphasis on development of basic vocabulary of words and phrases used in everyday conversation. Appropriate for Fulbright candidates. *Bon*

23.51 *Elementary French*
Prereq.: ——
Year: U (1) 3–0–5

23.52 *Elementary French*
Prereq.: 23.51
Year: U (2) 3–0–5
Necessary foundation for French language and literature. Training in pronunciation, elementary grammar, acquisition of useful vocabulary; reading of varied matter, part of which deals with French institutions and the history of France; practice in hearing and speaking French. *Schane*

23.53 *Intermediate French*
Prereq.: 23.52 or 2 years high school French
Year: U (1) 3–0–5
Practice in spoken French to develop fluency in everyday conversation; also in written French to increase accuracy. Mechanical devices used for improving pronunciation and intonation. Appropriate for Fulbright candidates. *Black*

23.54 *Conversational French*
Prereq.: 23.53 or 3 years of high school French
Year: U (2) 3–0–5
Practice in spoken French to develop fluency in cultural conversation; also in written French to increase accuracy. Appropriate for Fulbright candidates. *Black*

23.56T *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. Conducted 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*

23.59T *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*

23.61T *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 1964–65.*) *Black*

23.62T *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 1964–65.*) *Black*

23.701 *Crucial Problems in Linguistics*
Prereq.: ——
Year: G (1) *Arr.*
The history and present state of phonemic analysis. Phonemes and distinctive features. Phonetic typology and universals. *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) *Arr.*
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 1964–65.*) *Jakobson*

(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.

23.71 ***Special Problems in Language and Literature***
Prereq.: ——
Year: G (1) *Arr.*

23.72 ***Special Problems in Language and Literature***
Prereq.: ——
Year: G (2) *Arr.*
Advanced work in literature or linguistics for unusually well-prepared students. Offered by members of staff in their special fields. *Staff*

23.731 ***Structure of English*** **(A)**
Prereq.: 23.751
Year: G (1) 3–0–9
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. *Postal*

23.732 ***Structure of English*** **(A)**
Prereq.: 23.731
Year: G (2) 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. *Klima*

23.734 ***Structure of Russian*** **(A)**
Prereq.: 23.731, 23.762
Year: G (2) 3–0–9
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, Klima*

23.736 ***Structure of German*** **(A)**
Prereq.: 23.731, 23.762
Year: G (2) 3–0–9
Survey of the syntax, morphology and phonology of contemporary literary German, with emphasis on the application of modern theory to classical problems of Germanic linguistics. Consideration of the relevant historical evidence. (*Adequate knowledge of German required.*) (*Not offered 1964–65.*) *Klima*

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. *Postal*

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. *Matthews, Postal*

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. *Kurylowicz*

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*

23.771 ***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. *B. Hall*

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. *Postal*

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. (*Not offered 1964–65.*) *Chomsky*

23.783 ***Typology of Grammars***
Prereq.: 23.731 or 23.752
Year: G (1) 3–0–9
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.
Halle, Klima, Matthews

23.786 *Seminar on Linguistic Change* (A)
Prereq.: 23.785
Year: G (2) 3–0–9
Continuation of 23.785. *Halle, Klima, Matthews*

23.791J *Language, Symbolic Processes, and Computers* (A)
(Same subject as 6.541J)
Prereq.: 6.25 or 8.07 or 18.18 or 18.25 or 23.751
Year: G (1) 3–0–9
Symbols, their storage and manipulation: formal systems of symbols, natural languages, computer programming languages, codes, notation systems of mathematics, logic, physics, etc.; relation of symbols and symbol systems to the physical means of representation and manipulation and to the subject represented and its systematization; symbolic processes, induction, deduction, reasoning; translation and translatability. *Yngve*

23.792J *Mechanical Translation and Language Processing* (A)
(Same subject as 6.542J)
Prereq.: 23.791
Year: G (2) 3–0–9
A survey of research in the area of language processing by machine. Successes and inadequacies of current techniques. Remaining obstacles to adequate mechanical translation. Morphology; syntax; lexicography; semantics; automatic analysis and synthesis of sentences. Structure of English, German, and other languages. Syntax and semantics of programming languages. *Yngve*

23.87 *Dante I*
Prereq.: ——
Year: U (1) 3–0–5
Intensive literary analysis of the *Inferno* in the original, after preliminary training in fundamentals of Italian grammar and pronunciation. Designed for students with no previous knowledge of Italian. *Bottiglia*

23.88 *Dante II*
Prereq.: 23.87
Year: U (2) 3–0–5
Continuation of 23.87. Intensive literary analysis of the *Purgatorio* and the *Paradiso* in the original. *Bottiglia*

23.91 *Elementary Russian*
Prereq.: ——
Year: U (1) 3–0–5
Content directed first to speaking, then to reading ability. Emphasis on speaking, with extensive use of language laboratory. Basic grammar: sentence structure, declension, conjugation. Conducted in Russian from the fifth week. *Lipson*

23.92 *Elementary Russian*
Prereq.: 23.91
Year: U (2) 3–0–5
Extension of basic grammar to word formation — the expansion of roots with suffixes and prefixes. Selected readings from Russian literature and Soviet newspapers and film scripts, with and without dictionary. Conducted entirely in Russian. *Lipson*

23.93 *Intermediate Russian*
Prereq.: 23.92
Year: U (1) 3–0–5

23.94 *Intermediate Russian*
Prereq.: 23.93
Year: U (2) 3–0–5
Continuation of pronunciation and practice in conversation; reading of material on Russia, some standard modern authors. *M. Z. Freeman*

23.941 *Advanced Russian*
Prereq.: 23.94
Year: U (1) 3–0–5
Conversation and reading centered around topics of Russian history and culture, concentrating on the nineteenth and twentieth centuries. Emphasis on comprehension and use of spoken, idiomatic forms of the language. Use of mechanical devices for improving pronunciation, intonation, and comprehension. Conducted in Russian. *M. Z. Freeman*

23.95 *Great Books and Authors in Russian Literature*
Prereq.: 23.94
Year: U (1) 3–0–5
Reading and discussion of the outstanding works in the drama, poetry, and prose fiction of Russian literature. Conducted in Russian. (*Not offered 1964–65.*) *Pomorska*

23.96 *Modern Russian Literature*
Prereq.: 23.94
Year: U (2) 3–0–5
Reading and study of Russian Symbolism and post-Symbolist literature up to the Revolution. Conducted in Russian. *Pomorska*

23.97 *Scientific Russian*
Prereq.: ——
Year: G (2) 3–0–6
Intensive preparation for graduate language requirement in Russian. No previous study of Russian required. Group meetings for discussion of ways to facilitate comprehension of grammatical and syntactical difficulties. Section meetings by Courses for reading material in the field of the student. (*Open to graduate students only. No credit given.*) *Perlmutter*

23.98 *Soviet Literature*
Prereq.: 23.94
Year: U (2) 3–0–5
Study of Russian literature since the Revolution. Readings from authors such as Zamyatin, Babel, Sholokhov, Leonov, Majakovsky, Zoshchenko, Ehrenburg. Conducted in Russian. (*Not offered 1964–65.*) *Pomorska*

23.99 *Chekhov and the Nineteenth Century*
Prereq.: 23.94
Year: U (1) 3–0–5
Study of Chekhov's prose and drama in connection with the development of Russian literature in the second half of the nineteenth century. Conducted in Russian.
Pomorska

(See also 21.641, SYMBOLIC LOGIC; 9.59, PSYCHOLOGY OF LANGUAGE AND COMMUNICATION; 6.36, SPEECH COMMUNICATION, and 6.574, TRANSMISSION OF INFORMATION.)

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AS

Air Science

AS11 ***Evolution of Warfare***
Prereq.: ——
Year: 1 (1) 3–1–3
Study of historical development of warfare since the French Revolution through analysis of concepts and principles of war of great military theorists. Review of present U.S. military establishment. Survey of past military policy and its relationship to national power. Study of U.S. present military and national strategies of all types of warfare. Officer leadership training during laboratory periods. (*Restricted to students selected for A.F.R.O.T.C.*) *Brachtenbach*

AS12 ***Foundations of Air Power***
Prereq.: AS11
Year: 1 (2) 3–1–3
Study of the historical development of air power, with emphasis on its employment in the past, present and future, as influenced by technological developments and their effects on military concepts and world political situations. Officer leadership training during laboratory periods. (*Restricted to students selected for A.F.R.O.T.C.*) *Hart*

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.*) *Brachtenbach*

AS22 ***Aerospace Systems II***
Prereq.: AS21
Year: U (2) 0–1–0
Lecture series on concepts and fundamentals of astronautics and its impact upon the U.S. Air Force; and continuation of leadership laboratory. (*Restricted to students selected for A.F.R.O.T.C.*) *Brachtenbach*

AS31 ***Aerospace Systems Development***
Prereq.: AS22
Year: U (1) 0–1–0
Lecture series on managerial aspects of research and development in the U.S. Air Force with emphasis on current research activities; and continuation of leadership laboratory. (*Restricted to students selected for A.F.R.O.T.C.*) *Hart*

AS32 ***Preparation for Command and Staff Positions***
Prereq.: AS31
Year: U (2) 0–1–0
Lecture series on Air Force officer development in preparation for summer training; and continuation of leadership laboratory. (*Restricted to students selected for A.F.R.O.T.C.*) *Hart*

AS41 ***Principles and Techniques of Leadership***
Prereq.: AS32
Year: U (1) 3–1–5
Thorough investigation of the communicative process both oral and written, with special emphasis on improving each student's ability to express himself and to impart information or directions. Methods of instruction and teaching techniques. Understanding of people and interpersonal relations. (*Restricted to students selected for A.F.R.O.T.C.*) *J. D. Alexander*

AS42 ***Global Geography***
Prereq.: AS41
Year: U (2) 3–1–5
Development of the understanding of geographic fundamentals and concepts to allow the student to evaluate the political behavior of states, or aggregates of states, insofar as behavior is affected by geography, and to develop an understanding of the relationship between global strategic views and geography. Information concerning the Air Force that will be needed by the student on his entry to active duty. (*Required for students selected for A.F.R.O.T.C.; others admitted with permission of instructor.*) *J. D. Alexander*

MS

Military Science

MS11 ***Military Science***
Prereq.: ——
Year: 1 (1) 2–1–0
The fundamentals of Army organization in terms of its potential support of national security and foreign policy; the development of military arts and evolution of warfare as a foundation to further study in the fields of strategic, tactical and logistical matter; principles of military firearms with practical application through individual weapons and marksmanship training; leadership training to develop the characteristics of leadership such as initiative and self-confidence. *Staff*

MS12 ***Military Science***
Prereq.: MS11
Year: 1 (2) 2–1–0
Implications of unconventional warfare such as Chemical, Biological and Nuclear on national and foreign policy; principles of the art of warfare as exemplified in American military history; leadership training with emphasis on development of the individual characteristics of self-confidence and initiative. *Staff*

MS21 ***Military Science***
Prereq.: MS12
Year: U (1) 2–1–0
Continuation of the development of the military arts and evolution of warfare as a foundation to specialized study in the technical fields. Leadership training with emphasis on the responsibilities and functions of the junior leader. *Staff*

MS22 ***Military Science***
Prereq.: MS21
Year: U (2) 2–1–0
The study of maps and aerial photographs to include application of principles emphasizing terrain appreciation and evaluation, methods of orientation and resection, grid systems and classes of aerial photography; the principles of organization, mission and employment of military teams; leadership training. *Staff*

MS31 ***Advanced Military Science***
Prereq.: MS22
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. *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 units; principles of communications and communications 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 of newly commissioned officers to the 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. *Guay*

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. *Castano*

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. *Porter*

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. Some first semester topics: organization theory, production control, personnel and financial management, the principles and practice of naval leadership, and administration of naval organizations. *Castano*

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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Vice President, Academic Administration
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Dean of the School of Science
Dean of the School of Architecture and Planning
Dean of the School of Humanities and Social Science
Dean of the Alfred P. Sloan School of Management
Dean of the Graduate School
Dean of Student Affairs
Chairman of the Faculty
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Director of the Summer Session
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Executive Vice President of the Alumni Association
Assistant Dean of the School of Engineering
Administrative Assistant to the President

Scholarships for Undergraduates

A wide range of scholarship assistance is available to students entering 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 Financial Aid Committee may deem appropriate. While a limited number of full-need scholarship grants are made, the great majority of the awards made include some combination of scholarship, loan, and/or term-time employment.

All these forms of financial aid are in addition to the deferred payment plans described in Section 1 of this Catalogue.

FRESHMAN SCHOLARSHIPS

The principal four-year scholarships — the William Barton Rogers Scholarships, the Alumni Fund National Scholarships, the McDermott Scholarship, the Sloan National Scholarships, and others, including industrial grants — are open to all incoming candidates. Other scholarship grants depend, in part, upon a candidate's having some special qualification in addition to evidence of scholastic ability, such as that he come from a particular locality or be a graduate of a certain school. The Alumni Regional Scholarships, with awards for the freshman year, are limited to nineteen large metropolitan areas. A substantial number of Freshman Competitive Scholarships, with stipends varying from $300 to full tuition, are granted annually to qualified applicants who are not selected for a four-year award or an Alumni Regional Scholarship.

In the following list of freshman awards, the figure in parentheses gives the year when the scholarship or fund was established.

Sidney G. Albert Scholarship (1961)
This annual scholarship was established by Mr. Sidney G. Albert '29 for graduates of secondary schools who are residents of Long Island and New York. Grants are for the freshman year only and are apportioned according to demonstrated need.

Alumni Regional Scholarships (1926)
As a means of cooperating with M.I.T. alumni in various centers in attracting to the Institute students of exceptional ability and promise, several Regional Scholarships, carrying an award based on demonstrated need for the freshman year, are offered in Chicago, Denver, Detroit, District of Columbia, Kansas City, Los Angeles, New York, New Jersey, Northern Ohio, Philadelphia, Pittsburgh, Portland, Ore., Rochester, N.Y., San Francisco, St. Louis, Seattle, Schenectady, Southern Ohio, and Westchester County, New York. These are open to American citizens of good character and health whose standing in their preparatory school studies has been high and who have satisfied with high standing all entrance requirements.

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.

Army and Navy Scholarships (1930)
Sons of regular Army, Navy, Air Force, Marine Corps, and Coast Guard officers who are admitted as undergraduate students to the Institute will be considered for grants toward their tuition based on their demonstrated need, with a maximum of one-half tuition, upon recommendation of the Student Financial Aid Committee — the total number not to exceed ten each year. Preference will be given to qualified applicants admitted to the first-year class. Applications should be addressed to the Director of Student Aid and should be accompanied by documentary evidence that the applicant's father is a commissioned officer in the regular Army, Navy, Air Force, Marine Corps, or Coast Guard. Holders of these scholarships, if recommended by the Committee, may continue their grants during their second and succeeding undergraduate years

John B. Bezazian Fund (1960)
This fund was established by the bequest of John B. Bezazian to furnish grants, including tuition and assistance toward living expenses, according to demonstrated financial need, for male students majoring in engineering or science. First preference is given in the selection to any qualified American male student of Armenian extraction residing in the United States of America; second preference to male students residing in the metropolitan or suburban area of Chicago, Illinois.

Bridgeport Scholarship (1932)
Established by the Institute through a bequest from Horace T. Smith '98, this is known as the Horace T. Smith Scholarship Fund. A scholarship, carrying a stipend based on demonstrated need with a maximum of full tuition for the freshman year, is annually offered to a graduate of the high schools of Bridgeport, Connecticut. Application should be made to the Director of Student Aid.

Cabot Foundation Scholarships (1955)
The income of a fund established by the Cabot Foundation, Inc., provides scholarships for children (sons *and* daughters) of employees of Godfrey L. Cabot, Inc., and its subsidiary and associated companies. Candidates are required to have certification of their eligibility for scholarship grants by first applying to the Personnel Office of Godfrey L. Cabot, Inc., and are expected to comply with the usual policies governing the award of Institute scholarships.

Cambridge Scholarships (1916)
A limited number of scholarships are granted to students entering the first-year class at the Institute who are graduates of schools in Cambridge and children of legal residents of that city. These Cambridge Scholarships, which carry a stipend of full tuition, are confined to students who make application furnishing evidence of need. An award may be continued in the second, third, and fourth years upon annual reapplication, providing the holder maintains a satisfactory scholastic record and continues to furnish evidence of need.

Class of 1895 Scholarship Memorial Fund (1945)
This fund was given by the Class of 1895 on its fiftieth anniversary, "the income annually to be used to provide scholarships for suitably qualified descendants of members of the Class of 1895. If in any year the total income is not required for this purpose, the balance shall be added to the Technology Loan Fund."

Class of 1931 Compton Memorial Freshman Scholarship Fund (1956)
The income from this fund, established at the twenty-fifth reunion of the Class of 1931 as a memorial to Dr. Karl Taylor Compton, is used for freshman scholarships.

Class of 1938 Scholarship Fund (1938)
Gifts from the Class of 1938, "the income for scholarships."

W. A. Conant Scholarship Fund (1943)
A bequest of $150,000 was made "for the purpose of establishing a permanent fund to be known as the W. A. Conant Scholarship Fund, the income therefrom to be used for the education of native born American Protestant boys of New England of American Protestant parents, who are graduates of some high or preparatory school, public or private, in New England, preference to be given to the graduates of the public schools of Brookline, Massachusetts, but without limitation thereto, and whose parents are financially unable to send them to the Institute and whose own means are insufficient to allow them to attend the Institute." One scholarship, carrying a grant of full tuition for each of the four undergraduate years, is annually offered to an entering freshman.

Ralph E. Curtis Scholarship (1960)
Income of this fund, established by gifts of the Curtis Universal Joint Company, Inc., is used to assist needy and worthy young men of Springfield, Massachusetts, to achieve their educational objectives at the Institute. Open to entering freshmen, initial preference is given to children and nephews and nieces of five-year employees of the Curtis Universal Joint Company, Inc. In the selection of awards for entering students, first preference is given to graduates of Springfield Technical High School; second preference to graduates of other Springfield high schools; and third preference to secondary school graduates resident in western Massachusetts.

Thomas C. Desmond Scholarship (1952)
Established by the gift of Thomas C. Desmond '09, a tuition scholarship for the freshman year is available to a student who plans to study civil engineering.

Development Fund Scholarships (1950)
Scholarships provided by gifts to the M.I.T. Development Fund consist of four-year grants to students who maintain academic ranking in the top quarter of the class and demonstrate continued need for financial assistance. A number of these awards are for full tuition, others for three-quarters tuition, and some for half tuition. They are open to all candidates from secondary schools. Application for renewal of these awards for each succeeding year should be made to the Student Financial Aid Committee.

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.

East Bridgewater Scholarship (1932)
Established by the Institute through a bequest from Horace T. Smith '98, this grant is known as the Horace T. Smith Scholarship Fund. A scholarship carrying a stipend depending on demonstrated need, with a maximum of full tuition for the freshman year, is annually offered a graduate of the High School of East Bridgewater, Massachusetts.

Elks Scholarship (1959)
This grant from the Massachusetts Elks Association, Inc., for study in science or engineering, is open to residents of Massachusetts who are citizens of the United States and who wish to follow a course in either of these fields on completion of secondary school. The award is designed to assist an individual of excellent character, good health, first-rate academic promise, and with qualities of leadership. Stipends are determined on demonstrated need up to a maximum of $2,500 annually. Grants are on annual application renewable depending on achievement and financial need for the second and succeeding years, or a total of four years.

Fall River and Swansea Scholarships (1932)
These scholarships were established by the Institute through a bequest of Elizabeth R. Stevens, to be known as grants from the Albert G. Boyden Fund. A limited number of scholarships for the freshman year, carrying stipends based on demonstrated need, are annually offered to qualified applicants residing in Fall River or Swansea, Massachusetts.

Freshman Competitive Scholarships (1932)
These awards cover part tuition for the first year. There are no geographical restrictions of eligibility, and any candidate for admission to the freshman class directly from secondary school may apply. Competition is based upon academic records and evidences of non-academic merit of the competitors, and no special examinations are required.

General Motors Scholarships (1955)
These four-year grants, established under the General Motors College Scholarship Plan, are open to citizens of the United States and are intended for outstanding individuals. Seven awards are made to entering first-year students. Stipends will be fixed on the basis of demonstrated need.

Humphrey M. Haley Scholarship Fund (1958)
This bequest of Humphrey M. Haley '04 is held in trust and the income used as scholarship aid to one or more deserving students, with first preference to students residing in the St. James Parish in Salem, Massachusetts.

Charles Hayden Memorial Scholarships (1939)
Established through a grant from the Charles Hayden Foundation, these scholarship awards are in memory of the late Charles Hayden, a graduate of the English High School Class of 1886 and of the M.I.T. Class of 1890.

Jakobson Scholarship (1951)
Established by Jakobson Shipyard, Inc., this annual freshman scholarship carries a grant of $1,000. First preference is given to a son of an employee of Jakobson Shipyard, Inc.; second preference is to graduates of the following New York high schools: Glen Cove, Huntington, Manhasset, Oyster Bay, Port Washington, Roslyn, Sea Cliff; and third preference is to secondary school graduates who reside on Long Island, excepting the counties of Kings or Queens.

Amelia S. Kniesner Scholarship Fund (1944)
Gift of William T. Kniesner '16 and his sisters, the income is used "to provide scholarship aid to meritorious or needy students, either entering freshmen or undergraduate students of the Institute, preference to be given to graduates of the high school or high schools of Danbury, Connecticut."

Jacob and Jennie Lichter Fund (1949)
This scholarship fund is "for the aid of students who shall satisfy all entrance requirements of the Institute and be endorsed as to character and personality."

Littmann Foundation Scholarship (1960)
This four-year grant, supplied by the Littmann Foundation, is available in alternate years to a male student desiring to pursue a course of study either in engineering or management as related ultimately to manufacturing. First preference in the selection is given to a well-qualified secondary-school graduate, resident either in the general area of St. Louis, Missouri or Charles City, Iowa. The amount of the award is based on demonstrated need up to the amount of tuition.

Charles E. Locke Memorial Fund (1923)
Preference in making awards from this fund, which was established by the Class of 1896, is given to descendants of members of the Class of 1896, including freshmen.

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.

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.

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.

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.

George H. May Fund (1914)
A gift of $5,000 from George H. May '92 provides a scholarship "to assist graduates of the Newton High Schools who are students at M.I.T. and who have been recommended as eligible by the Superintendent and Head Master of the Newton High Schools." Beneficiaries under this fund are expected to issue notes agreeing to repay, without interest, the amounts received.

Milton High School Fund (1885)
Founded by the Institute in recognition of contributions from residents of Milton, this scholarship is conferred upon such former pupils of the Milton High School in good standing at the Institute as the Master of that school and the School Committee of the town may select.

Joseph R. Minevitch Memorial Scholarship Fund (1957)
This bequest of Joseph R. Minevitch '16, in the name of his mother, Fannie Minevitch, and his brother, Borrah Minevitch, is to assist deserving young men or women with first preference to graduates of the Boston English High School, second preference to graduates of any Boston public high school, and third preference to graduates of any other public high school in the United States.

M.I.T. Alumni Fund National Scholarships (1957)
These four-year scholarships were established by the M.I.T. Alumni Fund Board to give opportunity to well-qualified young people in the continental United States to come to the Institute. Grants are made on the basis of demonstrated financial need, and continued awards depend upon achievement as well as need for assistance.

M.I.T. Boston Stein Club — New England National Scholarship Fund (1955)
The income of this fund is granted to qualified applicants for the freshman year only. One or more awards are available to New England residents as well as to residents of other parts of the United States. There are no restrictions as to sex, religion, race, or color.

M.I.T. Club of Chicago Scholarship Fund (1944)
This gift of $6,000 was made by Harold B. Harvey '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."

Naval Architecture and Marine Engineering Scholarships (1957)
These grants were established by the Society of Naval Architects and Marine Engineers. One scholarship in the amount of $1,000 is awarded each year to a secondary school graduate in the United States who plans to enter the field of naval architecture and marine engineering and who gives promise of extraordinary talent and ability. Each grant may be renewed for three additional years.

Niarchos Scholarship (1956)
Established by Stavros S. Niarchos as a memorial for merchant mariners who gave their lives during World War II, these grants provide opportunities for higher education to the sons of merchant seamen. The awards are based upon demonstrated need and achievement in secondary school experience. Holders of these scholarships are given opportunities to work in the marine field during summer vacations as part of their total education. In the selection of candidates, first preference is given to sons of merchant seamen and ships' officers who lost their lives in the line of duty during wartime. In other cases, candidates' fathers must be regularly employed in a seagoing capacity or, if deceased, so last employed. These awards are not limited to courses in marine engineering and naval architecture, but consideration may be given to the desire of qualified candidates to pursue careers in these fields.

Procter and Gamble Scholarship (1955)
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.

Willis Ward Reeves, Jr., Fund (1945)
Established by Mr. and Mrs. Willis Ward Reeves of Hazard, Kentucky, "as a memorial to their son, Willis Ward Reeves, Jr., '46, late Lieutenant, U.S. Army Air Forces, killed in action over France during World War II . . . the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Kentucky."

William Barton Rogers Scholarships (1947)
A limited number of four-year grants established in honor of William Barton Rogers, founder of the Institute, enable young men of superior ability and future promise but of limited financial means to pursue an education in either engineering, science, or architecture. A stipend of 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.

Frederick J. Shepard Fund (1959)
Income from the gift of the Lewis-Shepard Fund in honor of Frederick J. Shepard, Jr. '12, is used to assist needy and worthy young men from New Hampshire, with first preference to graduates of Pinkerton Academy in Derry Village.

Frank Arnold Sherman Scholarship Fund (1947)
The income from this bequest of Frank Arnold Sherman '03, is used "first and preferentially for a scholarship to some boy graduate of Westerly High School, Rhode Island, or if no suitable candidate, preferentially to a boy graduate of some other Rhode Island high school."

Sloan National Scholarships (1953)
Established by the Alfred P. Sloan Foundation, Inc., these scholarships provide aid for students in science and engineering and are open to male students resident throughout the continental United States. Sloan National Scholars hold positions of academic honor at the Institute. Awards are made to men of high character, sound personality, leadership potential, and academic promise. Grants range from a $200 prize scholarship to $2,000 per annum. Awards are renewable each year, subject to performance and in accordance with changing financial need.

G. H. Miller Smith Fund (1945)
Established by Mr. and Mrs. George Blackwell Smith of Lookout Mountain, Tennessee, "as a memorial to their son, G. H. Miller Smith '43, late Lieutenant, U.S. Army, killed in action in France during World War II . . . the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Tennessee."

Albert F. Sulzer Scholarship (1955)
Established under the will of Albert F. Sulzer, this fund is "to be used by the trustees of the Massachusetts Institute of Technology for the establishment and maintenance of scholarships for meritorious first-year students who are non-residents of the State of Massachusetts."

Tau Beta Pi Memorial Scholarship Fund (1947)
This gift from members of Tau Beta Pi, Massachusetts Beta Chapter, on their twenty-fifth anniversary, provides an annual award of $500 for freshmen to be selected by the M.I.T. Student Financial Aid Committee. There is no restriction of geographical area, and candidates are selected on high scholastic standing, character, and future promise.

Union Carbide Engineering Scholarships (1960)
This grant from the Union Carbide Educational Fund is used for four year tuition grants in either mechanical, chemical, or metallurgical engineering.

Vermont Scholarship (1924)
This scholarship "in memory of Vermonters who, having received their education at the Institute, served as engineers in the Armies of the Allies in the World War," was founded by a gift of $76,000 from Redfield Proctor '02. The income is awarded annually "to worthy students . . . preference to any *bona fide* residents of Vermont doing undergraduate work at the Institute, and also Vermont students doing graduate work, or students who are graduates of or transfer from Middlebury College or Norwich University . . . who shall meet regular scholastic and other requirements."

Henry E. Warren Fund (1961)
As a memorial to Henry E. Warren '94, the Trustees of the Warren Benevolent Fund, Inc., contribute to the support of a limited number of entering freshmen. Grants are made by the Committee on Student Financial Aid to students who demonstrate financial need. The Committee gives first preference to well-qualified students domiciled in New England and second preference to women students from any part of the United States or its possessions. It is hoped that beneficiaries of this fund will make contributions to the Warren Fund after graduating, so that other students may benefit from it.

Granger Whitney Fund (1957)
Income of this bequest, made by the will of Julia Whitney in the name of Granger Whitney '87, is used to assist worthy students of the Institute, with first preference being given to students nominated by the Detroit M.I.T. alumni club.

SCHOLARSHIPS FOR UPPERCLASSMEN

The Institute holds several funds from which the income is used to make awards to students in the upper undergraduate years. It is the policy of the Student Financial Aid Committee to assist as many well-qualified students as possible by assigning, in general, amounts less than full tuition. Awards are made only to students who have completed at least one year of satisfactory work at the

Institute. The ability of the student, as indicated by his scholastic record, is the primary consideration in making selections. However, account is also taken of the applicant's evidence of need for financial assistance, of his good character, and of his general worthiness and professional promise. Applications should, except as noted below, be made on blanks to be obtained at the Student Aid Center, Room 5–115.

The scholarships or funds described are arranged in the alphabetical order of their names, the figures in parentheses being the dates of establishment.

Frank W. and Carl S. Adams Memorial Fund (1955)
Established by Mr. and Mrs. Charles E. Adams, with The First National Bank of Boston as Trustee, and named in memory of their two sons as the Frank W. and Carl S. Adams Memorial Fund, this fund is used to assist needy and deserving students at M.I.T. A limited amount may also be available to assist an impecunious student who is unable to participate in recognized functions incident to graduation.

American Machine & Foundry Company Scholarship (1960)
This two-year grant of $750 is awarded annually to a member of the junior class majoring in mechanical or electrical engineering. Recipients are chosen on the basis of academic achievement, demonstrated need, extracurricular activities, leadership, and citizenship. Preference is given to residents of New England, New Jersey, New York, and Pennsylvania.

American Smelting and Refining Company Scholarships (1946)
This gift of the Company was made to establish a scholarship of $500 to a student in metallurgy, with preference to third- or fourth-year students.

American Society for Metals Award (1954)
A grant of $500 is awarded annually to a second-year student in metallurgy under this scholarship. Selection is made on the recommendation of the Department of Metallurgy to the Student Financial Aid Committee from among students who have applied for assistance for the sophomore year and who have demonstrated good ability and need.

Nils Anderson Scholarship (1961)
This scholarship, founded by 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.

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."

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.

Billings Student Fund (1900)
A bequest of $50,000 from Robert C. Billings founded the Billings Student Fund. "Any student receiving benefit from this fund is expected to abstain from the use of alcohol or tobacco in any of their varied forms."

Huse Templeton Blanchard Fund (1946)
This bequest of Huse T. Blanchard '01 is for "the benefit of worthy boys of the State of New Hampshire."

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. . . ."

Harriet L. Brown Fund (1932)
This bequest of Harriet L. Brown is "to be held in trust as a scholarship . . . the income to be given to such needy and deserving young women desiring to become students at M.I.T., as would otherwise be unable to attend; and in case of two or more applicants of equal merit, preference shall be given to a native of either Massachusetts or New Hampshire."

Cabot Endowed Scholarship (1955)
The income from this endowment, a gift of Godfrey L. Cabot, Inc., is used as scholarships for undergraduate students of the Institute in accordance with the general Institute practices and procedures.

Godfrey L. Cabot Fund (1950)
Scholarships made possible by this gift are awarded with preference to students of chemistry or chemical engineering.

Thomas D. Cabot Scholarship Fund (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.

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 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 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.

Fred L. and Florence L. Coburn Fund (1932)
The income of this bequest of $5,000 from Fred L. Coburn "shall be expended by said Trustees in giving aid and assistance to students of M.I.T. . . . preference being given by said Trustees to students residing in Somerville, Massachusetts."

Coffin Memorial Fund (1929)
This gift from the executors of the estate of Charles A. Coffin — a bequest — carried out the wishes of Mr. Coffin. The fund is used for loans or other aid to students as determined by the Executive Committee of the Corporation.

College of William and Mary Scholarship (1904)
Established by the Institute in commemoration of the early association of President William Barton Rogers with the College of William and Mary, this scholarship provides a stipend of $400 per year; it is granted to a student nominated by the faculty of the College of William and Mary.

Albert Conro Scholarship Fund (1943)
This bequest of Mary T. Conro, sister of Emma O. Conro '84, in memory of their uncle, is "for the purpose of establishing and maintaining a scholarship . . . to be known as the Albert Conro Scholarship."

The George R. Cooke Fund (1939)
Established by a gift in memory of George R. Cooke '08, the income of this fund is awarded preferably to a student in civil engineering or a related field. Consideration is given to those who have had experience through employment in a field before undertaking formal study; the recipient need not necessarily be a candidate for a degree. Grants will be based on character, achievement, need, and future promise.

John G. Crane Scholarships (1951)
This gift of J. G. Crane '90 is for undergraduate awards.

Allen S. Crocker Memorial Fund (1961)
The income of this fund, established as a memorial by the wife of Allen S. Crocker '97, is used to assist worthy and needy young men. Stipendiary awards will be according to demonstrated financial need up to a maximum of tuition in any one year. First preference in the selection is given to students domiciled in the Rochester, New York area. Any unused income from this fund in any one year shall revert to the principal of the fund.

Lucretia Crocker Fund (1916)
By the will of Matilda H. Crocker, the Institute was made the residuary legatee of her estate "for the establishment of one or more scholarships for women in memory of my sister, Lucretia Crocker . . . the income to aid one or more young women in need of pecuniary assistance in obtaining instruction at said Institute."

Eunice McLellan Cruft Fund (1949)
This bequest of Eunice McLellan Cruft was made "to assist young men whose means are inadequate to pay their expenses at the Institute."

Isaac W. Danforth Fund (1903)
This bequest of $5,000 from James H. Danforth for scholarship purposes was a memorial to his brother, Isaac Warren Danforth.

The Delafield Memorial Fund (1960)
This fund was established by the parents of Benjamin T. Delafield '60 to be used to assist needy and deserving students at M.I.T. and at the discretion and judgment of the Director of Student Aid.

Orville B. Denison Memorial Fund (1960)
The income of this fund, donated by the members of the Class of 1911 as a memorial to Orville B. Denison '11, is used to assist worthy and needy undergraduates at the Institute.

Carl Pullen Dennett Memorial Scholarship Fund (1956)
Established by a gift in memory of Carl Pullen Dennett, this fund provides an award for students in the School of Science, either graduate or undergraduate, who are deemed qualified by scholastic performance, intelligence, character, and promise. The annual selections are made by the Director of Student Aid and the Dean of Students.

Thomas C. Desmond Scholarship Fund (1960)
The income of this gift of Thomas C. Desmond '09 is awarded to deserving undergraduates at the Institute in accordance with the general policies of the Institute.

Ann White Dickinson Fund (1898)
This bequest of $40,000 from Ann White Dickinson was made "to establish free scholarships in M.I.T. . . . such persons enjoying benefit . . . shall be worthy young men of American origin."

Fred C. Dobbs Fund (1960)
The income of this fund, established in the name of Dr. F. C. Dobbs by his friends, is used to assist undergraduates to meet their expenses at the Institute. Selection is limited to citizens of the United States who have demonstrated a need for financial assistance and have given evidence of promise.

Dormitory Fund (1903)
This fund was raised by miscellaneous subscriptions; it was formerly known as Students' Aid Fund.

Thomas Messinger Drown Scholarships (1928)
A bequest of $50,000 from Mary Frances Drown was designated "to establish scholarships for deserving undergraduate students, to be known as the Thomas Messinger Drown Scholarships."

Edgerton, Germeshausen and Grier, Inc., Scholarships (1955)
This gift funds scholarships, preferably for students in electrical engineering.

William Emerson Fund (1959)
The income of the bequest of the late William Emerson, Dean of the School of Architecture, is used for scholarships in the Department of Architecture.

Farnsworth Fund (1889)
This fund was founded by Mrs. Mary E. Atkins of Boston with a gift of $5,000.

Charles Lewis Flint Fund (1889)
This bequest of $5,000 from Charles L. Flint is for the "support of some worthy student, preference to be given to some graduate of the English High School, Boston."

Sarah S. Forbes Fund (1913)
Originally a fund of $2,800 given in trust in 1868 by Sarah S. Forbes to William Barton Rogers and Henry S. Russell, trustees, this fund was transferred in 1913 to the Institute "for the maintenance and education of a scholar in M.I.T."

Clara and F. Joseph Ford Scholarship (1951)
The income of a fund established by Mr. and Mrs. Joseph F. Ford is awarded "to worthy and well-qualified students who have demonstrated a democratic and tolerant spirit and who are well disposed toward people of all creeds and races."

Foundry Educational Foundation Scholarships (1947)
Established by the Foundry Educational Foundation, which represents the American Foundrymen's Association, the Gray Iron Founders' Society and the Malleable Founders' Society, and the Foundry Equipment Manufacturers Association, these awards are open to third- and fourth-year students in business and engineering administration, mechanical engineering, and metallurgy.

Arthur E. Fowle Fund (1956)
The income of this fund established under the will of Arthur E. Fowle '93 is to be used for undergraduate scholarships.

Evert W. Freeman Scholarship Fund (1956)
The income of this fund, established by bequest of Evert W. Freeman '20, "shall be awarded annually to a student . . . who shows promise of substantial accomplishment but is in financial need."

Philip Jacob Friedlander Fund (1945)
This fund was the gift of Israel Friedlander "in appreciation of the opportunity my son, Philip Jacob Friedlander, had of spending a little more than a year at M.I.T. before enlisting in the United States Naval Reserve . . . the income to be used with the income from other such funds for the purpose of helping qualified students at M.I.T. regardless of race, creed, or color, or geographical origin, who may be in need of financial assistance . . ."

Jurgis J. Geguzis Fund (1957)
Established under the will of the late Jurgis J. Geguzis, this fund is to be used for tuition and expenses for a student of Lithuanian parentage. The recipient is selected by the Institute upon the condition that he shall repay the amount of his award "when and if able so that other students may be granted the same benefits and privileges in the future."

Norman H. George Fund (1919)
This bequest of Norman H. George is "to be used for the assistance of needy and worthy students in obtaining an education in M.I.T."

Arthur B. Gilmore Fund (1941)
This bequest of $10,000 from Arthur B. Gilmore is ". . . for the purpose of assisting needy students who shall be members of the Beta Theta Pi fraternity . . . said net income to be divided among not more than two students in any one year."

James R. Glazebrook Fund (1959)
The income of this fund is to be used to assist needy and worthy undergraduates at the Institute.

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.

William T. Haebler Memorial Scholarship (1960)
This fund was established by his daughter in memory of her father, William T. Haebler '22. The income is used to assist worthy and needy students who are undergraduates and are citizens of the United States.

Lucia G. Hall Scholarships (1945)
The income from this bequest of Louise K. Gunn, to "be known as 'The Lucia G. Hall Scholarships' . . . is to be used for the aid of worthy students."

Hall-Mercer Scholarship Fund (1940)
The income from this bequest of Alexander G. Mercer is to be used "for the benefit of such poor students as have passed through some of the public schools with the best reputation for character and ability."

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."

Bancroft Hill Memorial Fund (1957)
This fund was established by Frances G. Hill in memory of her husband, Bancroft Hill '11. The income is used for scholarship assistance to students in civil engineering who are in need of financial help.

George Hollingsworth Scholarship (1916)
A bequest of $5,000 from Rose Hollingsworth founded this George Hollingsworth Scholarship.

Loren C. Holm Scholarship Fund (1950)
Established by Marie Holm in memory of her father, this fund is designated for worthy and needy students.

Elias Howe, Jr., Scholarships (1949)
The income from a fund established under the will of Julia Howe Stockwell Smith "shall be available for aiding such students and in such amounts as shall be recommended by the Faculty."

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."

Inland Steel Scholarships (1956)
Two scholarships are supported by the Inland Steel-Ryerson Foundation for students in engineering, with first preference to employees of the Inland Steel Company. Awards are made in alternate years on a four-year basis.

Charles L. Ireson Scholarship Fund (1959)
Income of this fund, established by the will of Jennie E. Ireson, is devoted to the education of worthy students who may require financial assistance.

I-T-E Foundation Scholarship (1952)
Established by the Harrison Jules Louis Frank and Leon Harrison Frank Memorial Corporation in memory of the founders of the Bulldog Electric Products Company, this $700 scholarship is designated for a needy and worthy junior or senior in electrical engineering who is interested in the field of distribution and/or control of electricity.

David L. Jewell Fund (1928)
The income from this bequest of $25,000 from Colonel David L. Jewell is "to be used to pay part of the tuition charges for five young men who may be selected by the President or Board of Trustees of the Institute as worthy of assistance, and who, were it not for such assistance, might be unable to pursue their studies at such Institute."

Edward A. Jones Scholarship Fund (1947)
A bequest of $25,000 from Edward A. Jones was designated "to be used for the establishment and maintenance of one or more scholarships."

Joy Scholarship (1886)
Established by the gift of Nabby Joy, this scholarship was created pursuant to a decree of the Supreme Judicial Court of Massachusetts for the benefit of "one or more women studying Natural Science at M.I.T."

Sarah Maude Kaemmerling Fund (1952)
This fund was established by a gift of $20,000 in 1952 and subsequently added to by a testamentary bequest in 1959. The income is used for scholarships or some alternate form of student aid.

William R. Kales Scholarship Fund (1953)
This fund, endowed by a gift of the Whitehead and Kales Company for scholarship purposes, provides income to assist worthy and needy undergraduates.

Bo Kwang Kim Scholarship Fund (1957)
Established under the will of Bo Kwang Kim, this scholarship is for students of complete Korean ancestry. It is open to any deserving and needy Korean students. An award of $500 is made only when the income of the Fund permits.

Kollsman Instrument Fund 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.

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."

Richard W. Lodge Fund (1955)
The income of this fund, established by the will of Mary L. Lodge in memory of Richard W. Lodge '79, is used for worthy and needy students.

Elisha T. Loring Fund (1890)
This bequest of $5,000 from Elisha Thacker Loring is for "the assistance of needy and deserving pupils."

Lowell Institute Fund (1923)
Gifts from the alumni of the Lowell Institute School founded this fund, the income of which is annually awarded to assist some graduate of that School who desires to enter upon undergraduate studies at M.I.T. Applications must be filed at the Office of the Director of Student Aid.

Percival Lowell Scholarships (1955)
The income of this gift is used for scholarships awarded from time to time at the discretion of the President of the Massachusetts Institute of Technology to students in astronomy, physics, and mathematics.

Alice Maclaurin Scholarship (1951)
Gifts created a scholarship in memory of Mrs. Richard C. Maclaurin.

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.

Francisco Marcucella Fund (1953)
This gift of Francisco Marcucella '27 was designated for scholarship purposes.

Rupert Anderson Marden Fund (1933)
This fund was established by an anonymous gift "toward a memorial to be known as the Rupert Anderson Marden Scholarship Fund, income available annually to aid a worthy student at M.I.T. — Protestant and of American origin — preference to a student taking the Cooperative Course in Electrical Engineering."

Margaret A. Matthews Fund (1947)
The income of this bequest from Margaret A. Matthews is "for the benefit of such of the women students at M.I.T. who intend to become teachers."

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."

James H. Mirrlees Fund (1886)
This gift of $2,500 from James Buchanan Mirrlees of Glasgow, Scotland, constituted a scholarship in memory of his son, James Henry Mirrlees, who died in 1886 while attending the Institute. The income is awarded to the "student in the third or fourth year of the Mechanical Engineering Course most deserving pecuniary assistance."

Morningstar Scholarship (1953)
This undergraduate scholarship gives first preference to students in the Physics Department. Grants are equivalent to one term's tuition and are continued to a recipient for the entire undergraduate period.

Fred W. Morrill Scholarship Fund (1941)
The income from this bequest of Hattie B. Morrill is to be used "for the purpose of providing financial assistance to some student or students at the discretion of the Trustees of said Institute. . . ."

Frederick Taft Moses Scholarship Fund (1959)
This scholarship provides four-year awards ranging from a $200 honorary prize to $2,000 annually, and is offered to young people of superior talent and promise.

Naval Architecture and Marine Engineering Scholarships (1953)
Two scholarships, established by gift of the Gulf and South American Steamship Company, are awarded annually: 1) to assist students who plan to spend the fifth year in Shipping and Shipbuilding (Course XIII-B); and 2) an annual scholarship for secondary school graduates who plan to go into the field of naval architecture and marine engineering. Selection will be made by the Department of Naval Architecture and Marine Engineering and the Student Financial Aid Committee.

Gertrude B. Newman Scholarship (1952)
This bequest from the estate of Mrs. Gertrude B. Newman is to aid worthy and deserving students.

Nichols Scholarship (1895)
This bequest of $5,000 from Mrs. Betsy F. W. Nichols constitutes the Nichols Scholarship in memory of her son, William Ripley Nichols '69, for sixteen years Professor of General Chemistry at the Institute. Preference is given to students in the Course in Chemistry.

Charles C. Nichols Scholarship (1904)
This bequest of $5,000 from Charles C. Nichols constitutes a scholarship.

William E. Nickerson Scholarship Fund (1949)
The income from this fund, established by the Nickerson Trust, is used for a scholarship for a worthy student.

Howard A. Noble Scholarships (1955)
The income from a fund established under the will of Katherine B. Noble is used to maintain one or more scholarships in engineering.

John Felt Osgood Scholarship (1909)
This bequest of $5,000 was made by Elizabeth P. Osgood "to establish and maintain a scholarship in electricity in memory of my husband, John Felt Osgood."

Louise Parks Knight and Charles F. Parks Memorial Fund (1952)
Established as a memorial to Louise Parks Knight and her father, Charles F. Parks '75, this fund is "used for the aid of poor but worthy students who have already entered upon a course of study but are unable to finish owing to lack of funds."

George L. Parmelee Fund (1921)
This bequest from George L. Parmelee of "one third of my property and estate" specified that "interest thereof be used for tuition of worthy students, either special or regular, according to the direction of the Faculty."

Langdon Pearse Memorial Scholarship (1958)
This fund was established by gift of Mrs. Langdon Pearse in memory of Langdon Pearse '01. Income from the fund is used toward the tuition of graduate students in the field of sanitary engineering, with second preference for undergraduate students in the field of civil engineering.

Frank Stetson Pecker Fund (1947)
This fund was established by the wills of Frank Stetson Pecker and Annie J. Pecker for a scholarship.

Richard Perkins Fund (1887)
The income from half of this bequest of $100,000 from Richard Perkins is available for the "support of free scholarships in said Institute."

Charles H. and Helen Bartlett Pray Fund (1950)
Established under the wills of Charles H. and Helen Bartlett Pray, this fund provides "for scholarships for needy young men."

Florence E. Prince Fund (1943)
This bequest of Florence E. Prince is "for the aid of worthy students who may need assistance in the matter of maintenance and living expenses while pursuing their studies."

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. . . ."

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.

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.

Thomas Sherwin Scholarship (1871)
Founded with a gift of $5,000 from the English High School Association in memory of Thomas Sherwin, this scholarship is limited to graduates of the English High School of Boston who are pursuing a regular course at the Institute.

H. Hilliard Smith Fund (1950)
This bequest of Grace J. F. Smith in memory of her husband, H. Hilliard Smith '96, is for the purpose of assisting young men in architecture.

Horace T. Smith Fund (1931)
This bequest from Horace T. Smith '98 provides scholarships to worthy students, with preference given to graduates of the East Bridgewater (Massachusetts) and Bridgeport (Connecticut) High Schools.

Sons and Daughters of New England Puritan Colony Scholarship (1931)
Holders of this scholarship, made possible by a gift of $600 from the Sons and Daughters of New England Puritan Colony, must be of New England ancestry.

Anna Spooner Fund (1939)
The income from this bequest of approximately $7,500 is used "in assisting meritorious students."

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.

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.

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.

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.

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."

Elizabeth Babcock Willmann Fund (1935)
This bequest from Elizabeth Babcock Willmann is "to help in paying the tuition of girl students taking the Chemistry Course."

John J. Wilson Scholarship Fund (1953)
The income from this fund, established by John J. Wilson '29, is used to assist a needy senior, first preference being one who has demonstrated interest and ability in the field of instrumentation for measurement and control and the intention of continuing his senior studies in this field.

Mary I. Wilson Scholarship Fund (1954)
Established by J. J. Wilson '29, this fund provides income to be used to assist worthy undergraduates in defraying their tuition obligations.

Morrill Wyman Fund (1915)
The income from this bequest of Morrill Wyman is "applied in aid of deserving and promising students, but without exclusion in regard to rank, upon the understanding that if in after life the person receiving aid shall find it possible, he shall reimburse the said fund for moneys so applied, but there shall be no legal obligation to make such reimbursement."

Conrad Henry Young Scholarship Fund (1957)
Established by the will of Abby W. Young in memory of Conrad Henry Young '96, the income of this fund is used for scholarships.

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 funds which individuals and corporations have given for the support of fellowships and scholarships at the Institute. 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 Airplane 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.

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
Two doctoral fellowships to graduate students in any department of either Harvard or M.I.T. writing a 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.

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.

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 $1,400.

Bendix Corporation
For an outstanding graduate student in automatic controls or control system components; tuition plus $2,100.

Douglas Aircraft Company
For a highly recommended graduate student; tuition plus $1,700.

C. S. Draper
Fellowship sponsored by the Dynamics Research Corporation for a graduate student in aeronautical engineering, preferably in the field of control or guidance; tuition plus $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.

Lockheed Leadership Fund
For a graduate student in the field of aerodynamics; tuition plus $2,000.

Sperry Gyroscope Company
Fellowship for a graduate student in aeronautics and astronautics; tuition plus $800.

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.

Francis W. Chandler
Income of $500 a year, for the support of a student in the Department of City 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.

BIOCHEMISTRY

Karl Taylor Compton Fellowships of the Nutrition Foundation
Fellowships for graduate work in the field of biochemistry; tuition plus $2,400.

Bio-Research Consultants, Inc.
Tuition plus $2,400.

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.

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.

Humble Oil and Refining Company
For several graduate students in chemical engineering for one semester each in the School of Chemical Engineering Practice; tuition plus $500.

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 student in his final year of graduate study; tuition plus $1,800 single, $2,100 married.

Scientific Design Company
For a graduate student in chemical engineering; tuition plus $1,500 single, $2,100 married.

Sun Oil Company
Two summer fellowships for graduate students of American citizenship; tuition plus $700.

Union Carbide Chemicals Company
For a student who attends the School of Chemical Engineering Practice for one, two, or three terms; tuition plus $1,400 single, $2,100 married, per twelve-month period.

CHEMISTRY

American Chicle Company
For a graduate student in chemistry; tuition plus $2,100.

Esso Education Foundation
For a graduate student in chemistry who has completed at least one year of graduate work; tuition plus $2,400 single or married without children; tuition plus $3,000 married with one or more children. Fellowship tenable for twelve months.

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 $1,400.

Minnesota Mining and Manufacturing Company
For a graduate student in chemistry; tuition plus $1,800.

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 $1,800.

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

Economic Development
For a graduate student in the Department of Economics; tuition plus $1,800.

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 up to $1,000.

Industrial Economics and Industrial Relations
For candidates for the doctorate in these fields; several, tuition plus $1,800.

Rand Corporation
For a graduate student in the field of mathematical economics; tuition plus $1,550.

Joseph N. Scanlon
In memory of Joseph N. Scanlon, formerly a Lecturer at M.I.T. in industrial relations; tuition plus $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.

Melpar, Incorporated
For a graduate student in electronics and communications; tuition plus $2,100 single, $2,700 married.

Schlumberger Foundation
For a graduate student in electrical engineering; tuition plus $2,100.

GEOLOGY AND GEOPHYSICS

Gulf Research and Development Company
For a graduate student in geophysics (preferably but not necessarily to a doctoral candidate beyond his first year of graduate study), for two regular terms; tuition plus $2,500.

Tidewater Oil Company
For a graduate student in geochemistry or oceanography, for two regular terms; tuition plus $2,100.

MANAGEMENT

General Electric Foundation
Fellowships for the support of graduate students in management.

Lord Heyworth
For a full-time student studying for the Master's degree in industrial management; tuition plus $1,000.

International Business Machines Corporation
For a graduate student in management; tuition plus $1,800 single or married with no children, $2,500 married with children.

Sloan School of Management
For advanced study and research in industrial management, for college graduates whose major studies have been in science, engineering, or engineering administration. A number of fellowships.

Sloan
For training in executive development for industrial executives of some experience who are nominated by their employers, a twelve months' program with grants.

United States Steel Foundation
A graduate fellowship for a U.S. student in the area of industrial management; tuition plus $1,300 single, $1,900 married.

MATERIALS

American Can Company
Two fellowships for pre-doctoral students in their 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.

Owen-Corning Fiberglas Corporation
For a graduate student in materials engineering; tuition plus $2,500.

Rohm and Haas Company
For a doctoral candidate in the field of materials; tuition plus $2,100

MATHEMATICS

General Electric Foundation
For a graduate student in mathematics; tuition plus $2,100.

Mathematics
For graduate students who are studying in the Department of Mathematics for careers in research or teaching in the various fields; tuition plus $1,300 to $2,100.

MECHANICAL ENGINEERING

Cummins Engine Foundation
For a U.S. citizen and full-time student preferably working toward a doctorate; tuition for 12 months plus $2,400 single or married with no children, $3,000 married with children. Stipend prorated for 9 months.

Procter and Gamble Company
For a graduate student in mechanical engineering; tuition plus $1,500 single, up to $2,200 married.

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.

Visking Company
For a graduate student in the final year of a doctoral program; tuition plus $1,800 single, $2,100 married.

METALLURGY

Allegheny-Ludlum Steel Corporation
One fellowship for a graduate student whose thesis research is on a topic of interest to the alloy steel industry; tuition plus $1,800 to $2,400.

American Brake Shoe Company
For a Master's degree candidate in fo ..dry engineering; tuition plus $1,400.

American Iron and Steel Foundation
A number of fellowships for graduate study and research of a chemical nature; tuition plus $1,600.

General Electric Foundation
For a graduate student in the field of ceramics; tuition plus $1,750 single, $2,100 married with no dependent children, $2,500 married with one or more dependent children, such status to be as of September 30 of the year of award.

International Nickel Company
For a graduate student in the field of materials science and engineering; tuition plus $2,100 per calendar year.

Kennecott Copper Corporation
For a graduate student in metallurgy; tuition plus $2,500.

National Steel Corporation
For a graduate student in metallurgy whose research is in the general field of the plastic behavior of steel; tuition plus $2,100.

Titanium Metals Corporation of America
For a graduate research student working in the field of deformation processing; tuition plus $2,100.

United States Steel Foundation
For a U.S student in the field of metallurgy; tuition plus $1,300 single, $1,900 married.

METEOROLOGY

Atmospheric Sciences and Oceanography
For graduate students in any year of work for a doctorate; tuition plus $3,000.

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.

MODERN LANGUAGES

International Business Machines Corporation
Fora graduate student in linguistics; tuition plus $1,800 single or married with no children, $2,500 married with children.

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.

Campbell Soup Company
For a graduate student in nutrition and food science; two fellowships, tuition plus $2,400 single, $3,000 married.

Procter and Gamble Company
For a U.S. student in nutrition and food science; tuition plus $1,800 to $2,100.

Bernard E. Proctor Memorial
Scholarship in memory of Professor Bernard E. Proctor '23, formerly head of the Department; tuition.

Roche Anniversary Foundation
Tuition plus $2,000.

PHYSICS

Kennecott Copper Corporation
For a graduate student in physics; tuition plus $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 $2,000 single or married with no children, $2,600 married with children. For 12 months, $2,500 single, $3,200 married with children.

RESEARCH LABORATORY OF ELECTRONICS

Hughes Aircraft Company
For graduate work in electronics; tuition plus $2,100 single, $2,700 married; advanced fellowships up to $3,600.

Radio Corporation of America
For graduate work in electronics; tuition plus $2,100 single, $2,700 married; advanced fellowships up to $3,600.

Sperry Gyroscope Company
For graduate work in electronics; tuition plus $2,100 single, $2,700 married; advanced fellowships up to $3,600.

Student Loan Funds

TECHNOLOGY LOAN FUND

Since its establishment in 1930, the Technology Loan Fund has provided more than $9,000,000 in loans to over 8,100 M.I.T. students.

In general, loans are made by the Student Financial Aid Committee to students entering the Institute who are well recommended and to students already in attendance who maintain a satisfactory level of academic achievement.

The maximum amount loaned to an undergraduate in a single year may not exceed the tuition fee, and the maximum total loans granted to an applicant may not exceed $6,000 for the total period of enrollment. A graduate student may receive assistance in excess of tuition if the circumstances indicate a definite need.

Application forms are available from the Student Aid Center. To receive favorable consideration an applicant must:

1. Be endorsed as to character and personality by: (a) an alumnus of the Institute from the community in which he has resided or by some other citizen of standing in that community; (b) the principal or head master of the high school or preparatory school or the president or dean of the college or university he has previously attended; and (c) his Registration Officer or the Head of his Course.

2. Have passed, with a standing satisfactory to the Committee, the physical examination required of all Institute students.

3. Submit a statement of his financial needs and such other information as the Committee may deem necessary, on the application form supplied by the Committee, such application to have the approval of his parent or guardian.

4. Be prepared to furnish as collateral such life insurance as may be required by the Committee.

No repayment is required until after graduation, and the recipient may have up to ten years to repay, depending upon the size of the loan. Repayments may be deferred up to a total of four years after graduation if the student continues his education in graduate school. These loans carry no interest while the student is in attendance or during any period in which his repayments are deferred for graduate study. Interest at the rate of 3 per cent is charged after the student completes his studies.

After he leaves the Institute, the recipient of a loan is required to advise the Committee annually, or at more frequent intervals, of his whereabouts, the character of the work in which he is engaged, the remuneration he is receiving, and his plans for the repayment of his obligations to this Fund.

NATIONAL DEFENSE STUDENT LOAN FUND

In order to extend the benefits of low-interest, educational loans to a larger segment of the student body, M.I.T. has recently joined the National Defense Student Loan Program. Students with demonstrated financial need may borrow up to $1,000 a year from this fund. The maximum total loans granted to an applicant may not exceed $5,000.

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.

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.

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.

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.

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 highest average grade among all the members of his class for all college work during the freshman year.

Karl Taylor Compton Prizes (1951)
These prizes are awarded in recognition and encouragement of outstanding contributions in promoting high standards of performance and good citizenship within the Institute community. They are awarded from the income of a fund composed of gifts by members and friends of the Boston Stein Club.

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 three doctoral students, one each in chemical engineering, chemistry, and physics, 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.

M.I.T. Women's Association Award (1958)
This award of $100 is given to an outstanding woman student in the junior class.

Outstanding Freshman Award
This award is made to recognize distinguished scholarship, integrity, breadth of interests, adaptability, and unselfish activity within the community at large. It is presented by Tau Beta Pi, 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.

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)
Yearly awards are presented to encourage skill in organized debating. They are made possible by the income of a fund established by the late President Samuel W. Stratton.

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 these awards to recognize "outstanding ingenuity" demonstrated by students in aeronautics and astronautics. The award is $600, with two honorable mentions of $200 each.

James Means Memorial Prize (1925)
A medal and monetary prize of $100 is offered annually to a senior for excellence in 16.71 FLIGHT VEHICLE ENGINEERING or 16.73 SPACE SYSTEMS ENGINEERING.

Henry Webb Salisbury Memorial Award (1941)
Established by the family and friends of Henry Webb Salisbury '33, this award consists of useful reference books presented to a student who has done outstanding work in the Department of Aeronautics and Astronautics.

ARCHITECTURE AND PLANNING

Alpha Rho Chi Medal (1932)
This medal is given each year to a graduating senior in the Department of Architecture who has shown an ability for leadership, performed willing service for his School and Department, and given promise of real professional merit through his attitude and personality.

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.

John Murray Clifford Award
The Clifford Award, established by the Class of 1948, 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.

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 the Student Chapter of the American Society of Civil Engineers.

ELECTRICAL ENGINEERING

Blonder-Tongue Foundation Award (1959)
This annual prize of $250, awarded to a student in electrical engineering who has completed his junior year, is presented in recognition of high scholastic attainment and the demonstration of outstanding potential in the field of electronics. The recipient is determined during the latter half of his junior year by the faculty of the Department of Electrical Engineering. The award is a gift of the Blonder-Tongue Foundation, supported by Blonder-Tongue Laboratories Inc.

Supervised Investors' Services, Inc., Awards
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.

MANAGEMENT

The Brooks Prize in Industrial 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 Industrial Management. Nominations may be made by the chairman of any Master's Thesis Committee to the Sloan School of Management's Prize Committee.

Industrial Management Association Award (1959)
This annual award of $100, established through the generosity of Samuel Berke '15, is made to the author of the best thesis submitted for the Bachelor of Science in Industrial Management.

MECHANICAL ENGINEERING

American Society of 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.

American Society of Tool and Manufacturing Engineers Prize (1945)
A prize of $100 is offered annually for the best graduation thesis on a subject related to the professional field of tool engineering. The prize is a gift of the Boston Section of the American Society of Tool and Manufacturing Engineers.

Luis de Florez Awards (1957)
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. The award is $600, with two honorable mentions of $200 each.

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 G. Rossby Award in Meteorology

The Carl G. Rossby Award is made in any year for a thesis judged to be outstanding that is submitted in partial fulfillment of the requirements for a graduate degree in 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.

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.

NUCLEAR ENGINEERING

General Electric Awards in Nuclear Engineering

A cash award, in amount between $200 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.

APPENDIX C: STUDENT HOUSING

The student Houses of the Institute are maintained to provide an atmosphere conducive to suitable study and living habits and an opportunity to participate in those social and extracurricular activities which properly supplement scholastic work. Members of the faculty are in residence with their families in Burton House, Baker House, the Graduate House, and on the East Campus. Resident Senior Tutors and Tutors, all members of the teaching staff, are associated with three of the undergraduate Houses, with several of the fraternity chapters, and with the Nonresident Students' Asso-tion building.

The Institute believes that it is to the great advantage of all students who do not live at home to live in Institute Houses or in fraternities. As far as accommodations allow, such residence is required for all freshmen unless other special arrangements are approved by the Dean of Residence. Upperclassmen are free to make whatever living arrangements they choose.

Determination and maintenance of living conditions within the Houses is the responsibility of the Dean of Residence. The student Dormitory Council organizes and supervises student activities, athletic and social, and cooperates with recognized undergraduate activities at the Institute. A House tax included in the rental is turned over to the Dormitory Council to support social and athletic activities. It is expected that all students will comply with those rules and regulations currently in effect. The Institute reserves the right to terminate the privilege of House residence for any student found violating either House regulations or acceptable standards of community behavior.

THE UNDERGRADUATE HOUSES FOR MEN

The Everett Moore Baker House (West Campus), located on the river front at 362 Memorial Drive, Cambridge, west of Massachusetts Avenue, accommodates some 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 rate is $240 per man per term. A member of the faculty is in residence.

The Senior House (East Campus) — Ware, Atkinson, Runkle, Holman, Nichols, and Crafts — on Memorial Drive, east of Walker Memorial and adjacent to the President's House, accommodates 194 students.

The Alumni Houses (East Campus) — Munroe, Hayden, Wood, Goodale, Bemis, and Walcott — near Walker Memorial, have accommodations for 417 men.

Dining facilities for residents of the East Campus Houses are in the Walker Memorial Building. They include a large cafeteria, where both commons meals and à la carte service are provided, and a modern social room and soda bar, where light refreshments are served. The latter, known as Pritchett Lounge, is open during evening hours and has a dance floor and other facilities for entertainment.

Furnishings and Maintenance

Provisions for furnishings and maintenance must necessarily reflect economic conditions, and are subject to review and change at the end of each academic year. All single rooms in the undergraduate Houses have a bed or studio couch, mattress, pillow, mirror, chiffonier or wardrobe, desk and chair, study chair, bookcase, wastebasket, light bulbs, and extra electrical outlets. Double and triple suites are furnished in a manner similar to the single rooms. Each occupant is required to complete an equipment inventory acknowledgment at the opening of the fall term, indicating the condition of the room and the furnishings. Bed linen and blankets are not furnished. Students may bring their own bedding with them or may obtain it through a rental service available at the desk of each House. For the current rent of $20, payable at the beginning of the fall term and refundable pro rata if the student does not complete the year, the service supplies blankets for a year and two clean sheets and one clean pillow case each week. Students in all Houses provide their own towels and soap and clean their own rooms, with occasional assistance from the porter staff.

For maintenance and safety, rooms are inspected regularly during normal working hours by responsible Institute personnel. Every effort is made for the physical safety of residents of the Houses, with proper fire alarm systems, fire extinguishers, and other equipment. Tampering with the protective systems or with the telephone system is a danger and a nuisance to others and is regarded as a serious offense, meriting the immediate and permanent exclusion of the offender from the Houses.

The Institute does not carry fire insurance covering property of residents of the Houses, who therefore may wish to provide their own by direct contract or by a rider on a family domestic policy.

Rents

Rooms in the Institute Houses are assigned on the basis of application forms distributed to residents each spring and to entering freshmen and transfer students with their notices of admission. Rooms are engaged for the full academic year; and with exceptions as approved by the Dean of Residence, a student who is assigned quarters on application is responsible for the rent thereof for the academic year of assignment.

Rates range from $185 to $250 per person per term and are subject to review and revision each January for the following academic year. Rental assignments are automatically canceled and a proportionate refund is allowed to any student who withdraws from the Institute during the first five weeks of the term. After the fifth week, refunds are made only in special circumstances approved by the Dean of Residence.

Rent for the full term is payable with tuition to W. A. Hokanson, Bursar, except when prior arrangements are made for deferred or periodic payments. Details of assignment, occupancy, and specific rentals — with other pertinent details — are published annually in a pamphlet entitled "Residence at M.I.T.," available from the Dean of Residence, Room 7–104.

Basic Regulations

In applying for a room in the Houses, a student is understood to agree to abide by the following basic regulations:

1. Only one room application form per student may be filed. Duplicate applications will not be considered.

2. Upperclassmen who are assigned rooms in the Houses in the spring will receive a card which must be signed and returned by July 15 in order to confirm acceptance of a room assignment. Students from whom no card is received will lose their assignment and be transferred to the bottom of the waiting list. Under special conditions approved by the Dean of Residence, students may be relieved of the responsibility for confirmed assignments up to, but not including, Registration Day in September.

3. Room changes within the dormitories will be made only in special circumstances and only with the approval of the Dean of Residence. Changes requested during the first three weeks of any term will not be effected until the end of the three-week period. Vacancies occurring during the first three weeks of any term will be filled directly from the waiting list, if any. At the end of the three-week period, priority in moves will be given residents as of Registration Day over men assigned rooms after Registration Day.

4. Students engaging rooms in the Houses will be considered responsible for the rent thereof for the full academic year except if they (1) leave the Institute, (2) move to a fraternity as indicated below, (3) secure a new occupant not in residence to take over the room, (4) present special circumstances to the satisfaction of the Dean of Residence.

5. Students living in the undergraduate Houses who desire to move to recognized fraternities during the first two weeks of either the first or second term will be refunded the rental fee less a pro rata charge for occupancy.

6. The Institute reserves the right to move students within the Houses at its discretion, in order to consolidate vacancies, to meet other demands upon dormitory facilities, etc. In these circumstances students will be allowed to leave the Houses, instead of moving, provided they have the approval of the Dean of Residence.

7. Students who do move from the Houses for any reason will be responsible for room rent until they have signed out at the office of the Dean of Residence, Room 7–104.

8. As a general rule, students may not occupy doubles as singles, triples as doubles, etc. If extra rooms are available, students may so occupy rooms at the Institute's convenience or protect the privilege in any given term by payment of $50.00 each.

9. For reasons of safety and sanitation, no cooking equipment may be used in the rooms of the Houses. Hot plates, electric frying pans, percolators, and other similar equipment therefore may not be kept in the rooms and will be confiscated. Upon a second offense, the violator may be excluded from the Houses. Exceptions to this regulation will be made only on approval of the Dean of Residence for special reasons such as medical necessity.

10. Refrigerators are allowed in students' rooms but must be licensed at a fee of $5.00 per term to cover costs. Refrigerators are subject to inspection for reasons of safety and sanitation.

11. Damage to Institute property in the Houses is the responsibility of the residents. Each student is held accountable for any damages in his own room. Damage to the entire dormitory or any part thereof will be charged to the residents of the dormitory. Student government may determine individual assessments.

12. All students electing to live in Burton House and Baker House are required to register for commons meals. Students who for medical or other reasons require special diets should consult the Dean of Residence.

13. Regulation of extracurricular activities in the Houses is among the responsibilities of student government in the Houses, in consultation with the Dean of Residence. The faculty and administration expect all students to abide by the regulations of student government.

14. Administration of parietal rules covering visiting hours for women guests is the responsibility of the Dean of Residence, in consultation with the appropriate student governing groups.

15. The manufacture, storage, or use of dangerous chemicals, explosives, or ammunition in the Houses is forbidden. Detonation of firecrackers or other explosives and the throwing of missiles of any kind from or within the Houses are forbidden. Tampering with fire-protection equipment in the Houses is forbidden. Violation of these regulations, or the committing of any other acts interfering with proper study conditions in the Houses or with the rights of the community at large, renders the violator subject to disciplinary action.

16. Storage of firearms, air rifles, air pistols, and ammunition for them is not permitted in any Institute House and is generally discouraged in independent living groups. Students who desire to bring firearms to the Institute may store them at the Campus Patrol Office, where suitable facilities and 24-hour security will be provided. Owners may remove weapons for legal use and return them to storage between the hours of 8:00 a.m. and 5:00 p.m. Separate storage facilities are provided for weapons belonging to members of the rifle and pistol teams and recognized clubs. All students are reminded that firearms must be licensed in accordance with the laws of the Commonwealth of Massachusetts.

Key Deposits

A deposit of $1 is required for a room key, subject to refund in full upon return of the key.

Parking and Automobile Regulations

Because of the acute shortage of on-campus parking space, the Institute cannot provide parking facilities for use of resident students. A limited number of spaces are provided, with the approval of the Dean of Residence, for residents with physical handicaps demanding use of an automobile. All motor vehicles operated by students must be registered with the Campus Patrol, Room 20C-128, within thirty days after Registration Day.

Operators of motor vehicles should consult the Massachusetts Registry of Motor Vehicles regarding regulations and insurance on out-of-state motor vehicles. All such vehicles must be registered with the Registry through the Cambridge Police Department within thirty days.

RESIDENCE FOR WOMEN

McCormick Hall, a new building at 320 Memorial Drive in Cambridge, overlooking the Charles River and adjacent to the main educational buildings, has accommodations for 116 students in 64 single and 26 double rooms. The building has its own kitchen and dining room, and there are guest rooms for visitors, seminar rooms, lounges, library, study room, and sun deck. A member of the faculty is in residence with his family as Master.

The second floor includes one double and four single rooms; each of the third through seventh floors, the main residential floors in the building, includes five double and twelve single rooms, a lounge with adjoining kitchenette, and laundry facilities. Rooms are furnished with bed, bureau, desk, desk chair, and bookcase for each resident; there is telephone service in each room.

The inclusive rate for the academic year is $1,150, which provides for occupancy of a single or double 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.

RESIDENCE FOR GRADUATE MEN

The Graduate House, at 305 Memorial Drive, is a center for the social life of the graduate student community. Its rooms, accommodating 450, are reserved exclusively for men graduate students.

Application forms for rooms are distributed to residents each spring and to entering graduate students with their notifications of admission. They should be filed with the Manager of the Graduate House. In general, accommodations are insufficient to meet the demand at the beginning of each year, and there is usually a waiting list. Priority is granted to graduate students already living in the House whose applications are filed in accordance with instructions distributed each spring.

Notices of assignment will be forwarded to applicants as promptly as possible. Acceptances must be returned as requested; otherwise, the rooms may be reassigned. The assignment of rooms is in order of application; the right is reserved to reject any applicant for sufficient reason.

Rents in the Graduate House range from $160 to $235 per person per term. Rent for the full term is payable with tuition to W. A. Hokanson, Bursar, except when prior arrangements are made for deferred or periodic payments.

Rooms are engaged for the full academic year. Reservations are automatically canceled and proportionate refunds are made to students who cancel their registration during the first five weeks of the term. After the fifth week no refund is made except in special circumstances approved by the Dean of Residence.

Equipment and service in the Graduate House, basic regulations, key deposits, and parking and automobile regulations are the same as those given above for the undergraduate Houses.

RESIDENCE FOR MARRIED STUDENTS

Westgate, an apartment development of five new buildings at the west end of the M.I.T. campus, provides modern, efficient housing for 210 married student families. A sixteen-story tower contains 90 one-room efficiency-type apartments and 60 one-bedroom units, and four three-story garden-type buildings provide a total

of 60 two-bedroom apartments. There are also such community facilities as laundry, store, service area, free parking, and playground equipment.

Further information is available from the Dean of Residence.

MAIL AND MESSAGES

Mail for dormitory residents should be addressed to the House concerned:
Burton House and Conner Hall, 420 Memorial Drive
Baker House, 362 Memorial Drive
McCormick Hall, 320 Memorial Drive
Graduate House, 305 Memorial Drive
Alumni Houses, 3 Ames Street
Senior House, 4 Ames Street
all in Cambridge, Massachusetts (02139). Local and long distance telephone calls to resident students may be made by calling area code 617, 864-6900 (Cambridge, Massachusetts), and asking for the House concerned.

Mail for residents of Westgate should be addressed to the individual apartment number. Telephone service for Westgate residents is arranged directly with the New England Telephone and Telegraph Company and numbers are listed in the Boston telephone directory.

DINING SERVICES FOR MEN

Commons meals for men students are served Monday through Friday in Institute dining rooms in Walker Memorial, Burton House, Baker House, and the Graduate House, except during stated vacation periods. Commons meals are required for Burton House and Baker House residents; residents of the other undergraduate Houses may elect the commons plan in Walker. A la carte service is also available in Walker Monday through Friday and in the Graduate House dining room seven days a week.

Election of the commons plan is for the full term in which it is made. The contract is automatically canceled and a proportionate refund is made upon withdrawal of a student from the Institute during the first five weeks of the term. After the fifth week refunds are made, at the rate of $6 per week or more, in special circumstances approved by the Dean of Residence.

The price of commons meals is reviewed each January for the following academic year. For the academic year 1964–65; the rate will be $14.50 per week: $246.50 for the fall term and $232 for the spring term. All fees for commons meals are payable, with rent and tuition, to the Bursar at the beginning of each term. Students may arrange before the term begins to make deferred or periodic payments.

OTHER STUDENT HOUSING FACILITIES

Information about other housing facilities, as described in Section 1 of this Catalogue, may be obtained as follows:

For fraternities, write to the Interfraternity Conference, Walker Memorial, M.I.T., Cambridge (02139).

For cooperative living, write to the President of the M.I.T. Student House, 111 Bay State Road, Boston (02115).

For married students, write to the Dean of Residence, M.I.T., Cambridge (02139).

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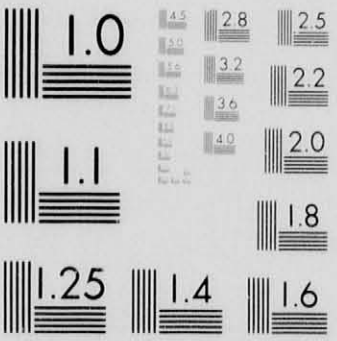

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