M.I.T. ANNUAL CATALOGUES AND BULLETINS
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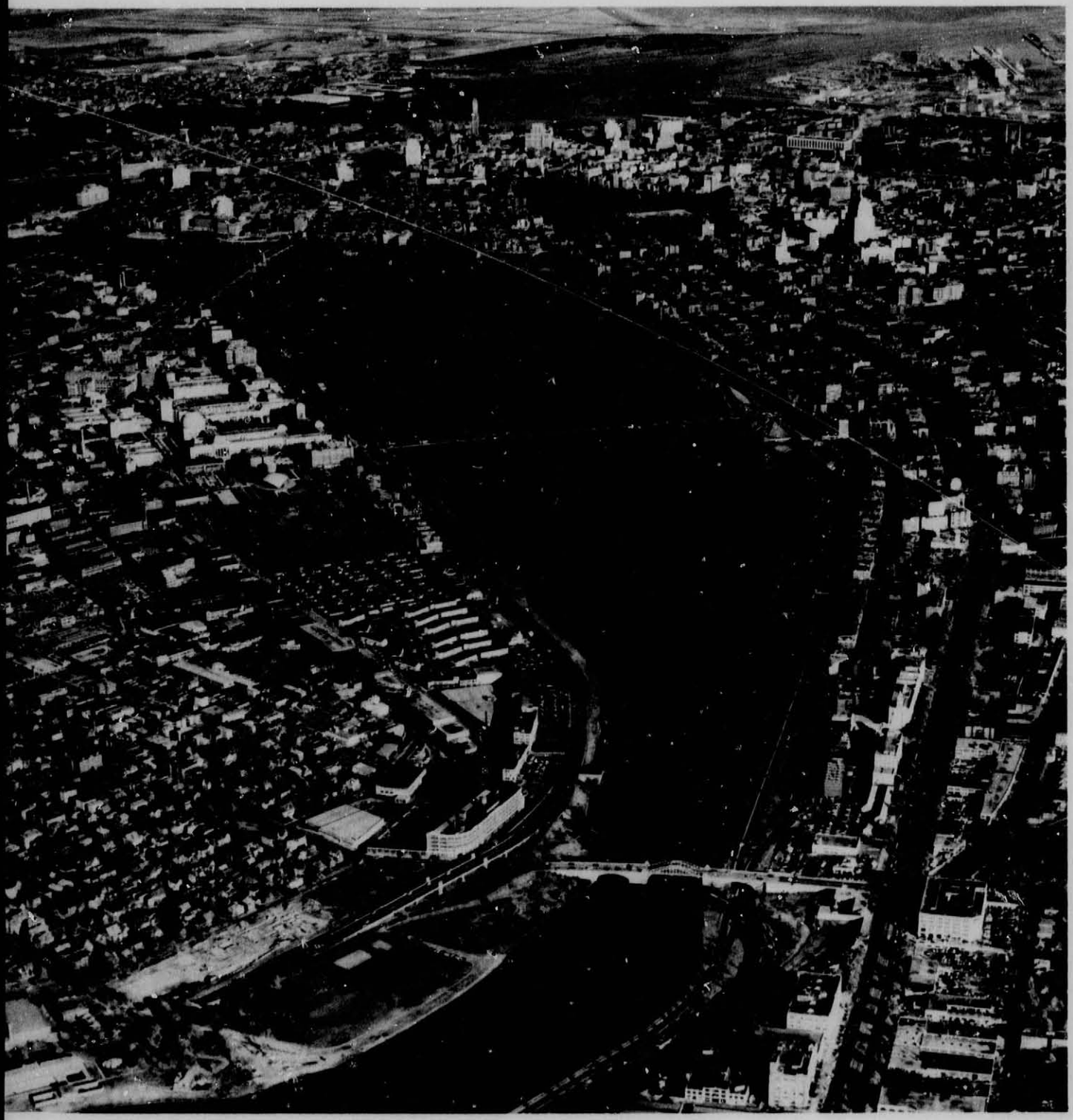

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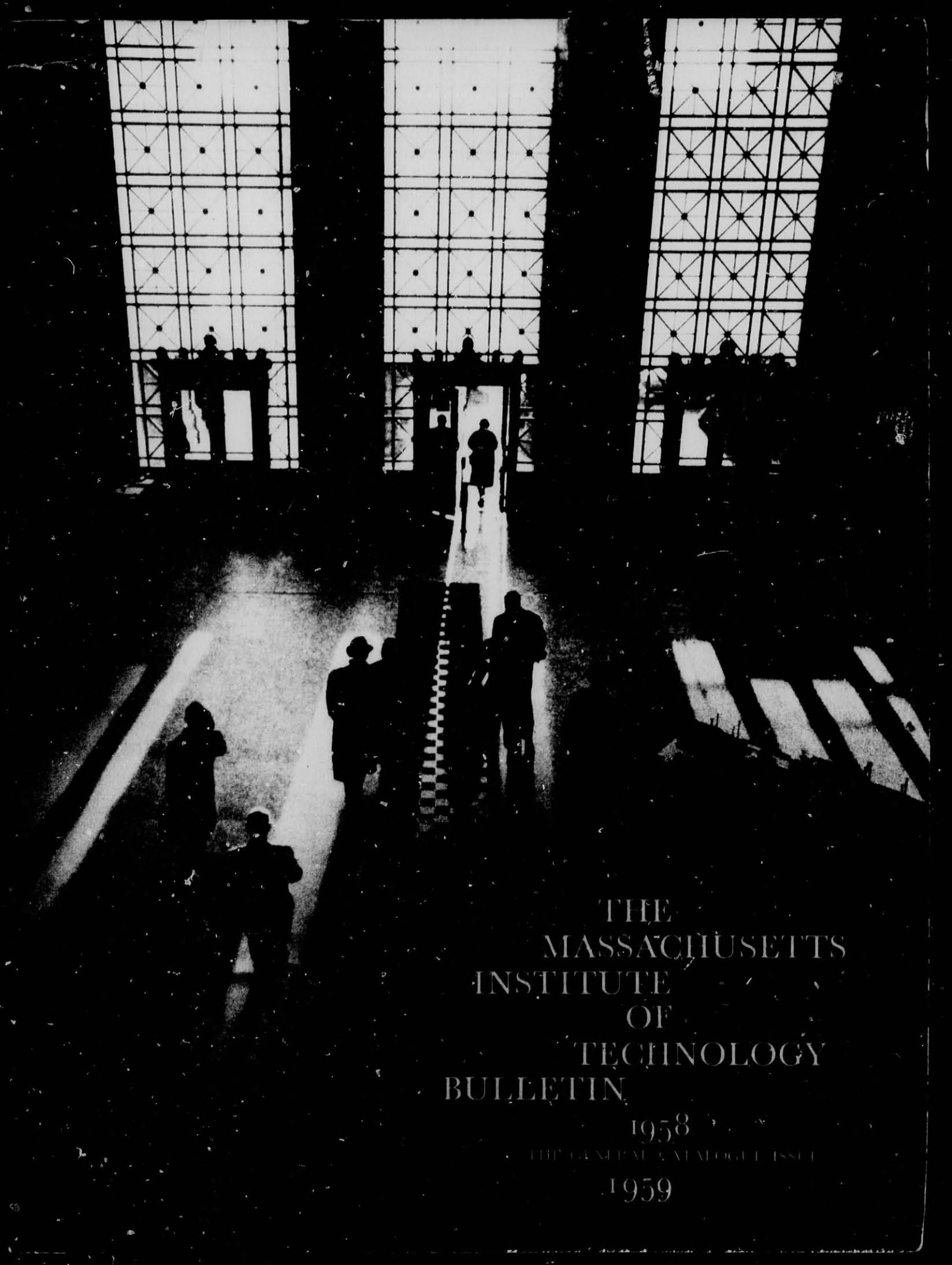

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY BULLETIN

1958

THE GENERAL CATALOGUE ISSUE

1959

MASSACHUSETTS INSTITUTE OF TECHNOLOGY BULLETIN

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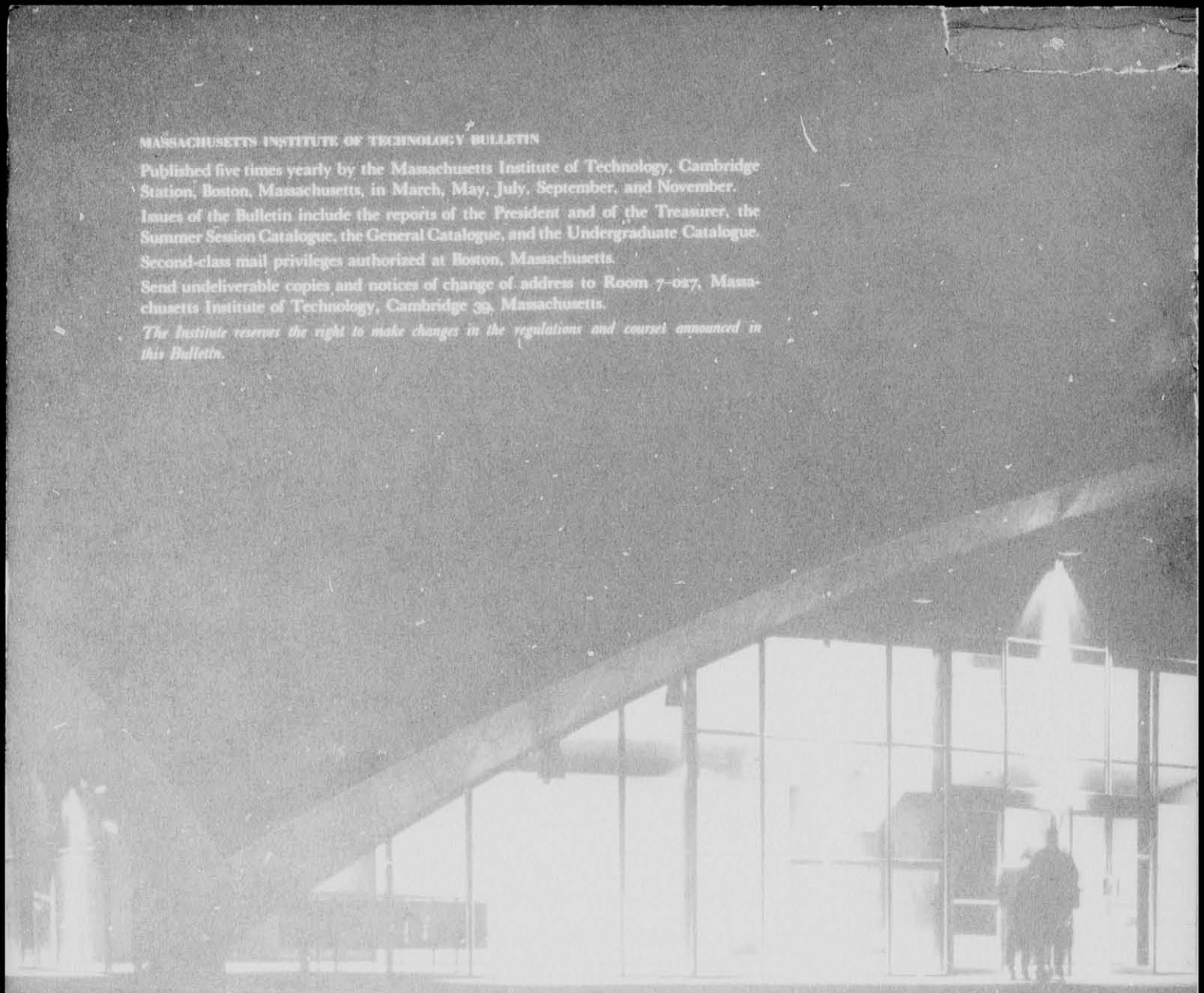

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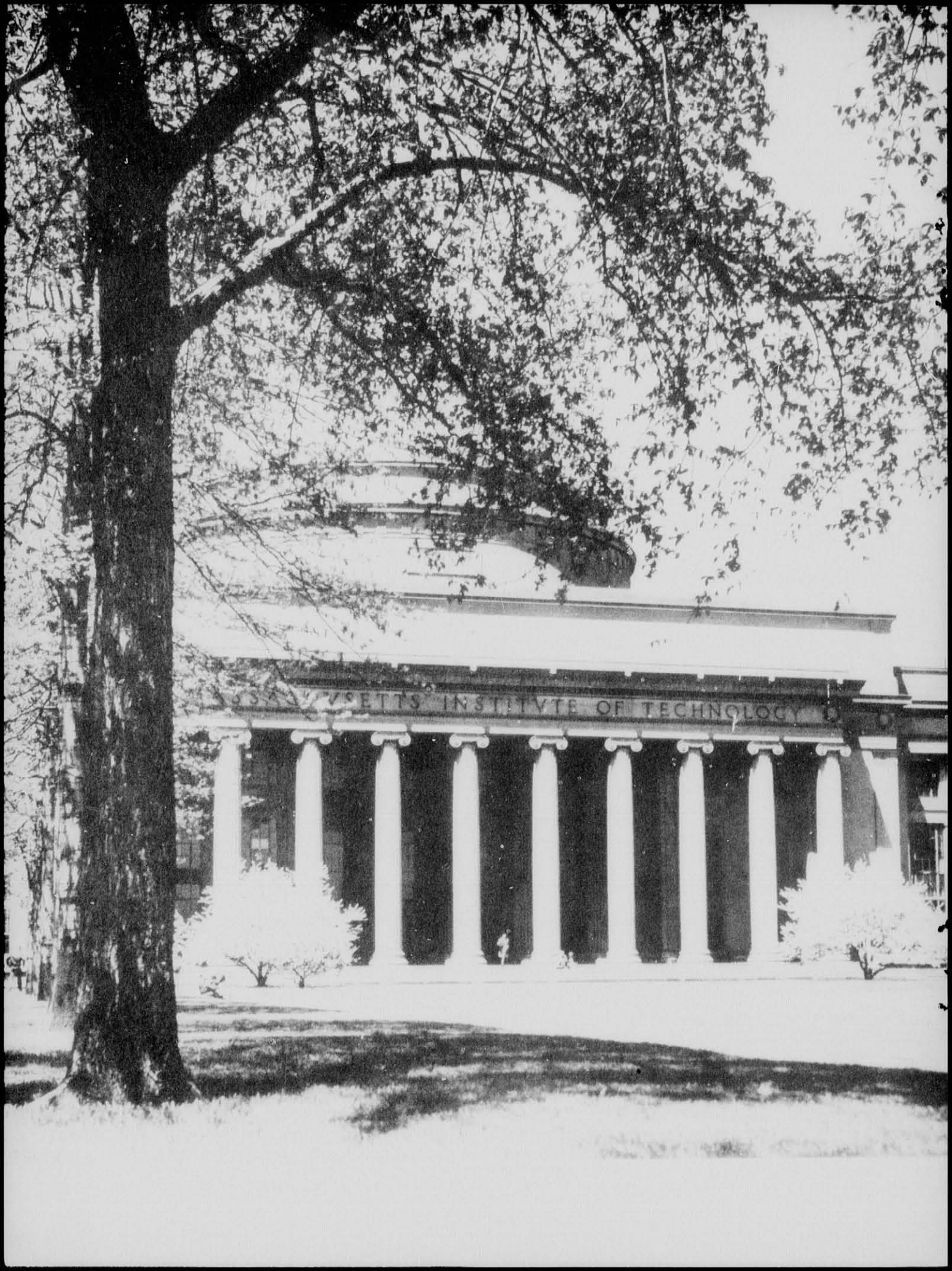
ETTS INSTITVTE OF TECHNOLOGY

ACADEMIC CALENDAR

1958

SEPTEMBER 18	FIRST TERM BEGINS FOR FRESHMEN
SEPTEMBER 22	FIRST TERM BEGINS FOR UPPERCLASSMEN AND GRADUATE SCHOOL
OCTOBER 12	COLUMBUS DAY *(holiday) (Exercises omitted Monday October 13)*
NOVEMBER 11	VETERANS' DAY *(holiday)*
NOVEMBER 27 *through* NOVEMBER 30	THANKSGIVING VACATION
DECEMBER 20 *through* JANUARY 4	CHRISTMAS VACATION

1959

JANUARY 21	LAST EXERCISES OF THE TERM
JANUARY 22 *through* JANUARY 24	READING PERIOD
JANUARY 26 *through* JANUARY 30	EXAMINATION PERIOD
FEBRUARY 9	SECOND TERM BEGINS
FEBRUARY 22	WASHINGTON'S BIRTHDAY *(holiday) (Exercises omitted Monday February 23)*
MARCH 30 *through* APRIL 5	SPRING VACATION
APRIL 19	PATRIOTS' DAY *(holiday) (Exercises omitted Monday April 20)*
MAY 26	LAST EXERCISES OF THE SECOND TERM
MAY 27 *through* MAY 29	READING PERIOD
MAY 30	MEMORIAL DAY *(holiday)*
JUNE 1 *through* JUNE 5	EXAMINATION PERIOD
JUNE 12	COMMENCEMENT DAY
JUNE 22	SUMMER SESSION 1959 BEGINS
SEPTEMBER 21	FIRST TERM 1959 BEGINS

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

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Commissioner of Education

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

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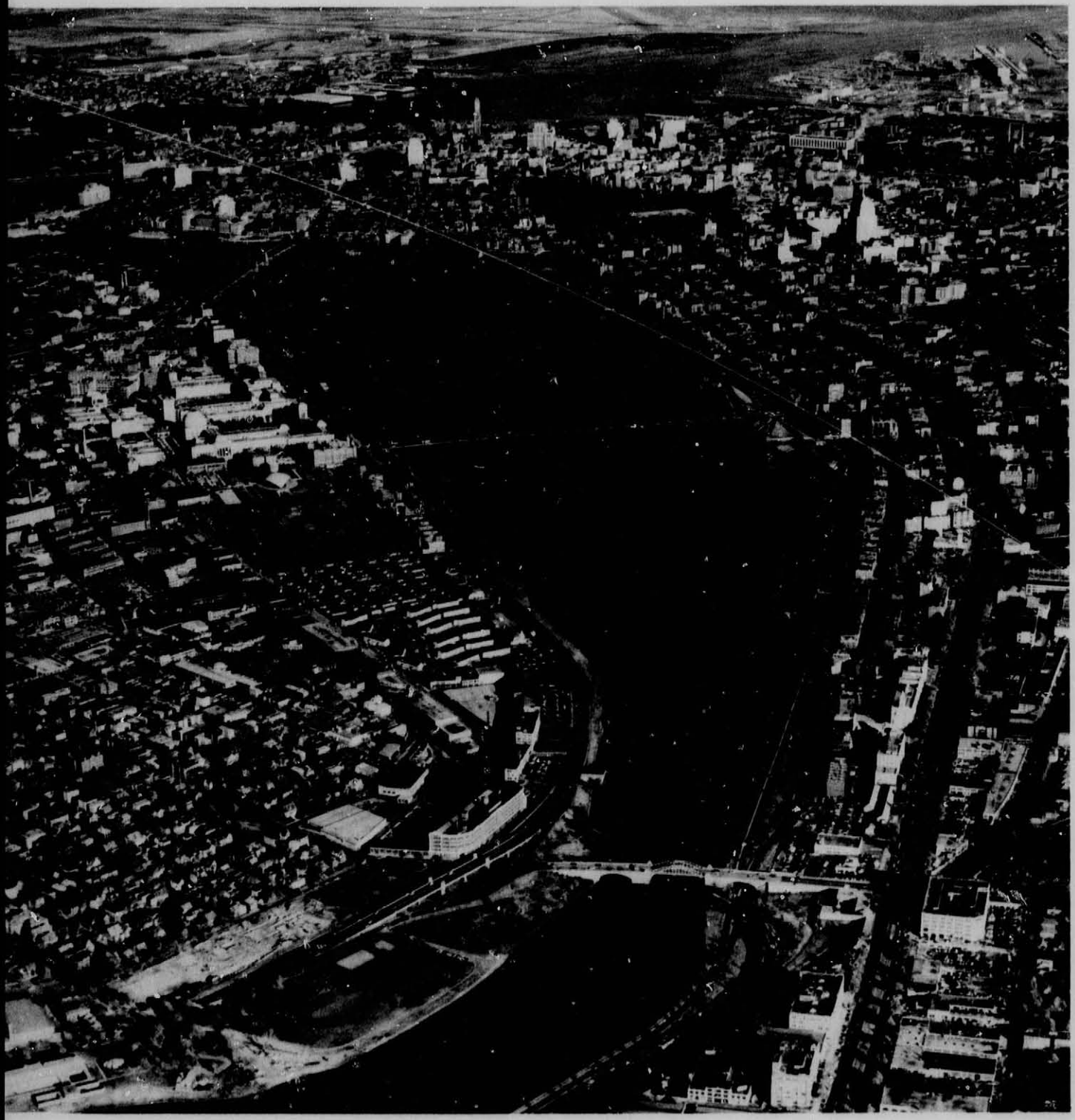
Captain, U.S. Navy — *Head*



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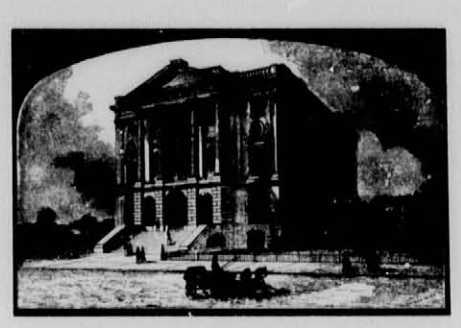


Objectives and Policies

A statement by Dr. James R. Killian, Jr., President of the Massachusetts Institute of Technology

With a lively and prophetic vision of the part that science was to play in advancing human welfare, William Barton Rogers, geologist and natural philosopher of the University of Virginia, planned and worked for nearly a decade prior to the Civil War for the establishment of a great institute of technology. As its first president, he set the Massachusetts Institute of Technology on the course of intellectual leadership and public service that has given it continuing vitality and that has made it an institution of national and international influence.

Since its establishment, M.I.T. has constantly kept before it three objectives —the education of men, the advancement of knowledge, and service to industry and nation. In its early years the Institute pioneered in extending the laboratory method of instruction as an indispensable educational technique. Later, it virtually created the modern profession of chemical engineering;

M.I.T.'s Courses in electrical engineering, aeronautical engineering, and applied physics were among the first in the world. Today the Institute's undergraduate programs in architecture, engineering, humanities, management, and science are so broad and fundamental as to constitute an excellent general preparation for careers in other fields as well as these. And its graduate programs, deriving exceptional strength from the extensive research activities here, are preparing increasing numbers of students for professional leadership.

In both undergraduate and graduate programs M.I.T.'s concern is to maintain not only exacting academic programs directed to a high level of intellectual achievement but also to prepare for life and for citizenship. Indeed, the environment here is one which in the broadest sense performs an educational function in itself; living facilities, activities, and the entire academic atmosphere contribute to the development of responsibility, breadth, and standards of taste and judgment among our students. A broad program in the humanities and the social sciences, included in all regular undergraduate curricula, deepens students' understanding of themselves and their environment. There is a wholesome regard for extracurricular activities. Students here accept unusual responsibilities for their own intellectual progress and for the conduct of the student community.

To vitalize its education and to fulfill its obligation in the advancement of knowledge, the Institute emphasizes fundamental research in all the fields represented here. Teaching of the highest type, especially in science and its applications, thrives best in the stimulating atmosphere of creative work at the boundaries of human knowledge. He who is still a student, who is still himself learning, can best guide those about to enter on professional careers. The most striking features of research at the Institute are the spirit of cooperative effort in which it is conducted and the extent to which both undergraduate and graduate students participate in it as an integral part of their educational experience.

All this makes M.I.T. a university in the truest sense—a university with selected objectives, built around science and social technology but embracing the arts, the social sciences, and the humanities as essential partners. In fulfilling these objectives, M.I.T. traditionally seeks and demands the highest standards of academic and professional achievement.

JAMES R. KILLIAN, JR.

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

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

The Corporation

In a legal sense, the Institute is a body of trustees known as the Corporation. Its members include the Chairman and the four corporate officers of the Institute—the President, Chancellor, and two Vice Presidents—and more than fifty distinguished leaders of science, engineering, industry, and education, a number of whom are Institute alumni. *Ex officio* members include the Governor of the Commonwealth, the Chief Justice of the Supreme Judicial Court, and the Commissioner of Education. Four stated meetings of the Corporation are held each year, in October, December, March, and June. Between meetings it functions through its officers, its Executive Committee, and other committees on membership, finance, development, and auditing.

The Corporation appoints Visiting Committees for each department and for certain of the principal administrative functions at 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 the departments.

The Faculty

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

In all, there are about 600 members of the faculty. The academic staff of the Institute—including administrative officers, instructors, research associates, and teaching, research, and technical assistants who are not members of the faculty—totals about 1800.

Administrative Officers

The Institute's chief executive officer is the President. Working in association with him is the Chancellor, who is responsible for the administration of the academic programs and is the President's deputy for all Institute affairs. These two officers are aided by two Vice Presidents, responsible in the areas of finance and sponsored research.

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

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

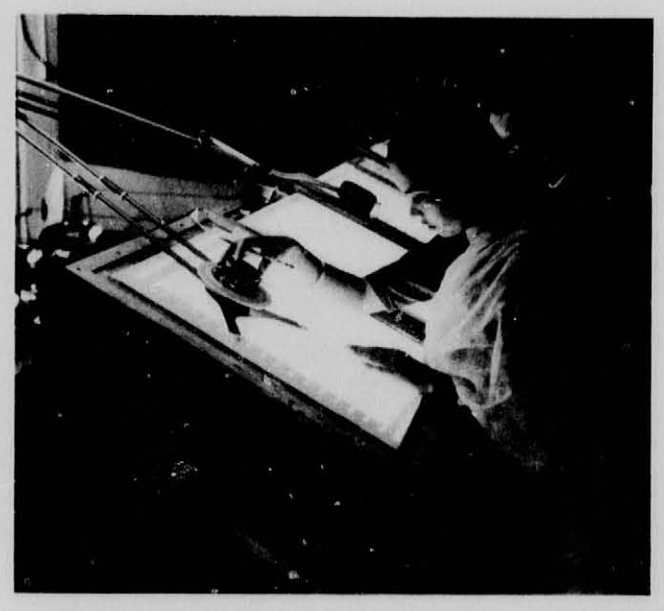
The Students

In all, M.I.T.'s enrollment totals about 6200 students. Of these, some 3700 are undergraduates, most of whom enter as first-year students having completed accredited high and preparatory school programs. However, M.I.T. welcomes a limited number of undergraduate students who have studied one, two, or sometimes three years in other colleges. Of the 2500 graduate students, roughly one-third hold undergraduate degrees from M.I.T.; others come from colleges and universities throughout the United States and foreign countries. In recent years about 10 per cent of M.I.T.'s graduate and undergraduate students have come from foreign countries, the largest proportion of total enrollment of any American university. For scholars who hold advanced degrees, M.I.T.'s facilities are available through the School for Advanced Study.

As careers in science, engineering, and architecture have become more available to women, M.I.T.'s enrollment of women students has increased. In a typical year about 130 women are enrolled, 70 of them undergraduates.

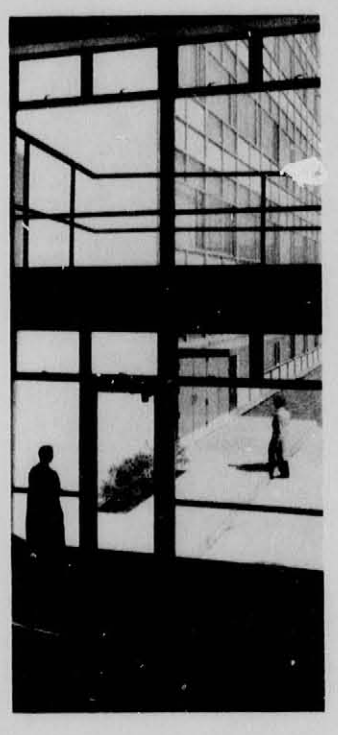
SPECIAL STUDENTS

The Institute also accepts a limited number of students who wish to carry on special studies and who are not candidates for degrees; they are known 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 or Dean of the Graduate School. Applicants must present academic credentials of high quality or evidence of professional experience which justifies undertaking the program planned.



THE COMPTON LABORATORIES FOR ELECTRONICS AND NUCLEAR SCIENCE

THE SLOAN LABORATORIES FOR AIRCRAFT AND AUTOMOTIVE ENGINES



THE DORRANCE LABORATORY FOR BIOLOGY AND FOOD TECHNOLOGY

THE CHARLES HAYDEN MEMORIAL LIBRARY

THE GUGGENHEIM AERONAUTICAL LABORATORY

THE ROTCH LIBRARY

THE STEIN CLUB MAP ROOM

THE HAYDEN READING ROOMS

Educational Facilities

The Massachusetts Institute of Technology's 115-acre campus extends for more than a mile along the Cambridge side of the Charles River basin, facing the skyline of Boston. Nearly all the academic activities are brought together in a group of connected educational buildings which are designed to permit maximum flexibility and easy communication among the departments and schools. The extensive athletic plant and playing fields are on the campus, fully accessible. So are the recreational buildings, dormitories, and dining halls.

This convenient arrangement is an expression of the unity that pervades the Institute—unity among the sciences and humanities, among faculty, students, and administration, among the intellectual, social, and recreational aspects of living. M.I.T. was built to contain, in harmonious grouping, a single intellectual family.

THE LIBRARIES

The M.I.T. libraries are well equipped to serve and enrich Institute programs of study and research. Resources are in excess of 600,000 volumes, including about 6,500 current periodicals, 1,500 government-document series, and collections in special fields such as electrical engineering. There are strong holdings in all major fields of interest.

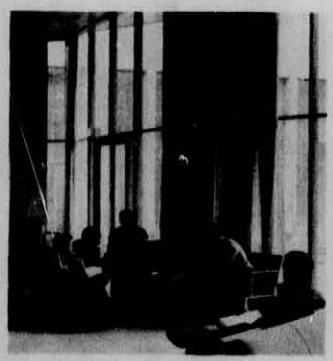
The library system, with headquarters in the Charles Hayden Memorial Library building, includes a General Library and five divisional libraries: The Arthur Rotch Memorial Library of Architecture and Planning, the Dewey Library (economics, industrial management, and industrial relations), the Engineering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

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

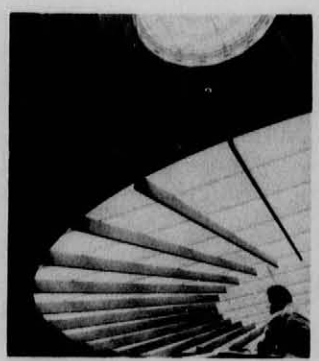
Of special interest in the Hayden building are the Boston Stein Club Map Room, with its unique six-foot revolving relief globe, and the Music Library, whose five-channel audio system was electronically and acoustically designed especially for the main listening room.

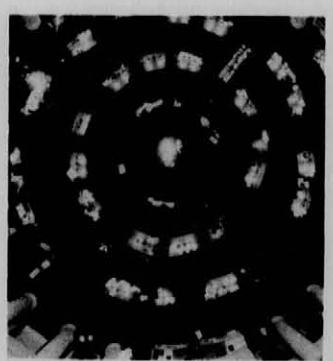
The libraries serve primarily Institute students, faculty, staff members, and their families. Others wishing to use the facilities may obtain library cards at a moderate fee by applying to the Director of Libraries.

THE MUSIC LIBRARY



THE ENGINEERING LIBRARY





OTHER FACILITIES

Other teaching facilities of the Institute extend beyond the Cambridge campus. Students in the Cooperative Courses study at a number of industrial plants throughout the East; the School of Chemical Engineering Practice operates field stations at Bound Brook and Bayway, in New Jersey. The Department of Geology and Geophysics shares in the Nova Scotia Centre for the Geological Sciences, near Antigonish.

The Engineering Practice School at Oak Ridge, Tennessee, is open to qualified graduate students in all M.I.T. departments. Under the direction of members of the faculty resident in Oak Ridge, students study in the Gaseous Diffusion Plant and in the Oak Ridge National Laboratory, both operated for the Atomic Energy Commission by the Union Carbide Nuclear Company. The program emphasizes the application of engineering principles to development, research, or production problems encountered in the rapidly growing atomic energy field. There are two terms each year—from September through January and from February to early June – each of which carries academic credit for 48 units. The School is administered by the Department of Chemical Engineering, and inquiries should be addressed to the Department Headquarters at M.I.T.

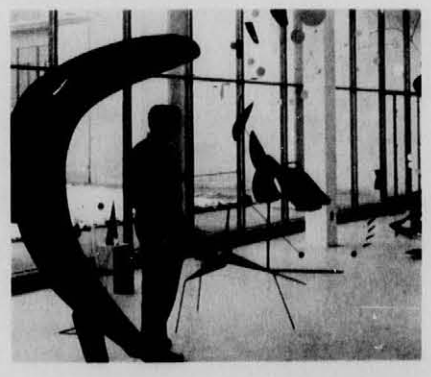
PRACTICAL EXPERIENCE IN THE ATOMIC INDUSTRY IS AVAILABLE TO M.I.T. STUDENTS AT THE ENGINEERING PRACTICE SCHOOL AT OAK RIDGE.

MUSEUMS

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

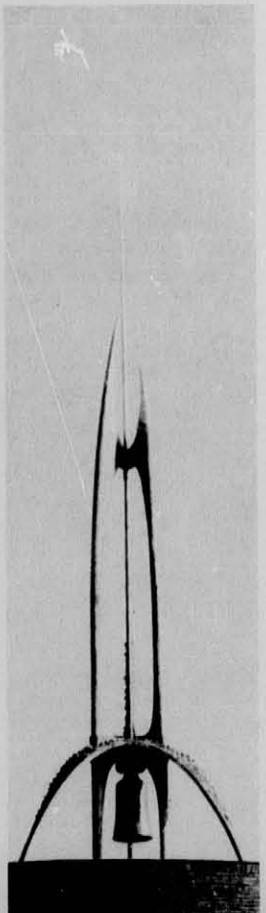
In addition to the permanent displays, the Institute provides monthly exhibitions in the New Gallery in the Hayden Library. These presentations, often the only showings of their kind in the Boston area, range from handcraft to machine craft, from primitive through contemporary art.

MUSEUMS WITH PERMANENT EXHIBITS AND TRAVELLING SHOWS CONTRIBUTE TO THE M.I.T. COMMUNITY.



ENDICOTT HOUSE

Endicott House, located in suburban Dedham, is M.I.T.'s center for off-campus conferences. It has meeting and dining rooms, overnight accommodations for about 35 guests, and large landscaped grounds.



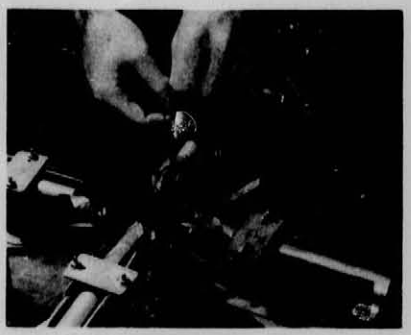
AUDITORIUM AND CHAPEL

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 1200, an experimental theater for 200, and rehearsal rooms for musical and dramatic performances. It thus provides equipment and environment for the finest public performances of music and drama, as well as for lectures and more informal events.

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

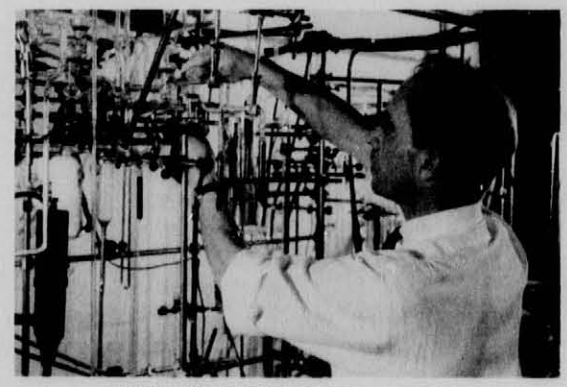
THE SUB-CRITICAL GRAPHITE-MODERATED PILE

IN THE BIOLOGY LABORATORIES

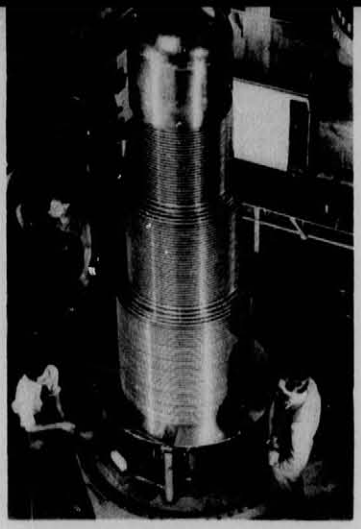


A COUNTER IN THE RADIOACTIVITY CENTER

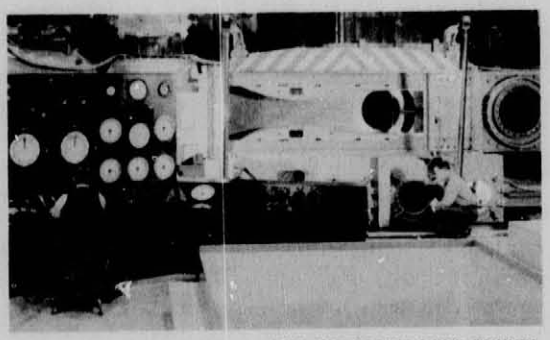
POWDER METALLURGY IN THE METALS PROCESSING LABORATORY



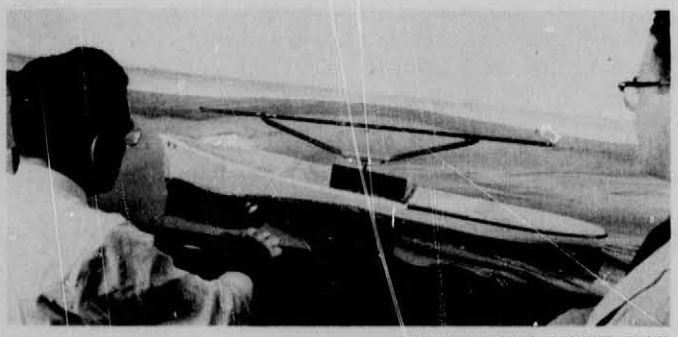
IN THE DEPARTMENT OF GEOLOGY AND GEOPHYSICS



THE ROCKEFELLER VAN DE GRAAFF GENERATOR



THE SUPERSONIC WIND TUNNEL



THE SHIP MODEL TOWING TANK

Research Resources

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

The Institute has research facilities unusual —and in some cases unique—among educational institutions. There are more than 70 special laboratories on the campus in Cambridge. For the most part these facilities are described elsewhere in this book by the departments which operate them. Outstanding are the nuclear reactor and Nuclear Engineering Laboratory (Department of Nuclear Engineering), the supersonic wind tunnels (Department of Aeronautical Engineering), Servomechanisms Laboratory (Department of Electrical Engineering), and I.B.M. computer in the Computation Center. Round Hill, the ocean-front estate of the late Colonel E. H. R. Green in South Dartmouth, Massachusetts, is used for a number of Institute research activities; in addition, a beachfront cottage—Tech House—is available to students and faculty, and the beach is open to all members of the M.I.T. family.

In addition to laboratories and facilities organized within departments, there are a number of interdepartmental laboratories established so that their activities may freely cross the lines of traditional disciplines. These include the Computation Center, the Laboratory of Earth Sciences (geology and meteorology), the Research Laboratory of Electronics (electrical engineering and physics), the Laboratory for Nuclear Science (physics and chemistry), and the Spectroscopy Laboratory (chemistry and physics). These and other cooperative research activities are described on the following pages.

Laboratory of Earth Sciences. The Laboratory of Earth Sciences is jointly sponsored by the Departments of Geology and Geophysics and of Meteorology. Its program is based on an integrated approach to experimental and theoretical investigations of man's physical environment: the atmosphere, the oceans, and the surface and interior of the solid earth.

Research Laboratory of Electronics. The Research Laboratory of Electronics is a federation of many different faculty and student groups, all with a common interest in physics and mathematics and their applications. The staff is typically drawn from the Departments of Physics, Electrical Engineering, Economics, Chemistry, Mathematics, and Modern Languages. Since the Laboratory's research program is defined largely by the specific interests of these different groups, it changes considerably from year to year. Currently studies are being made in many different aspects of communication, including statistical communication theory, noise theory, properties of speech signals, radio signal propagation, communications biophysics, neurophysiology, and methods of translating languages by means of machines; circuit theory; switching circuits; physical electronics, low-temperature physics; atomic beams; and electron spectroscopy.

Laboratory for Nuclear Science. The Laboratory for Nuclear Science was organized in 1946. Its major equipment now includes a number of high-energy accelerators—a 7 Mev proton cyclotron, a 17 Mev electron linear accelerator, a 350 Mev electron synchrotron, and two Van de Graaff positive ion accelerators capable of producing particles with energies up to 4 Mev and 10 Mev; many other experimental facilities are also available. The Laboratory is engaged entirely in basic research. Among many projects are theoretical studies of the atomic nucleus; studies of the photoproduction of mesons and other high-energy nuclear phenomena; studies of the new fundamental particles involving broad experimental endeavors using nuclear emulsions, cloud chambers, and bubble chambers; studies of cosmic rays, including a program oriented toward the astrophysical aspects of these rays; a broad program of precise nuclear energy level measurements; and programs in nuclear chemistry and radioactivity. As part of its program the Laboratory is engaged also in experiments in high-energy physics at the Brookhaven National Laboratory and at the Radiation Laboratory of the University of California.

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

Computation Center. The Computation Center, one of M.I.T.'s newest laboratories, is the largest and most versatile data processing facility available today entirely for education and basic research. The Center has the dual role of training students in the operation and use of computer facilities and of helping them provide computation service for university research groups throughout New England. Its I.B.M. Type 704 Electronic Data Processing Machine was installed early in 1957 by the International Business Machines Corporation; the company contributes to maintenance and operation costs and also makes funds available to students from many New England colleges, who study at the Center as research assistants. The principal fields in which the computer has thus far seen use are operations research, the application of new data processing methods to complex manufacturing and distribution problems; aerodynamics; meteorology; atomic research; and solid state physics.

Other Interdepartmental Activities. There are, in addition, a number of other interdepartmental groups which indicate the Institute's growing concern with the interrelationships of the scientific and engineering disciplines. The Committee on *Plastics Research* coordinates studies in plastics involving chemical, architectural, and civil and mechanical engineering aspects of plastics. An interdepartmental steering committee is responsible for research in *solar energy utilization*. The Institute Committee on Operations Research has for several years supervised graduate training and thesis research in the emerging field of *operations research*, intermediate between mathematics, engineering, and the social sciences. Graduate students registered in many departments have been able to specialize in this new field under the guidance of this interdepartmental Committee; it also sponsors weekly seminars.

Center for International Studies. The Center was founded in 1951 to apply the methods of

social science to problems bearing on the peace and development of the world community. It reflects the growing interest of M.I.T., whose focus is on the natural sciences and engineering, in the social, political, and economic aspects of technological change. Many of the Center's staff are faculty members of the Departments of Economics and Social Science and of Humanities; the Center provides research opportunities which are important to the professional development of these departments. There are opportunities for graduate students to participate in these research programs. Current studies at the Center include the economic and political problems of underdeveloped nations in Asia and Africa; Soviet efforts in scientific research and development; and the relation between American institutions and foreign policy.

Center for Urban and Regional Studies. A part of the School of Architecture and Planning, the Center for Urban and Regional Studies focuses attention on the character of the physical environment of the city and of the region, its adequacy in meeting human needs, its processes of transformation, and the means by which these processes may be guided most effectively. Areas of special interest include transportation, housing, the influence of technological developments, and problems of growth in underdeveloped areas. It presents important research opportunities for graduate students in planning and related fields.

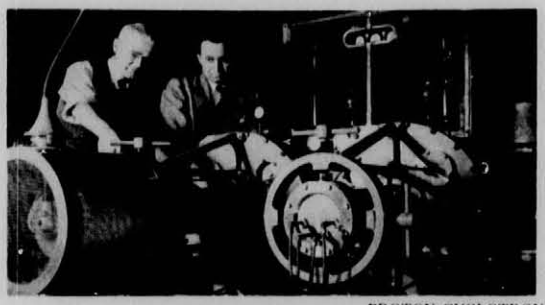
Center for Communication Sciences. The Center for Communication Sciences coordinates research programs in communication processes in both natural and man-made systems. The Center is affiliated with the Research Laboratory of Electronics and uses the Laboratory's administrative and research facilities. M.I.T. students and staff, as well as distinguished guests from outside the Institute, participate in the Center's activities.

Cambridge Electron Accelerator. The Cambridge Electron Accelerator, a 6 Bev accelerator made possible by a grant of the Atomic Energy Commission, is being designed and constructed and will be operated jointly by M.I.T. and Harvard on the Harvard University campus. It should be completed and become available for research operations in early 1960.

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

The Lincoln Laboratory. The Lincoln Laboratory, located in Lexington, Massachusetts, is an electronics research and development center established in 1951 supported by the three Armed Services through the Air Research and Development Command of the Air Force. The Laboratory's research and development is oriented primarily towards the communications and electronics required in the defense of North America against air attack.

Lincoln sponsors a Staff Associate Program, combining full-time graduate study at M.I.T. during the academic year with professional work at the Laboratory during the summer. A number of Staff Associate positions are available to students who can qualify for both employment at the Laboratory and admission to the M.I.T. Graduate School. This is normally a two-year program leading to a Master's degree.



PROTON CYCLOTRON

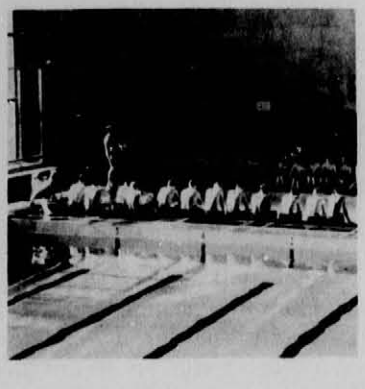
ATOMIC BEAM APPARATUS

LINCOLN LABORATORY

THE BAKER HOUSE

THE GRADUATE HOUSE

EAST CAMPUS HOUSE



Recreational and Housing Facilities

Dormitories and athletic and social facilities are an integral part of M.I.T.'s campus in Cambridge. Indeed, the Institute seeks in every way to provide its students with a rich and well-rounded collegiate experience—so that as they develop professional competence they also gain experience and insight in many human activities and human relationships.

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

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

The boat house on the Charles River is supplied with eight-oared shells and indoor rowing machines, and there are excellent facilities for dinghy sailing at the nearby Sailing Pavilion.

THETA DELTA CHI FRATERNITY

BURTON HOUSE

HOUSING FACILITIES

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.

The Houses for Undergraduate Men. There are comfortable facilities for undergraduate men in 12 Houses on the East Campus and in 3 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 residents. Baker House has its own dining room, and Burton House has an ample snack bar.

Members of the faculty are in residence in Burton House, Baker House, and the Munroe and Crafts units of the East Campus Houses. As Faculty Residents they collaborate with students in social and intellectual activities and are ready with counsel and guidance when needed.

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

The Dormitory Council 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.

Rooms in the Institute Houses are assigned on the basis of application forms distributed to residents each spring and to entering freshmen and transfer students with their notices of admission. Rooms are engaged for the full academic year; and with exceptions as approved by the Dean of Residence, a student who is assigned quarters on application is responsible for the rent thereof for the academic year of assignment. Rates range from $150 to $235 per person per term. Rental assignments are automatically cancelled and a proportionate refund is allowed upon withdrawal of a student 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. 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. Dormitory rentals and fees for meals are to be paid to the Bursar in advance of the beginning of each term; details are given elsewhere in this Section of this Catalogue.

Further information about the Institute Houses and detailed instructions for application will be found in a special publication on "Residence at M.I.T.," copies of which are available from the Office of the Dean of Residence. The operating regulations in effect are summarized in Appendix B of this Catalogue.

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

Residences for Women Students. The M.I.T. Women's Dormitory at 120 Bay State Road in Boston, about 20 minutes' walk from the Institute, is an attractively furnished house for 17 girls—three upperclass women and the 14 resident first-year women admitted yearly. Residence here is required for first-year women students, except for those who may live in their family homes.

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

Bexley Hall, at 52 Massachusetts Avenue in Cambridge, is an apartment dormitory for upperclass women and a few women graduate students, totaling 33. The apartments, fully furnished and equipped except for bedding and draperies, are each arranged to accommodate two or three residents. A member of the faculty and his family are in residence in the Hall, and a number of Institute families have apartments in other sections of the building. Application for residence in Bexley Hall should be made through the Dean of Residence.

Fraternities. Recognized fraternities at the Massachusetts Institute of Technology include 28 chapters situated on private property in Cambridge, Boston, and Brookline. Fraternities participate in M.I.T. student government through the Interfraternity Conference, and each house has one or more members of the Institute faculty or alumni as advisers. Each has its own dining room, and each fraternity provides experience in community planning and living similar to that achieved in the Institute Houses. Further information may be obtained from the Interfraternity Conference, Walker Memorial, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

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

The Graduate House. The Graduate House, with a capacity of 452 residents, is reserved exclusively for male graduate students. It is located at Memorial Drive and Massachusetts Avenue, Cambridge, directly opposite 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 students of mature professional interests; there are lounges, a library, cafeteria, 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 Faculty Resident. A student House committee, acting with the advice and assistance of the Faculty Resident, 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.

As in the undergraduate Houses, application forms for rooms are distributed to residents each spring and to entering graduate students with their notifications of admission. 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.

Rooms are engaged for the full academic year. A proportionate refund is made to a student who cancels his 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.

Dining Services. Commons meals are served Monday through Friday in Institute dining rooms in Walker Memorial and Baker House. Residents of Baker House are required to partake of Commons there. Residents of the other undergraduate Houses and of the Graduate House may elect the Commons plan in Walker Memorial. Such election is for the full term in which it is made. The contract is automatically cancelled 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 rate for the academic year 1958–59 is $212.50 for the fall term; $200 for the spring term. A la carte service is available in Walker Memorial Monday through Friday and the Graduate House dining room seven days a week.

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

SYMPHONY ORCHESTRA

BRASS CHOIR

CHORAL SOCIETY

OUTING CLUB

DRAMASHOP

TECH SHOW

STUDENT PLACEMENT BUREAU

Institute Services

Among the important Institute services for students and visitors are:

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 for which they are particularly fitted and aids industry in selecting men for positions requiring engineering or scientific education.

Military and Selective Service Office. M.I.T. undergraduates who may be subject to selective service will find help in their dealings with their draft boards at the Institute's Military and Selective Service Office. Selective Service College Qualification Tests are given each year at M.I.T., and freshmen are advised to take these tests as soon as they are eligible. No other action is necessary by any student until he receives a classification questionnaire from his local board. Students must be registered for a full-time program during the academic year in order to qualify for deferment. Class 2-S deferments are recommended. The Graduate School Office provides similar assistance to graduate students, described in Section 3 of this Catalogue.

The Technology Press. The Technology Press is designed primarily to assist members of the M.I.T. faculty and staff with preparing and publishing books of intellectual importance or educational value. In recent years the Technology Press has broadened its interests to include the social sciences as well as science and engineering, and it now has a list of about 60 titles.

The Alumni Association. The M.I.T. Alumni Association provides a complete program for keeping 47,000 graduates and former students informed of M.I.T. affairs. Chief among its publications is *The Technology Review*, a monthly alumni magazine. There are nearly 100 regional M.I.T. clubs throughout the world, and the Alumni Fund ranks annually in the country's top half-dozen. Other alumni activities include Alumni Day, the Monday following Commencement; the Mid-Winter Meeting, about February 1 each year; class reunions between Commencement and Alumni Day; and day-long Regional Conferences in major cities.

The Information Office. Here, at the main entrance from Massachusetts Avenue (Room 7–111), are maps, catalogues, telephones, and information about how to reach various destinations at M.I.T.

The 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.

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

The Academic Community

The Massachusetts Institute of Technology is an academic community of broad interests. There are, of course, professional opportunities of the highest character; most departments have seminar series, and many of these attract foreign visitors as well as leading American scientists and engineers. These activities are supplemented by open lectures in many fields throughout the year.

The community also has many other interests—music, drama, art, hobbies, and other recreation—all at home on this many-sided and busy campus. Boston and its suberbs contribute richly to the facilities and experiences which await M.I.T. students. Boston today has as wide a spread of cultural interest as is to be found anywhere else in the United States outside of New York City.

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

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

Lecture Series Committee. The majority of lectures on general cultural subjects at M.I.T. are arranged by students under the auspices of the Lecture Series Committee. The Committee has its own budget and is responsible for the entire undertaking, with advice available from the Dean of the School of Humanities and Social Studies. Recent lecturers have included Mrs. Franklin D. Roosevelt, Harold E. Stassen, Commander Jacques-Yves Cousteau, Ogden Nash, and former President Harry S. Truman. In addition, the Committee sponsors a program of motion pictures of special interest.

The Humanities Series. Chamber music groups, concert soloists, and the Boston Symphony Orchestra 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.

The 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 three regular two-year courses in engineering fundamentals—mechanical, electrical, and structural or civil—and a number of supplementary single subjects. 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 39.

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

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

The Technology Dames. The wives of M.I.T. students—both undergraduate and graduate—and of members of the junior staff form the Technology Dames. A social organization, the group sponsors a variety of programs of interest to young women and publishes a monthly newsletter.

The Technology Matrons. The wives of members of the faculty and senior staff, the Technology Matrons meet monthly at general meetings, and there are a number of hobby and special-interest groups.

The Technology Community Association. With the help of a permanent staff, T.C.A. conducts a diversified program of service to the M.I.T. community. Work with Boston boys' clubs, a handbook for new arrivals on the campus, Tech House for weekend outings, and annual blood

donor and clothing drives are a few of the activities sponsored by the student members.

Music. M.I.T. is a musical community. In addition to the Humanities Series, there is a busy season of concerts and activities by many student groups, all of which are open to graduate as well as undergraduate students. The Combined Musical Clubs include a Glee Club, Choral Society, Symphony Orchestra, Concert Band, and a Woodwind and Brass Ensemble—all out-of-classroom activities which draw a large following among the musicians in the student body. These organizations give public concerts in Boston and the neighboring communities, frequently in combination with musical groups of other colleges. The Choral Society joins with members of the Boston Symphony Orchestra for two annual major concerts, and in 1956 it toured Germany for a three-week summer concert series; the Glee Club appears with the Boston Pops Orchestra in Symphony Hall; and the Concert Band plays a Sunday afternoon concert at the Hatch Memorial Shell on the Boston Esplanade.

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, four workshop productions of one-act plays directed and acted by students, and a Celebrity Series of lectures by prominent theatrical people. The M.I.T. Community Players, a group of graduate students and staff and their families, join to present under professional direction a number of plays each year. Tech Show is a musical comedy written and produced by students.

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

Publications. Student publications at M.I.T. include *The Tech*, semi-weekly newspaper; *Technique*, yearbook; *Tech Engineering News*, monthly magazine of engineering students; and *Voo Doo*, humor magazine. In addition, there are other less formal outlets for journalism talents in the newspapers of the Institute Houses and in departmental newsletters of many kinds. A special newspaper for graduate students is published by the Graduate Student Council.

Other Student Activities. There are more than 60 student activities and clubs at M.I.T., many of them open to both undergraduate and graduate students. Among the most active are the Outing Club, the Model Railroad Club (with its own railroad, the Tech Nickel Plate, on the campus), the Hobby Shop (complete facilities for woodworking, printing, photography, and other activities), the Debating Society, and the Radio Society.

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

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

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, adjacent to the chapel.

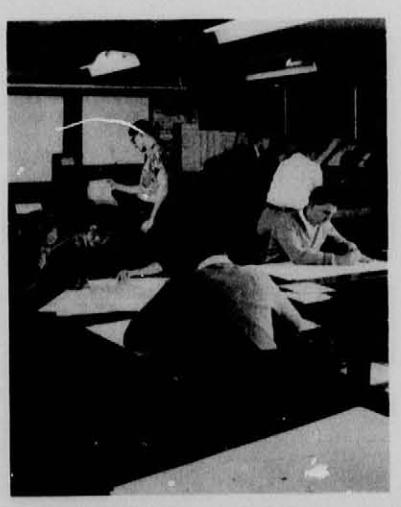
Students take an active part in the religious activities of many of the neighboring churches in Boston and Cambridge. In the last few years the new chapel has made it possible for the religious groups to center more of their activity, especially their services of worship, on the campus.

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.

Athletics. The purpose of athletics at the Institute is to encourage all students to participate in some form of physical recreation. No attempt is made to concentrate on coaching the few men composing a single varsity team. Instruction is given to all men reporting for a sport.

The wide diversity of the intercollegiate program last year provided 750 M.I.T. students with competition in 18 sports, while others joined intramural teams. These figures do not include sailing, by far the most popular recreational activity. More than 1300 members of the Nautical Association sail for recreation; intercollegiate dinghy racing originated at M.I.T. in 1936, and about 70 colleges from coast to coast have followed that lead.

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



The Schools, Departments, Courses, and Degrees

Though the Institute has a single faculty which meets and deliberates as a unit, its teaching is organized under five academic schools. Within these schools are 21 academic departments, most of which offer undergraduate and graduate instruction.

DEGREES AWARDED

Degrees are awarded on the basis of satisfactory completion of Courses. Curricula are prescribed by the departments under the supervision of the faculty. Undergraduate Courses 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.), Aeronautical Engineer (Aer.E.), Building Engineer (Bldg.E.), Chemical Engineer (Chem.E.), Civil Engineer (C.E.), Electrical Engineer (E.E.), Marine Mechanical Engineer (Mar.Mech.E.), Mechanical Engineer (Mech.E.), Metallurgical Engineer (Met.E.), Mineral Engineer (Min.E.), Naval Architect (Nav.Arch.), Naval Engineer (Nav.E.), Sanitary Engineer (San.E.), Doctor of Philosophy (Ph.D.), and Doctor of Science (Sc.D.).

The list on the opposite page shows schools, departments, and fields in which degrees are offered.[1]

[1] The Departments of Air Science, Military Science and Tactics, and Naval Science offer undergraduate instruction but have no school affiliation. The Courses in General Engineering and General Science, discontinued except for the Class of 1959, are under special administration.

School of Architecture and Planning

Department of Architecture
ARCHITECTURE

Department of City and Regional Planning
CITY PLANNING

School of Engineering

Department of Aeronautical Engineering
AERONAUTICAL ENGINEERING

Department of Chemical Engineering
CHEMICAL ENGINEERING
CHEMICAL ENGINEERING PRACTICE

Department of Civil and Sanitary Engineering
CIVIL ENGINEERING
BUILDING ENGINEERING AND CONSTRUCTION
SANITARY ENGINEERING

Department of Electrical Engineering
ELECTRICAL ENGINEERING
ELECTRICAL SCIENCE AND ENGINEERING

Department of Mechanical Engineering
MECHANICAL ENGINEERING
TEXTILE TECHNOLOGY

Department of Metallurgy
METALLURGY
CERAMICS
MINERAL ENGINEERING

Department of Naval Architecture and Marine Engineering
NAVAL ARCHITECTURE AND MARINE ENGINEERING
SHIPPING AND SHIPBUILDING MANAGEMENT
NAVAL CONSTRUCTION AND ENGINEERING

Department of Nuclear Engineering
NUCLEAR ENGINEERING

School of Humanities and Social Studies

Department of Economics and Social Science
ECONOMICS, POLITICS, AND ENGINEERING
ECONOMICS, POLITICS, AND SCIENCE
ECONOMICS AND ENGINEERING
ECONOMICS AND SCIENCE
INDUSTRIAL ECONOMICS
POLITICAL SCIENCE

Department of Humanities
HUMANITIES AND ENGINEERING
HUMANITIES AND SCIENCE
SCIENCE AND MATHEMATICS TEACHING

Department of Modern Languages

School of Industrial Management
INDUSTRIAL MANAGEMENT

School of Science

Department of Biology
QUANTITATIVE BIOLOGY
BIOLOGY
BIOCHEMISTRY
BIOPHYSICS

Department of Chemistry
CHEMISTRY

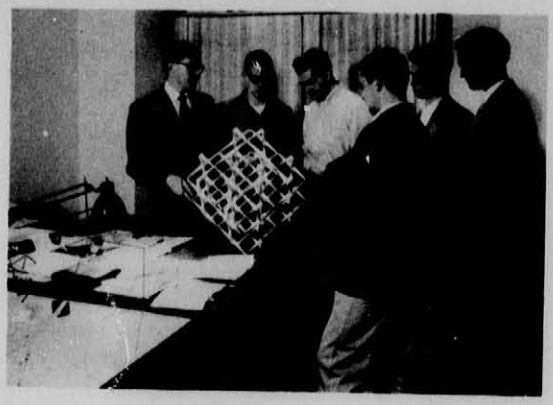
Department of Food Technology
FOOD TECHNOLOGY
BIOCHEMICAL ENGINEERING

Department of Geology and Geophysics
GEOLOGY AND GEOPHYSICS

Department of Mathematics
MATHEMATICS

Department of Meteorology
METEOROLOGY

Department of Physics
PHYSICS



General Regulations

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

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

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.

Registration Officers. Every student is assigned to a Registration Officer, a member of the faculty who serves as his academic adviser. Each student's program must be approved by his Registration Officer; changes may be made only with the Registration Officer's approval. First-year students have as their advisers faculty members of the Freshman Advisory Council.

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.

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

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 in writing of adequate evidence of sickness or other valid reason for the absence, the Dean of Students may permit a student whose term work has been satisfactory to take an ensuing examination on the subject.

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 inconsistent with general good order, wherever it may occur, is held to be 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.

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

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

Examinations for Advanced Standing. Registered undergraduate students of outstanding ability may take examinations for advanced standing during the condition 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.

Faculty-Student Relations. The faculty does not intend that Registration Officers 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 Students 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.

Health of Students

The Institute maintains a well-equipped Medical Department, centrally located in the Homberg Memorial Infirmary, a wing of M.I.T.'s main buildings. The dispensary on the ground floor has treatment rooms and special facilities for minor surgery, ophthalmology, otolaryngology,

dentistry, x-ray, and laboratory diagnosis. On the second and third floors are the offices of the psychiatrists, an infirmary of 21 beds and an operating room. 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 health insurance plan has been adopted by the Institute for all students. For a premium of $15 per term, the insurance company agrees with certain limitations to pay up to $1,500 toward meeting the cost of each illness or injury. Students adequately protected by other insurance or who, for other reasons, do not wish to be enrolled in this plan must sign a waiver before September 10 of the year concerned. This insurance is available for the summer months (from Commencement Day to the beginning of the fall term, wherever the student may be in residence) for an additional premium of $15, payable directly to the insurance company. Insurance is not required for Army, Navy, or Air Force students who are attending M.I.T. on military assignment or for veterans attending under Public Law 894. Insurance is not available to full-time employees of the Division of Sponsored Research who are taking one or more subjects.

Any student may receive routine medical care in the clinic without charge. If he is referred to one of the special clinics, a moderate fee is charged; in the case of an insured student, this is paid by the insuring agency. Psychiatric service —covered by health insurance through the twentieth visit—is charged for after the fifth interview in any one fiscal year.

Infirmary charges are low: food, nursing, and medical care in the wards cost $12 per day; the same service in a private room is furnished for $15 per day. For insured students the cost of these services is borne by the insuring agency. Fees at other Boston and Cambridge hospitals which may be used by students on recommendation of the Medical Department are the responsibility of the student; if he is insured, hospital fees up to $15 per day are paid by the insurance company.

Every entering student, undergraduate or graduate, is required to be immunized against tetanus and smallpox prior to matriculation. After registering, he is required to report to the Medical Department for a complete physical and dental examination and an x-ray of the chest within six weeks after matriculation. The initial x-ray will be made without charge before December 15 of each year, but after that date there will be a charge of $5. For students entering in the second term, there will no charge until after March 1. All other students are urged to have an x-ray of the chest every second year; this will be done without charge by the Medical Department.

No student is permitted to engage in intercollegiate or intramural athletics without having had a physical examination at some time during the academic year in which he participates.

Expenses: Fees, Deposits, and Payments

Tuition. The regular tuition for full-time undergraduate and graduate students in the first and second terms is $650 per term. Special tuition rates apply to the Summer Session; these are published each year in the Summer Session Catalogue, available about March 15.

The tuition fee for a student taking cooperative work in electrical engineering (Course VI-A) after the second year is $433 for each term, including the summer term, provided that he attends three consecutive terms in a twelve-month period and that one of these terms is at the industrial plant; otherwise, the regular term tuition of $650 is applicable.

Students in the Cooperative Courses in Mechanical Engineering (Course II-B) and Aeronautical Engineering (Course XVI-B) will pay the specified tuition fees for the subjects for which they register during the Summer Session they attend. They will also register and pay an $80 tuition fee for the six months' period they are at the plant.

For the School of Chemical Engineering Practice (Course X-A) or for the Engineering Practice School at Oak Ridge, for the period September through January or February through June, the tuition fee is $650. For a single field station of the School of Chemical Engineering Practice, the fee is $380.

Regular students (other than doctoral candidates) and special students[1] (including Division of Sponsored Research appointees) who take only a few subjects and who apply to the Bursar for a reduction will be charged at the rate of $20 per unit credit (minimum $80, maximum $650).

[1]A regular student is one who is enrolled as an applicant for an academic degree; others are special students (see the previous description in this Section).

The tuition fee for thesis research for the Doctor's degree, irrespective of the number of units, is $650 per regular term. The tuition fee for thesis research for the Master's or Engineer degree is $20 per unit credit in either regular term, with a minimum of $80 and a maximum of $650. Special students are not permitted to register for thesis.

The tuition fee for thesis presentation only is $80 for the Bachelor's, Master's, or Engineer degree and $125 for the Doctor's degree. Thesis presentation refers to those necessary academic events beginning with the actual delivery of the completed document.

No bills are sent. All payments are to be made to W.A. Hokanson, Bursar, Massachusetts Institute of Technology, Cambridge 39, Massachusetts, by the time specified in the registration instructions issued prior to the opening of each term. Many students choose to make their payments on an installment plan, arranged before the beginning of the term. This plan is described on the next page.

Tuition Refunds. Full-time students withdrawing during the first five weeks of the term will be charged $55 per week; for others, the charge will be proportionately adjusted. There will be no refund after the first five weeks of the term.

Dormitory Rentals and Meal Fees. 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 with him before the beginning of the term to make periodic payments, as with tuition fees. *No bills are sent.*

Other Fees. A charge of $10 is made for each condition or special examination and $10 for the completion of incomplete work. The premium for health insurance, which is required of all students who do not sign waivers (with certain exceptions—see Health of Students, above) is $15 per term.

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

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

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 (MS 21 and MS 22) or AIR SCIENCE (AS 21 and AS 22).
2. All undergraduate and graduate students taking subjects requiring the use of 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 school year except to students who leave the Institute.

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 academic registration*[1]	*Tuition per term*[2]
Full-time	18 units	$250
Half-time	30 units	390
Third-time	38 units	520

[1] If, *without interfering with staff duties*, a load somewhat greater than "normal" can be carried, the student's Graduate Registration Officer *may* permit registration by full-time staff up to 24 units, by half-time staff up to 36 units, and by third-time staff up to 48 units.

[2] 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 half-time) who has the opportunity to progress on thesis research at the rate of a full-time student shall pay the full tuition fee ($650 per regular term) and shall be permitted to register for a full academic load of 48 units. A full-time staff appointee who can progress on thesis research at the rate of a half-time student shall pay a tuition fee of $390 per regular term and shall be permitted to register for a maximum of 36 units. In intermediate cases, the tuition principle may normally be satisfied by an appropriate combination of full-time and half-time thesis research registration in successive terms. The increase in academic load above the range normal for the academic appointment is limited to thesis.

The fee for thesis presentation only is $80 for a Master's or Engineer degree and $125 for a Doctor's degree.

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.

Tuition for Members of the Staff in the Summer Session, beginning 1959. The Summer Session tuition for members of the staff (not Division of Sponsored Research) on academic appointment for the entire Summer Session is given below:

Tuition for regular subjects is the same as for all other students.

Tuition for thesis (normal academic registration) is as follows:

For the Bachelor's, Master's, or Engineer degree: $20 per unit credit, with the minimum $80; the maximum $125 if full-time appointment, $195 if half-time, and $260 if one-third-time.

Doctor's degree: $125 if full-time appointment, $195 if half-time, and $260 if one-third-time.

For thesis presentation only, with or without thesis examination, for the Bachelor's, Master's, or Engineer degree, $80; for the Doctor's degree, $125.

The maximum total tuition for members of the staff (not D.S.R.) is $200 if full-time appointment, $315 if half-time, and $415 if one-third-time.

Tuition for thesis (more than normal academic registration) is as follows:

For the Bachelor's, Master's, or Engineer degree: $20 per unit credit, with the maximum $325 if registration is at the rate of a full-time student, $220 if half-time student.

For Doctor's degree, $325 if at the rate of a full-time student, $220 if half-time student.

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

Installment Payment of Fees

A student or his parents may arrange with the Bursar, by mail or in person, to pay fees in eight installments during the academic year. This arrangement may include all or part of the total charges incurred by the student. No interest or carrying charge will be 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 1958–59 fees is as follows:

Fees		*Payments*	
Tuition	$1,300.00	Sept. 17, 1958	$ 270.00
Average dormitory		Oct. 15, 1958	270.00
rent	370.00	Nov. 17, 1958	270.00
Commons meals	412.50	Dec. 15, 1958	270.00
Health insurance	30.00	Feb. 4, 1959	270.00
Laboratory and/or		March 2, 1959	270.00
military equip-		April 1, 1959	270.00
ment deposit	50.00	May 1, 1959	272.50[1]
	$2,162.50		$2,162.50

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

On November 1 and March 2 a statement will be rendered by the Bursar to either the parent or student, as previously requested, detailing actual charges and payments to date. A final statement will be rendered in June.

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

Financial Aids

M.I.T. has a broad program of financial assistance for both undergraduate and graduate students. Three types of financial aid—scholarships, loans, and part-time campus work—are available to undergraduates; these are described in detail in Section 2 of this Catalogue. For graduate students there are scholarships, fellowships, loans, and a number of teaching and research appointments, all described in detail in Section 3. Scholarships, fellowships, and loan funds are listed in Appendix A.

[1]The final payment would be adjusted for the actual charges during the year against the $50 laboratory and/or military equipment deposit.

UNDERGRADUATE EDUCATION 2.

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

Four elements are combined in a typical undergraduate program at M.I.T. The basic subjects are mathematics, physics, and chemistry; on their mastery depends the power to attack with confidence the most difficult technical problems of the engineering and scientific professions. These are followed by the fundamental or elementary professional subjects, which deepen understanding of the basic sciences and mathematics by using their principles in the field which each student has personally chosen. Third, an integrated program of studies in the humanities extends through the four 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. Advanced professional subjects come in the third and fourth (and, in some cases, fifth) years; they develop special competence and lay the foundation for future growth in specialized assignments.

The Institute believes that this four-year pattern is a fitting design for modern education, excellent for those who will follow the professions of architecture, engineering, science, economics, or industrial management, and offering moreover a sound foundation for those who may be destined for careers partly or wholly unrelated.

Courses of Study

An undergraduate at M.I.T. may choose his major field of study from among 31 Courses.[1] To complete work for a Bachelor's degree in any Course, he is required to 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.

Roman numerals are used to designate the Courses of study; individual subjects are numbered in Arabic numerals according to the department under which the instruction is given. Thus the Course in Metallurgy is designated as Course III, and the number 3.11 indicates a subject given by the Department of Metallurgy.

Four departments which do not have Courses of study do offer subjects: Air Science, Modern Languages, Military Science and Tactics, and Naval Science.

The Departments of City and Regional Planning and of Nuclear Engineering offer graduate degrees only. Information about undergraduate preparation for advanced work in these fields is given in the departmental description elsewhere in this Catalogue.

The program for the Bachelor of Science degree requires in each case four years of study; Architecture (Course IV-A) requires five years for the degree of Bachelor in Architecture. The following Courses require five years of study and lead to Bachelor's and Master's degrees, awarded simultaneously: the Cooperative Course in Electrical Engineering (Course VI-A); Electrical Science and Engineering (Course VI-B); Geology and Geophysics, Five-Year Plan (Course XII-A); and Shipping and Shipbuilding Management (Course XIII-B). Science and Mathematics Teaching (Course XXI-C) leads in five years to the degrees of Bachelor of Science from M.I.T. and Master of Arts in Teaching from Harvard University.

In addition to the prescribed curricula given during the regular academic year, certain Courses require instruction during a summer period, as indicated in their undergraduate schedules.

[1]M.I.T. makes a clear distinction between the words *Course* and *subject*. At the Institute, *Course* refers to an organized curriculum—sequence of studies—approved by the faculty as leading to a specified degree. *Subjects* are the individual classes.

The following list of undergraduate Courses shows the Roman numerals assigned to each and the degree(s) to which each leads.

School of Architecture and Planning
ARCHITECTURE, IV-A, B. Arch.

School of Engineering
Department of Aeronautical Engineering
AERONAUTICAL ENGINEERING, XVI, S.B.
COOPERATIVE COURSE IN AERONAUTICAL ENGINEERING Course XVI-B, S.B.
Department of Chemical Engineering
CHEMICAL ENGINEERING, X, S.B.
CHEMICAL ENGINEERING PRACTICE, X-B, S.B.
Department of Civil Engineering
CIVIL ENGINEERING, I, S.B.
Department of Electrical Engineering
ELECTRICAL ENGINEERING, VI, S.B.
COOPERATIVE COURSE IN ELECTRICAL ENGINEERING, VI-A, S.B.—S.M.
ELECTRICAL SCIENCE AND ENGINEERING, VI-B, S.B.—S.M.
Department of Mechanical Engineering
MECHANICAL ENGINEERING, II, S.B.
COOPERATIVE COURSE IN MECHANICAL ENGINEERING, II-B, S.B.
Department of Metallurgy
METALLURGY, III, S.B.
Department of Naval Architecture and Marine Engineering
NAVAL ARCHITECTURE AND MARINE ENGINEERING, XIII, S.B.
SHIPPING AND SHIPBUILDING MANAGEMENT, XIII-B, S.B.—S.M.
Under special administration
GENERAL ENGINEERING, IX-B, S.B.[1]

School of Humanities and Social Studies
Department of Economics and Social Science
ECONOMICS, POLITICS, AND ENGINEERING, XIV-A, S.B.
ECONOMICS, POLITICS, AND SCIENCE, XIV-B, S.B.
Department of Humanities
HUMANITIES AND ENGINEERING, XXI-A, S.B.
HUMANITIES AND SCIENCE, XXI-B, S.B.
SCIENCE AND MATHEMATICS TEACHING, XXI-C, S.B. (M.I.T.) and A.M.T. (Harvard University)

School of Industrial Management
INDUSTRIAL MANAGEMENT, XV, S.B.

School of Science
Department of Biology
QUANTITATIVE BIOLOGY, VII, S.B.
Department of Chemistry
CHEMISTRY, V, S.B.
Department of Food Technology
FOOD TECHNOLOGY, XX, S.B.
BIOCHEMICAL ENGINEERING, XX-B, S.B.
Department of Geology and Geophysics
GEOLOGY AND GEOPHYSICS, XII, S.B.
GEOLOGY AND GEOPHYSICS, XII-A, S.B.—S.M.
Department of Mathematics
MATHEMATICS, XVIII, S.B.
Department of Meteorology
METEOROLOGY, XIX, S.B.[1]
Department of Physics
PHYSICS, VIII, S.B.
Under special administration
GENERAL SCIENCE, IX-A, S.B.[1]

[1]Discontinued except for the Class of 1959.

Selection and Change of Course. In their first year at M.I.T., students take basic subjects which are in general common to the background of all educated people today, with an emphasis on science and mathematics heavier than is usual in university curricula. During this year each student has the opportunity to strengthen his interests, judge his abilities, and choose a Course of study which satisfies both. He is expected to talk with his instructors and adviser about his potentialities and about opportunities in fields with which he may not be familiar; he is further encouraged to attend departmental orientation programs, to visit plants, and to talk with people who have experience in the fields which interest him.

Although students are asked to indicate a tentative choice of major field in their applications for admission, this choice does not affect their programs of study until after the first year. Admission to a Course at the beginning of the second year and continuation in it thereafter depends on the staff and facilities available; the choice made at the beginning of the second year is considered definite and may be changed only with the permission of the departments concerned, and the Registrar should be notified of any such change. The similarities between Courses in the second and third years are greater than their differences, and it is then often possible to change Courses with few if any unsatisfied requirements to be made up.

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

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

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 in outside preparation. Each subject is listed with two credit numbers, the first representing classroom and laboratory time, the second preparation time. The normal student schedule requires a total of 45 to 50 hours per week spent on studies. Accordingly, a student who takes a 45-hour schedule for one 15-week term is registered for 45 units credit, one unit being equivalent to 15 hours of work. The division of class time between lecture (or recitation) and laboratory (or drawing) is shown in the Tabulation 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 which is approved by his department and which satisfies both the general Institute requirements established by the faculty of the Institute and the specific departmental requirements established by the department.

Two requirements included in the foregoing statement are the physical education requirement, described in the following paragraph, and the humanities requirement, described elsewhere in this Section.

Physical Education Requirement. The Institute expects each student to gain experience in recreational athletics during his first two years at M.I.T.; by the end of this period he must have compiled at least 8 points of athletic credit. These points may be acquired by participating in a physical education class (2 points) or by membership on one of the 18 intercollegiate freshman or varsity teams (2 points for fall or spring sports, 4 points for winter sports).

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

Although there are no specific requirements for women students, they are encouraged to participate in the class and intercollegiate programs suited to their abilities and interests.

Undergraduate Thesis. The ability of each student to perform original research is considered an important feature of his degree requirements, and theses are included in all undergraduate curricula.

Costs

The Institute is an independent, endowed institution; the tuition of $1300 per year paid by each student covers less than half the cost of facilities and teaching; the balance is met by income from endowment and by gifts.

Basic Expenses. The following list gives an estimate of the average student's basic costs for the academic year 1958–59 at M.I.T.:

Tuition	$1,300
Board	650
Room	370
Books and materials	100
Health insurance	30
	$2,450

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

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

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

Financial Aid for Undergraduates

Financial aid is available to M.I.T. undergraduates in three forms: scholarships, loans, and part-time campus work. These 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.

All incoming and undergraduate students may apply for scholarship aid. Except for those students who enter under a two-degree plan, students who have attended another college are not eligible for scholarship aid until they have satisfactorily completed one year's work. 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 sustantial number of scholarship grants (full and part tuition), as well as awards from the M.I.T. loan funds, for the freshman year. Approximately one quarter of the entering class receives some aid from this source, which includes several four-year grants based on demonstrated need sponsored by several corporations, foundations, and industrial organizations; among these are the Alfred P. Sloan and the Alumni Fund National Scholarships. Applications for any freshman grant must be filed before February 15. (See Appendix A for complete details.)

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

The Technology Loan Fund is also available to students with satisfactory academic records after one year of residence. Awards from this fund, made on application to the Student Financial Aid Committee, are in addition to any scholarship grants and may reach full tuition for any one year, with a maximum of $5,000 for undergraduate study. Loans bear interest at one per cent during enrollment and two per cent thereafter. They are repayable at the rate of $150 every six months after graduation. Complete details are given in Appendix A.

Student Employment. The Office of Student Personnel is maintained to help students who wish to help themselves meet part of their expenses by earnings in on-the-campus jobs. The requirements of the Institute curriculum are such that only a limited amount of time may be given to employment, and prospective students are advised to have sufficient funds to cover the expenses of the first year at least. The average that can be earned through part-time employment does not usually exceed $150 per term. This amount may be realized in a number of jobs on the campus, such as those in the dining services, the library, and residence halls. Some outside jobs are available in Boston and Cambridge, but these are likely to be limited by the difficulty in scheduling them without conflict with academic appointments.

The Undergraduate Program in Humanities and Social Sciences

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

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

In his first two years each student takes a series of four subjects: FOUNDATIONS OF WESTERN CIVILIZATION (21.01, 21.02) and THE UNITED STATES: MEN AND ISSUES OF MODERN WESTERN IDEAS AND VALUES (21.03, 21.04). Through intensive work with original texts he is given training in critical reading, a sampling of the liberal disciplines—notably history, philosophy, and literature—and a foundation for more advanced study in these and related fields. Frequent written exercises, with criticism from his instructors in scheduled conferences, give him an opportunity to improve his writing ability. Students with insufficient training or other language handicaps are urged to take advantage of small-group remedial instruction; for those who are seriously deficient such instruction is required.

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

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

The humanities field is selected on a basis of particular interest, except that students enrolled in Shipping and Shipbuilding Management (COURSE XIII-B) or in Industrial Management (COURSE XV) may not select either Economics or Labor Relations, and those in Architecture (COURSE IV-A) may not select Visual Arts. Students in the School of Humanities and Social Studies are exempted from these requirements.

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

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

IN THE MAP ROOM.

CHARLES MUNCH AND THE BOSTON SYMPHONY ORCHESTRA IN THE HUMANITIES SERIES.

ANDRÉ MARCHAL, ORGANIST, IN KRESGE AUDITORIUM.

MRS. ELEANOR ROOSEVELT, SPONSORED BY THE LECTURE SERIES COMMITTEE.

PROFESSOR ERNST LEVY, FACULTY RESIDENT.

SENIOR SEMINAR IN INTERNATIONAL POLITICS.

HIGH-POWERED RADAR DEVELOPED BY LINCOLN LABORATORY

HUMANITIES FIELDS AND SUBJECTS

FIRST YEAR

First Term: FOUNDATIONS OF WESTERN CIVILIZATION (21.01)
Second Term: FOUNDATIONS OF WESTERN CIVILIZATION (21.02)

SECOND YEAR

First Term: HUMANITIES (21.03)—THE UNITED STATES: MEN AND ISSUES OF MODERN WESTERN IDEAS AND VALUES
Second Term: HUMANITIES (21.04)—THE UNITED STATES: MEN AND ISSUES OF MODERN WESTERN IDEAS AND VALUES

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

HISTORY AND THE HISTORIAN (21.41)†
plus any two of the following:
POLITICAL PROCESS IN INDUSTRIAL AMERICA (21.42)†
GROWTH OF THE AMERICAN INDUSTRIAL ECONOMY (21.43)†
THE CHANGING ROLE OF THE INDUSTRIAL LEADER (21.44)†
AMERICAN FOREIGN POLICY IN ACTION (21.45)†
RELIGIOUS THOUGHT AND AMERICAN SOCIETY (21.46)†
TECHNOLOGY AND ECONOMIC GROWTH (21.48)†
EUROPE—THE EXPANSION OF EUROPE (21.51)†
MODERN EUROPE—WAR, SOCIETY AND THE STATE (21.52)†
THE RUSSIAN REVOLUTION AND THE SOVIET UNION (21.54)†
HISTORY OF ENGINEERING (21.55)†
HISTORY OF ENGINEERING (21.56)†
ART AND INDUSTRIAL CIVILIZATION (21.58)†
SPECIAL TOPICS IN HISTORY (21.591)
SPECIAL TOPICS IN HISTORY (21.592)

FIELD TWO: PHILOSOPHY

Any three subjects:
PHILOSOPHIC PROBLEMS AND SYSTEMS (21.61)†
PHILOSOPHIC PROBLEMS AND SYSTEMS (21.62)
CLASSICAL PHILOSOPHY (21.65)†
MAJOR RELIGIONS OF THE WEST (21.66)†
PHILOSOPHIES AND RELIGIONS OF THE EAST (21.67)†
PROBLEMS IN CONTEMPORARY PHILOSOPHY (21.69)†
PHILOSOPHY OF HISTORY (21.71)
METAPHYSICS (21.72)†
NATURE OF MAN (21.73)†
PHILOSOPHY IN LITERATURE (21.74)
ETHICAL THEORY (21.75)
SYMBOLIC LOGIC (21.76)†
SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS (21.81)†
SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT (21.82)
PHILOSOPHY OF SCIENCE (21.83)
TOPICS IN THE HISTORY AND PHILOSOPHY OF SCIENCE (21.84)
SPECIAL TOPICS IN PHILOSOPHY (21.891)
SPECIAL TOPICS IN PHILOSOPHY (21.892)

FIELD THREE: LITERATURE

INTRODUCTION TO LITERATURE (21.11)†
plus any two of the following:
THE EPIC (21.13)
COMEDY IN THE THEATRE (21.15)
TRAGEDY AND MODERN DRAMA (21.16)
SHAKESPEARE (21.17)
NON-WESTERN LITERATURE (21.18)
MAJOR BRITISH AND CONTINENTAL WRITERS OF THE 19TH AND EARLY 20TH CENTURIES (21.19)
THE BIBLE (21.20)
DOSTOEVSKY, TOLSTOI AND MODERN RUSSIAN LITERATURE (21.21)
THE NATURE OF POETRY (21.22)
THE COMIC SENSIBILITY (21.24)
THE MODERN NOVEL (21.25)
MAJOR WRITERS OF THE ENGLISH RENAISSANCE (21.26)
AMERICAN FOLKLORE (21.31)
NINETEENTH-CENTURY AMERICAN LITERATURE (21.33)
TWENTIETH-CENTURY AMERICAN LITERATURE (21.34)
SPECIAL TOPICS IN LITERATURE (21.391)
SPECIAL TOPICS IN LITERATURE (21.392)
LANGUAGE AND SOCIETY (L.75)
LINGUISTIC STRUCTURE (L.78)

FIELD FOUR: MODERN LANGUAGES

Group A—German:

INTERMEDIATE GERMAN (L14)
or
INTRODUCTION TO LITERATURE (21.11)†
plus any two of the following:
GERMAN LITERATURE 1919–1933 (L15)†
LITERATURE OF POSTWAR GERMANY (L16)†
GREAT BOOKS AND AUTHORS IN GERMAN LITERATURE (L20)†

Group B—French:

INTERMEDIATE FRENCH (L54)
or
INTRODUCTION TO LITERATURE (21.11)†
plus any two of the following:
CONTEMPORARY FRENCH LITERATURE (L55)†
FRENCH LITERATURE OF THE THIRD REPUBLIC (L56)†
GREAT BOOKS AND AUTHORS IN FRENCH LITERATURE (L59)†

Group C—Study of Languages:

LANGUAGE AND SOCIETY (L75)†
and
PROBLEMS OF PHONOLOGY (L76)
and
LINGUISTIC STRUCTURE (L78)

FIELD FIVE: MUSIC

INTRODUCTION TO MUSIC (21.91)†
and
WESTERN MUSIC FROM THE MIDDLE AGES TO THE PRESENT (21.92)
plus one of the following:
TWENTIETH CENTURY MUSIC (21.94)
THE OPERA (21.95)
THE STRING QUARTETS OF BEETHOVEN (21.96)
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
ECONOMIC PROBLEMS SEMINAR (14.09)
or
PRICES AND PRODUCTION (14.03)
or
INDUSTRIAL ORGANIZATION AND PUBLIC POLICY (14.04)
or
ECONOMICS OF INVENTION (14.21)
or
MONEY AND INCOME (14.40)
or
PUBLIC FINANCE (14.43)
or
INTERNATIONAL TRADE (14.54)

FIELD SEVEN: POLITICAL SCIENCE

Any three subjects in one of the following groups, or approved combinations of groups:

Group A:

ECONOMIC PRINCIPLES I (14.01)†
THE AMERICAN POLITICAL PROCESS (14.91)†
COMPARATIVE POLITICAL AND ECONOMIC SYSTEMS (14.92)†
SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS (14.93)
GOVERNMENT, POLITICS, AND TECHNOLOGY (14.94)

Group B:

PERSONALITY AND SOCIAL STRUCTURE (14.71)
POLITICS, SOCIETY, AND POLICY MAKING (14.95)
INFLUENCES ON POLICY DECISIONS (14.96)

Group C:

INTERNATIONAL RELATIONS (14.51)†
PRINCIPLES AND PROBLEMS OF AMERICAN DIPLOMACY (14.52)
SEMINAR IN INTERNATIONAL POLITICS (14.53)

Group D:

BASIC IDEAS OF WESTERN POLITICS AND ETHICS, 500 B.C.—1500 A.D. (14.55)
RISE OF MODERN POLITICAL AND SOCIAL SCIENCE, 1500–1914 (14.56)
CONTEMPORARY IDEAS ON POLITICAL AND ECONOMIC DEVELOPMENT (14.57)
NATIONALISM AND NATIONAL DEVELOPMENT (14.58)

FIELD EIGHT: LABOR RELATIONS

ECONOMIC PRINCIPLES I (14.01)†
or
ORGANIZATION AND COMMUNICATION IN GROUPS (14.73)†
or
PERSONALITY AND SOCIAL STRUCTURE (14.71)
and
LABOR RELATIONS (14.63)†
and
LABOR ECONOMICS AND PUBLIC POLICY (14.64)

FIELD NINE: PSYCHOLOGY

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

Group A:

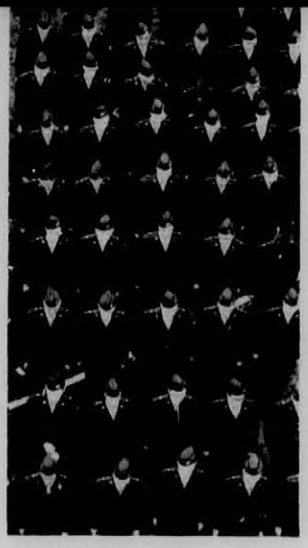
PSYCHOLOGY OF LANGUAGE AND COMMUNICATION (14.77)
LEARNING (14.79)
PSYCHOLOGY OF PERCEPTION (14.81)
PSYCHOLOGY OF MOTIVATION (14.82)

Group B:

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

FIELD TEN: VISUAL ARTS

Any three of the following:
VISUAL DESIGN PROBLEMS (4.031)†
VISUAL DESIGN PROJECTS (4.032)
INTRODUCTION TO ART AND ARCHITECTURE (4.65)†
MODERN ART AND ARCHITECTURE (4.66)†



Military Science, Air Science, and Naval Science

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

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

THE ARMY R.O.T.C. PROGRAM

The Army R.O.T.C. program at M.I.T. has been established to qualify graduates for commissions as reserve or regular officers in the United States Army in the five following technical branches: Corps of Engineers, Signal Corps, Ordnance Corps, Chemical Corps, and Quartermaster Corps. The program is divided into two parts, the Basic Course and the Advanced Course.

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. The Basic Course subjects have two hours of recitation and one hour of drill per week (2-1-0). There is no required outside preparation. 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 elective credit required during the first two years, as specified under the "First Year" of each school.

Advanced Course. Study in the tactics and techniques of the Corps of Engineers, Signal Corps, Ordnance Corps, Chemical Corps, and Quartermaster Corps is given in the Advanced Course. The objective of this program is to qualify students for commissions in the reserve or regular components of one of these technical branches of the Army. Credit for the Basic Course is a prerequisite for admission into the Advanced Course. Students in the Advanced Course must complete 12 semester hours of subjects from the list on the next page, according to the branch in which they are enrolled. The programs of Military Science subjects required in the five technical branches are as follows:

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

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

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

A student who enrolls in the Advanced Course must sign a deferment agreement and a contract to remain in the Course for two years; both agreement and contract will be cancelled 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.

For those students enrolled in the Advanced Course, M.I.T. receives from the government an allowance of $100 per student, which is applied against the cost of the student's uniform. 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.

ARMY R.O.T.C. ELECTIVE SUBJECTS

Subject name and number		Semester hours	Corps of Engineers	Signal Corps	Ordnance Corps	Chemical Corps	Quartermaster Corps
STATICS AND DYNAMICS	1.40	3	•				
FLUID MECHANICS	1.611	3	•			•	
APPLIED MECHANICS II	2.002	3	•	•	•	•	•
or							
STRENGTH OF MATERIALS	2.04	3	•	•	•	•	•
STRENGTH OF MATERIALS	2.081	3	•	•	•	•	•
HEAT ENGINEERING	2.42	3	•	•	•	•	•
or							
HEAT ENGINEERING	2.421	3	•	•	•	•	•
MACHINE DESIGN	2.731	3.5	•	•	•	•	•
INTERNAL COMBUSTION ENGINES	2.791	3	•	•	•	•	•
INTERNAL COMBUSTION ENGINES	2.792	3	•	•	•	•	•
‡INTRODUCTION TO MACHINE TOOLS	2.85	2	•	•	•	•	•
or							
MACHINE TOOL LABORATORY	2.851	2	•	•	•	•	•
ENGINEERING MATERIALS	3.11	5	•	•	•	•	•
PHYSICAL METALLURGY I	3.31	5.5	•	•	•	•	•
ORGANIC CHEMISTRY I	5.41	4	•		•	•	•
ORGANIC CHEMISTRY II	5.42	4	•		•	•	•
PHYSICAL CHEMISTRY I	5.61	4	•	•	•	•	•
PHYSICAL CHEMISTRY II	5.62	4	•	•	•	•	•
ELECTRON DEVICES AND CIRCUITS	6.02	5.5	•	•	•	•	•
FUNDAMENTALS OF ELECTRICAL ENGINEERING	6.18	3.5	•	•	•	•	•
GENERAL BIOLOGY I	7.01	3				•	•
and							
GENERAL BIOLOGY LABORATORY I	7.011	1.5				•	•
GENERAL BIOLOGY II	7.02	3				•	•
and							
GENERAL BIOLOGY LABORATORY II	7.021	1.5				•	•
BIOCHEMISTRY OF MICROORGANISMS	7.831	5	•			•	•
PHYSICS	8.04	4.5	•	•	•	•	•
PHYSICS OF ATOMS, MOLECULES, AND NUCLEI I	8.05	4	•	•	•	•	•
STATISTICAL MECHANICS AND THERMODYNAMICS	8.07	4	•	•	•	•	•
ELECTRONICS	8.08	4	•	•	•	•	•
INDUSTRIAL CHEMISTRY	10.18	3			•	•	•
CHEMICAL ENGINEERING THERMODYNAMICS	10.28	4	•		•	•	•
MINERALOGY I	12.011	5	•			•	•
PHYSICAL GEOLOGY	12.301	5					•
ENGINEERING GEOLOGY	12.321	3	•				•
PETROLEUM GEOLOGY	12.44	3					•
INTERNATIONAL RELATIONS	14.51	3	•	•	•	•	•
PRINCIPLES AND PROBLEMS IN AMERICAN DIPLOMACY	14.52	3	•	•	•	•	•
LABOR RELATIONS	14.63	3	•	•	•	•	•
INTRODUCTORY PSYCHOLOGY	14.70	3	•	•	•	•	•
ORGANIZATION AND COMMUNICATION IN GROUPS	14.73	3	•	•	•	•	•
COMPARATIVE POLITICAL AND ECONOMIC SYSTEMS	14.92	3	•	•	•	•	•
INTRODUCTION TO INDUSTRIAL MANAGEMENT	15.11	3	•	•	•	•	•
PERSONNEL ADMINISTRATION	15.30	3	•	•	•	•	•
BUSINESS LAW	15.61	3	•	•	•	•	•
PRODUCTION MANAGEMENT	15.71	3	•	•	•	•	•
STRUCTURAL ANALYSIS	16.21	4	•		•		
AIRCRAFT PROPULSION	16.53	3			•		
DESCRIPTIVE METEOROLOGY	19.02	3		•		•	
METEOROLOGICAL OBSERVATIONS	19.21	2.5		•		•	
ANALYSIS	M 831	3			•		
ANALYSIS	M 832	3			•		

‡Discontinued 1958-59.

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

The Air Force course of study is divided into a Basic Course, in the first and second years, and an Advanced Course, during the junior and senior years and the intervening summer. Successful completion of the Advanced Course qualifies a cadet for appointment as a commissioned officer in the United States Air Force. The cadet is furnished with all necessary textbooks and uniforms for both programs.

The two-year Basic Course is planned to give a fundamental understanding of air power and its implications in the world. All students completing the Basic Course will earn twelve units of elective credit required during the first two years, as specified under the "First Year" of each school.

The Advanced Course provides instruction designed to develop each cadet's officer potential. Close attention is given to his ability to communicate, to think clearly, and to deal with people; at the same time, the work develops his knowledge and understanding of global concepts and Air Force operational principles. The Advanced Course involves approximately 45 hours of instruction each semester; in addition, a four-week summer training period is required, normally between the junior and senior year.

Elsewhere in this Catalogue are more complete descriptions of subjects in both the Basic and Advanced Courses. The curriculum also includes many features to stimulate the cadet's interest in the Air Force and to help him develop the qualities of a good officer: orientation flights, visits to Air Force bases, social activities, interdetachment competitions, and guidance sessions are all part of the program. Students have many opportunities to apply principles of leadership, management, and staff work in actual working situations.

Because the Air Force can select only the most qualified individuals for appointment as commissioned officers, enrollment in the Advanced Course is highly selective. The Basic Course, therefore, gives each cadet an opportunity to decide whether or not he should apply for the Advanced Course, and in turn it gives the Air Force time to make a realistic evaluation of each cadet.

Cadets in the Advanced Course receive subsistence at the rate of 90 cents per day, vacations included, during their junior and senior years, except during summer training, when they receive $78 per month. At the beginning of the Advanced Course each cadet must sign a contract to remain in the program for the two years and to accept a commission as a second lieutenant in the United States Air Force upon completion of his studies. He must also sign a draft deferment agreement.

Throughout the Air Force R.O.T.C. course of study, cadets follow an educational program complementary to the Institute's. While this material is specifically intended to prepare students for careers as Air Force officers, much of it will be useful to them in civilian occupations.

THE NAVAL R.O.T.C. PROGRAM

The purpose of the Naval R.O.T.C. program is to provide instruction and training in essential naval science subjects, which, when coupled with the prescribed M.I.T. engineering curricula, will qualify selected male students for commissions as Naval Reserve Officers in the restricted line category (engineering duty only). Students are enrolled in the program at the beginning of the first term of their freshman year as civilians under contract to the Navy.

The program of instruction and training consists of four undergraduate years of classroom and laboratory work, drill, and one summer period of approximately six weeks 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, and ordered to active duty in an engineering duty billet either afloat or ashore for a period of two years. At the end of this two-year period he may be released to inactive duty, but he must retain his commission as a Reserve Officer for a total period of six years from the date of its original acceptance. In special cases, active duty may be postponed for graduate study leading to a Master of Science degree.

Eligibility Requirements. To be eligible for the Naval R.O.T.C. program, a student must meet these requirements:

1. 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. Plan 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), Quantitative Biology (VII), Chemical Engineering Practice (X-B), Geology and Geophysics (XII and XII-A), Economics, Politics, and Engineering or Science (XIV-A and XIV-B), Cooperative Course in Aeronautical Engineering (XVI-B), Food Technology (XX), Biochemical Engineering (XX-B), and Science and Mathematics Teaching (XXI-C).
6. Willing to sign a contract with the Navy which obligates the student, after completing the requirements for a commission, to fulfill the following additional requirements: to accept a commission, to serve on active duty for a period of two years subsequent to graduation, and to retain the commission for a period of six years from the date of original acceptance.

The Four-Year Program. Students in the Naval R.O.T.C. program must, while completing degree requirements in one of the Courses specified above, take the required subjects in Naval Science (omitting certain subjects in the M.I.T. Course schedules) as indicated here:

FIRST YEAR
First Term
NS 11 ORIENTATION AND SEA POWER (4–5)
(omit elective subject (6).)
Second Term
NS 12 ORIENTATION AND SEA POWER (4–5)
(omit elective subject (6).)

SECOND YEAR
First Term
NS 21 NAVAL GUIDED MISSILES (1–0)
Second Term
NS 22 NAVAL GUIDED MISSILES (1–0)

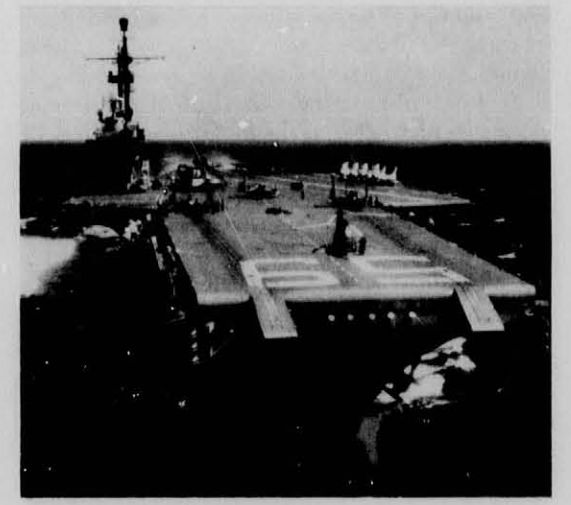
THIRD YEAR
First Term
NS 31 NAVAL NUCLEAR PROPULSION (1–0)
Second Term
NS 32 NAVAL NUCLEAR PROPULSION (1–0)

FOURTH YEAR
First Term
NS41 NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP (4–5)
(omit one elective subject (9).)
Second Term
NS42 NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP (4–5)
(omit one elective subject (9).)

Application Procedure. Eligible students should apply for admission to the Naval R.O.T.C. program only after they have been notified of their admission to the Institute. Applications may then be made directly to the Commanding Officer of the Naval R.O.T.C. Unit, either by mail or by personal visit not later than two weeks prior to the beginning of Freshman Week.

It should be noted that the Naval R.O.T.C. program at M.I.T. is open *only* to qualified male students definitely accepted for admission to M.I.T. at the freshman undergraduate level; it is *not* open to students selected under the nation-wide Navy scholarship program known as the Regular N.R.O.T.C. or Holloway Plan. Further inquiries regarding the M.I.T. Naval R.O.T.C. program should be addressed to the Commanding Officer.

Selection Procedure. Selections from among eligible applicants are made by the Commanding Officer of the Naval R.O.T.C. Unit, after considering and evaluating the following factors: adequacy of secondary school training, past academic record, record of past achievements in scientific pursuits, evidence of leadership capabilities and personal motivation, and predicted academic and scientific capabilities. Enrollment is normally limited to 40 students each year. Students who have been selected are notified by letter prior to Registration Day.



Undergraduate Admission to M.I.T.

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

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

ADMISSION FROM SECONDARY SCHOOLS

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

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

Choice of Course. Each candidate is requested to indicate his tentative choice of professional Course at the time of filing his application. After admission, he may reconsider his choice; and he has the option of changing at any time during the first year and in many cases at later dates as well.

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 to 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. A candidate's training in English should enable him to read with intelligence and sensitivity and to express his ideas clearly in oral and written form. In mathematics, emphasis should be on thorough mastery of fundamental principles, operations, and definitions rather than on covering a wide range of topics.

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

English (3)
Algebra (2)
Plane Geometry (1)
Physics (1)
Trigonometry ($\frac{1}{2}$)

English is normally studied through four years, and this is counted as three units. In some states, algebra is completed in $1\frac{1}{2}$ 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 mostly devoted to plane geometry but which includes some work in analytic geometry, solid geometry, or other fields, as suggested by the Commission on Mathematics of the College Entrance Examination Board. The inclusion of some topics from solid geometry is particularly recommended.

In addition to the above subjects specifically required, the applicant must also have completed $7\frac{1}{2}$ additional units, or their equivalent, in secondary school studies; no limitations are imposed in the choice of these elective subjects. In the selection of the entering class the Committee will be guided by the quality of the applicant's work and by his apparent promise on grounds of intellect and character, rather than by his choice of electives.

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

While there is no requirement of language for admission, the study of modern foreign languages in secondary school is obviously desirable and is recommended. No limitations are imposed with regard to languages, except that if a language is offered at all it must total at least two units. 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, should naturally study the appropriate language. Those who look forward to advanced work in research or design in a scientific or engineering field are likely to 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.

Advanced Placement. Any student from a secondary school which gives college-level courses under the auspices of the College Entrance Examination Board Advanced Placement Program should not hesitate to ask for advanced standing in individual subjects if he wishes to proceed at the next higher level. Under this plan the student takes an advanced placement examination given by the College Board at his school late in the spring of his senior year. These examinations are scored by the College Board and are then forwarded to the college of the student's choice. When the student arrives at M.I.T. in the fall, the Institute will have on file his examination paper, his examination grade, a description of his advanced course written by his secondary school teacher, and a recommendation from his school concerning advanced placement. The amount of credit will then be determined by the Institute department best qualified to evaluate the material, in consultation with the student.

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

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

Each applicant will be referred for a personal conference to a member of the Council at the time of receipt of his Preliminary Application in the Admissions Office. This personal conference is an essential portion of the final application and should be completed at some time in the year prior to the date of entrance. Whenever possible, the conference should be held prior to the March 14 (or February 14, for those who are also applying for student aid) of the year of desired entrance.

Counselors will be glad to speak with any applicants, prior to the year of desired entrance, for general information and counseling purposes. In such cases another conference should be held during the year immediately preceding that in which the applicant wishes to enter.

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

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

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

Apply to the College Entrance Examination Board, Box 592, Princeton, New Jersey. (Residents of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah,

Washington, Wyoming, Alaska, Hawaii, Alberta, British Columbia, Mexico, Australia, Pacific Islands, Japan, and Formosa should apply to the College Entrance Examination Board, Box 27896, Los Angeles 27, California.)

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

The Committee on Admissions will decide whether an applicant's complete set of College Board scores, along with the school marks and other supporting material, are satisfactory. A candidate who completes the tests in March and has submitted all other required material will be notified about admission in early May.

ADMISSION WITH ADVANCED STANDING

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 apply for admission 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.

Applicants for admission with advanced standing should take the test program described above, given by the College Entrance Examination Board. The afternoon achievement 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 with the Director of Admissions a Preliminary Application for Admission with Advanced Standing on a form obtainable from the Admissions Office. On receipt of this application, the Director of Admissions will advise the applicant of those parts of the regular entrance requirements which he must fulfill and will arrange for the final application material to be sent.

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

1. A completed Application for Admission with Advanced Standing, indicating all subjects which he will have completed at the time of transfer, and a non-returnable fee of $10. A check or money order, payable to W. A. Hokanson, Bursar, is preferred.
2. A certified transcript of his college record to date, including a statement of honorable dismissal or its equivalent. A certified statement covering subjects subsequently taken should be sent as soon as it is available.
3. Catalogue pages describing all subjects which will have been completed; the applicant's name should be written on each page and each subject indicated by a check mark in the margin. Complete catalogues should not be sent.

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

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 desiring credit in ELECTRICAL ENGINEERING LABORATORY should present their reports as well as their college records in that subject.

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

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

The Two-Degree Plan. A number of liberal arts colleges grant their Bachelor's degree to students who have attended for three years and who have then gone on to qualify for a Bachelor's degree in engineering, science, 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 studies, can usually obtain the Bachelor of Science degree at M.I.T. in two additional years (three for the Bachelor of Architecture).

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

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

ADMISSION OF FOREIGN STUDENTS

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

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

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

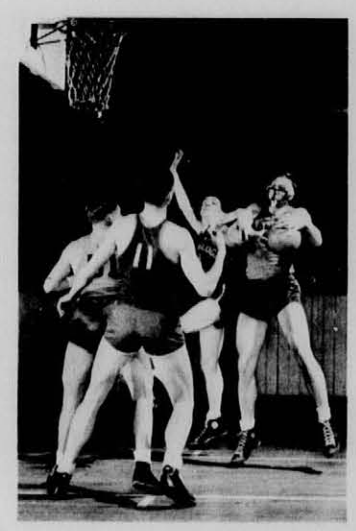
Foreign students who wish to enter the Institute for graduate study should refer to Section 3 of this Catalogue.

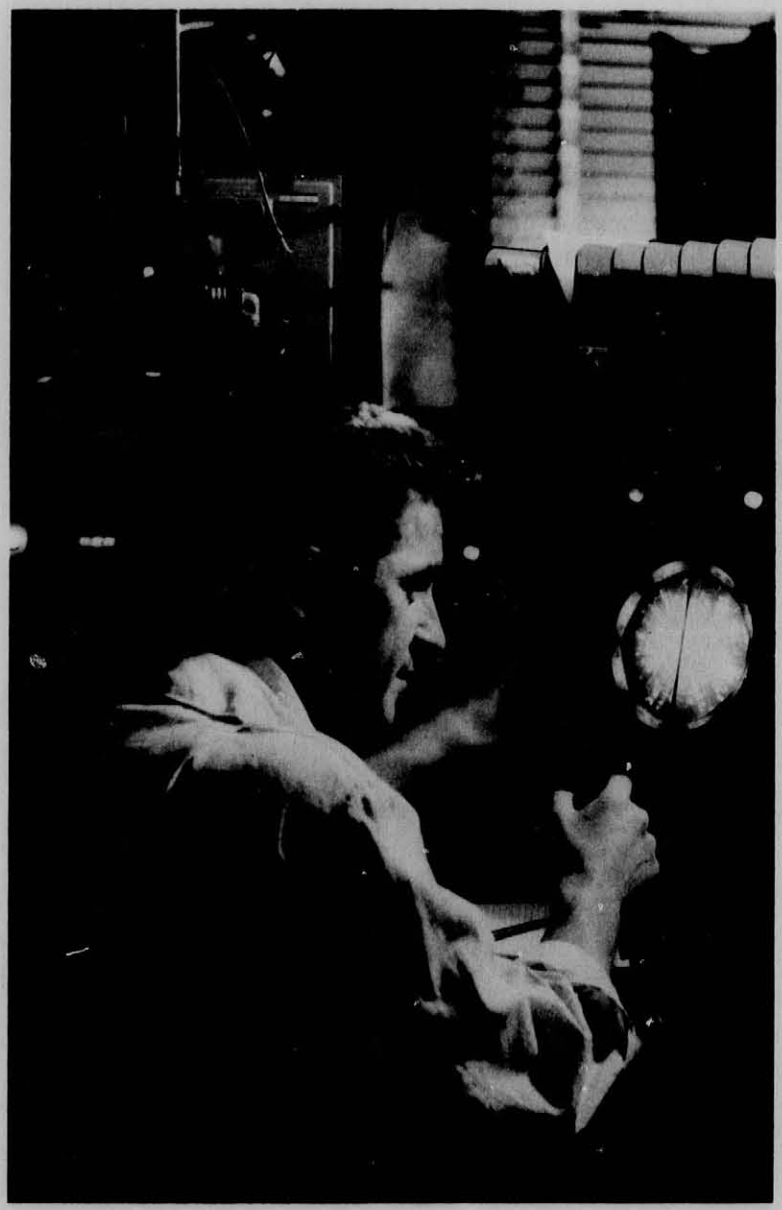
Further information about the admission of foreign students is available from the Office of the Adviser to Foreign Students, M.I.T.

SPECIAL STUDENTS

The admission of students who are not candidates for degrees is described in Section 1 of this Catalogue.

UNDERGRADUATES FIND M.I.T.'S ACADEMIC COMMUNITY A COMPLETE AND REWARDING ONE, WITH RECREATIONAL ACTIVITIES OF ALL KINDS.





GRADUATE EDUCATION 3.

COMMITTEE ON GRADUATE SCHOOL POLICY

HAROLD L. HAZEN, SC.D.
Dean of the Graduate School, Chairman*
ERNEST H. HUNTRESS, PH.D.
Secretary of the Graduate School, Secretary*
B. ALDEN THRESHER, S.B., A.M.
*Director of Admissions**
PHILIP M. MORSE, PH.D., SC.D.
*Chairman of the Faculty**
MARTIN A. ABKOWITZ, PH.D.
Associate Professor of Naval Architecture
WILLIAM P. ALLIS, SC.D.
Professor of Physics
JAMES M. AUSTIN, SC.D.
Associate Professor of Meteorology
WILLIAM H. BROWN, M.ARCH.
Associate Professor of Architecture
HAROLD W. FAIRBAIRN, PH.D.
Professor of Geology
TRUMAN S. GRAY, SC.D.
Associate Professor of Engineering Electronics
ROLAND B. GREELEY, A.B.
Associate Professor of Regional Planning
THOMAS M. HILL, A.B., M.B.A.
Associate Professor of Industrial Management
MYLE J. HOLLEY, JR., S.M.
Professor of Structural Engineering
CHARLES P. KINDLEBERGER, PH.D.
Professor of Economics
EDWARD A. MASON, SC.D.
Associate Professor of Nuclear Engineering
JOHN T. R. NICKERSON, PH.D.
Associate Professor of Food Processing
JOHN T. NORTON, SC.D.
Professor of the Physics of Metals
SHATSWELL OBER, S.B.
Professor of Aeronautical Engineering
WARREN M. ROHSENOW, D.ENG.
Professor of Mechanical Engineering
JOHN C. SHEEHAN, PH.D.
Professor of Organic Chemistry
GEORGE B. THOMAS, JR., PH.D.
Associate Professor of Mathematics
DAVID F. WAUGH, PH.D.
Professor of Biophysics
GLENN C. WILLIAMS, SC.D.
Professor of Chemical Engineering

* *Ex officio*

CHAIRMEN OF DEPARTMENT COMMITTEES ON GRADUATE STUDENTS

SHATSWELL OBER
Aeronautical Engineering
LAWRENCE B. ANDERSON
Architecture
DAVID F. WAUGH
Biology
HOWARD SIMPSON
Building Engineering and Construction
GLENN C. WILLIAMS
Chemical Engineering
JOHN C. SHEEHAN
Chemistry
JOHN T. HOWARD
City and Regional Planning
MYLE J. HOLLEY, JR.
Civil Engineering
CHARLES P. KINDLEBERGER
Economics and Social Science
JEROME B. WIESNER
Electrical Engineering
BERNARD E. PROCTOR
Food Technology
HAROLD W. FAIRBAIRN
Geology and Geophysics
THOMAS M. HILL
Industrial Management
WILLIAM T. MARTIN
Mathematics
WARREN M. ROHSENOW
Mechanical Engineering
JOHN T. NORTON
Metallurgy
JAMES M. AUSTIN
Meteorology
MARTIN A. ABKOWITZ
Naval Architecture and Marine Engineering
EDWARD A. MASON
Nuclear Engineering
PHILIP M. MORSE
Physics
ROSS E. McKINNEY
Sanitary Engineering

The M.I.T. Graduate School

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

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

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

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

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

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

While the graduate student tends normally toward intensive preoccupation with his professional field, M.I.T. encourages breadth of experience as well. Doctoral Minors are occasionally taken in fields entirely unrelated to the Major field. Leaders in many fields give lectures, seminars, and concerts on the campus. Greater Boston is an outstanding intellectual and cultural center. The M.I.T. community has a notably cosmopolitan character: Graduate School enrollment typically includes citizens of 50 foreign countries who together account for about one in every six graduate students. Many graduate students take advantage of these exceptional opportunities for extending interests and understanding to new fields.

Student Organizations and Activities

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

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

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

Organization of the Graduate School

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

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

DEGREES

Graduate students may pursue work leading to any of the following degrees:
Doctor of Philosophy, Ph.D.
Doctor of Science, Sc.D.
Engineer Degrees (see page 58)
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 PLANNING, Course IV-B

School of Engineering

Department of Aeronautical Engineering
AERONAUTICAL ENGINEERING, Course XVI
- Aerodynamics
- Design
- Instrumentation
- Power plants
- Structures

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

CHEMICAL ENGINEERING PRACTICE, Course X-A

Department of Civil Engineering
CIVIL ENGINEERING, Course I
- Hydromechanics and hydraulic engineering
- Photogrammetric engineering
- Soil engineering
- Structural engineering
- Transportation engineering

SANITARY ENGINEERING, Course XI
BUILDING ENGINEERING AND CONSTRUCTION, Course XVII
- Building management
- Materials of construction
- Structural design

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

Department of Mechanical Engineering
MECHANICAL ENGINEERING, Course II
- Applied mechanics
- Heat engineering
- Materials
- Propulsion
- Textile technology

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

Department of Naval Architecture and Marine Engineering
NAVAL ARCHITECTURE AND MARINE ENGINEERING, Course XIII
- Marine engineering
- Naval architecture

NAVAL CONSTRUCTION AND ENGINEERING (U.S.N. and U.S.C.G.), Course XIII-A
SHIPPING AND SHIPBUILDING MANAGEMENT, Course XIII-B

Department of Nuclear Engineering
NUCLEAR ENGINEERING, Course XXII

School of Humanities and Social Studies

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

School of Industrial Management

INDUSTRIAL MANAGEMENT, Course XV

School of Science

Department of Biology
BIOLOGY, Course VII
- Analytical biology
- Biochemistry
- Biophysics
- General physiology
- Microbiology

Department of Chemistry
CHEMISTRY, Course V
- Analytical chemistry
- Inorganic chemistry
- Nuclear chemistry
- Organic chemistry
- Physical chemistry

Department of Food Technology
FOOD TECHNOLOGY, Course XX
- Food bacteriology
- Food engineering
- Food processing
- Food technology
- Industrial microbiology
- Nutritional biochemistry
- Radiation preservation
- Rheology of foods

BIOCHEMICAL ENGINEERING, Course XX-B
- Biochemical engineering

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

Department of Mathematics
MATHEMATICS, Course XVIII

Department of Meteorology
METEOROLOGY, Course XIX

Department of Physics
PHYSICS, Course VIII

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

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

REGISTRATION

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

ACADEMIC STANDARDS

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

Admission to the Graduate School

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

Admission to a Master's program is unlikely if the applicant has not ranked in the upper half of his class at graduation. In the case of a doctoral applicant, rank in the upper third or satisfactory completion of requirements for a Master of Science degree in an institution acceptable to the Director of Admissions at M.I.T. is a normal requisite.

UNDERGRADUATE PREPARATION FOR ADVANCED DEGREES

While departmental requirements vary somewhat, evidence of satisfactory preparation is required by most departments in the following undergraduate subjects:

Mathematics. Preparation substantially equivalent to the Institute's first- and second-year mathematics: CALCULUS (M11, M12, and M21) and DIFFERENTIAL EQUATIONS (M22).

Chemistry. Preparation substantially equivalent to the Institute's first-year chemistry: GENERAL CHEMISTRY (5.01, 5.02).

Physics. Preparation substantially equivalent to the Institute's first- and second-year physics: MECHANICS (8.01); MECHANICS: HEAT AND KINETIC THEORY (8.02); ELECTRICITY AND MAGNETISM (8.03); and OPTICS AND ATOMIC PHYSICS (8.04).

Humanities. At least six semester subjects in English, history, economics (or allied subjects), or other subjects equivalent in scope to those included in the undergraduate humanities curricula of the Institute. Deficiencies may be satisfied by presenting satisfactory grades in the Area Tests of the Graduate Record Examination or by completing appropriate subjects from fourth-year or graduate electives in the humanities and social studies.

Professional Subjects. The specific professional subjects required by individual departments are given in each department's statement on graduate education.

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

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

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

APPLICATION FOR ADMISSION TO THE GRADUATE SCHOOL

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

Applicants for admission to the Graduate School should in general plan to enter in September, which is the beginning of the academic year. Applications for such admission, including all credentials, should be submitted by March 1. Acceptance of later applications is possible only if vacancies remain in the department specified by the applicant. When circumstances warrant, admission may be approved for entry in February or June at the beginning of the corresponding spring or summer terms.

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

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

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

ADMISSION AS A PROVISIONAL GRADUATE STUDENT

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

ADMISSION AS A SPECIAL STUDENT

A qualified applicant who wishes to enroll for graduate subjects with a clearly defined objective, but not as an applicant for a degree, may be admitted term-by-term as a Special Graduate Student. He will be enrolled in the department which has approved his admission.

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

ADMISSION OF FOREIGN STUDENTS

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

consideration only under exceptional circumstances.

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

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

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

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

GRADUATE RECORD EXAMINATION

Applicants who have taken the Area Tests of the Graduate Record Examinations may submit an official report of these examinations, but this is entirely optional. Satisfactory grades in the Area Tests may be accepted in lieu of deficiencies in entrance requirements in the humanities.

Students who wish to take these examinations should write for information about them to the Graduate Record Examinations, Educational Testing Service, 20 Nassau Street, Princeton, New Jersey. Inquiries from students in the western states should be addressed to 4640 Hollywood Boulevard, Los Angeles 27, California.

Cooperative Arrangement with Harvard University

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

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

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

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

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

Military Service

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

Each prospective graduate student must see that his Selective Service Board is supplied with certification both of his class standing during his last undergraduate year and of his admission to the Graduate School. The official statement of his class standing must be supplied by the

institution from which he received his baccalaureate degree. It is the student's responsibility to see that his undergraduate school sends this information directly to his draft board (on S.S.S. Form 109) within 30 days of his graduation. Since the student himself is also entitled to this information, he may request that a copy be sent to him at the same time. The Graduate School will send to the draft board of each admitted student, on a separate S.S.S. Form 109, an official certification of his Graduate School admission; a copy of this certification will also be sent to the prospective student.

Requirements for Degrees

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

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

THE MASTER'S DEGREES

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

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

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

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

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

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

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

THE ENGINEER DEGREES

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

the Engineer degree of two academic years beyond a baccalaureate in the same field.

The following Engineer degrees are awarded: Civil Engineer (C.E.), Mechanical Engineer (Mech.E.), Metallurgical Engineer (Met.E.), Mineral Engineer (Min.E.), Electrical Engineer (E.E.), Chemical Engineer (Chem.E.), Sanitary Engineer (San.E.), Marine Mechanical Engineer (Mar.Mech.E.), Naval Architect (Nav.Arch.), Naval Engineer (Nav.E.), Aeronautical Engineer (Aer.E.), and Building Engineer (Bldg.E.).

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

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

THE DOCTORATES

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

The four basic requirements for a doctorate are:

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

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

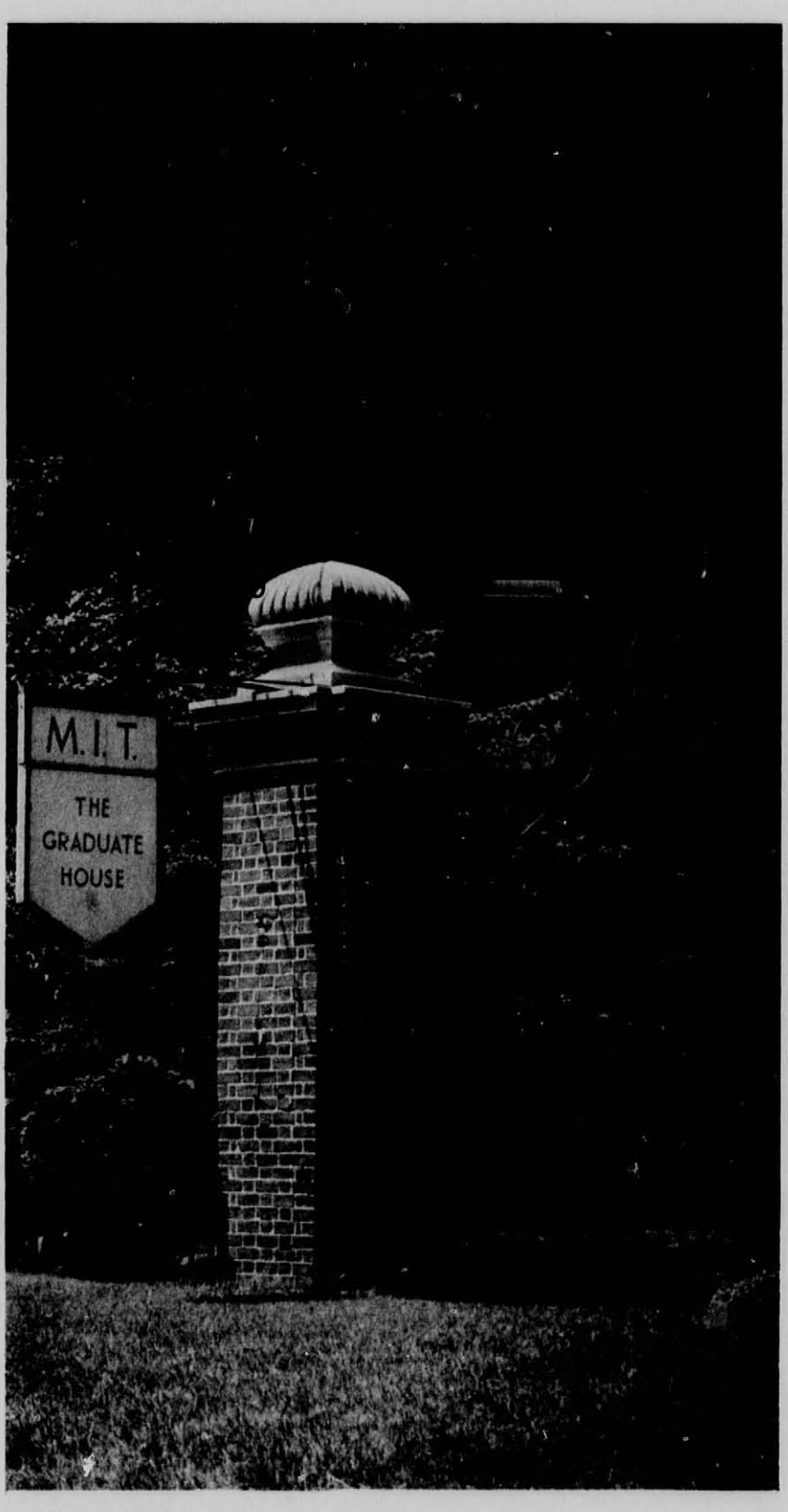
Each doctoral candidate will have a general examination on his Major field at such time and in such manner as his department Committee approves. This examination consists of both oral and written parts.

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

The complete Minor program must have full approval before it is begun. The field of the Minor must be approved by the student's Registration Officer, and the individual subjects must be approved by the chairman of the Committee on Graduate Students of the department in which a majority of the Minor subjects is taken.

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

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


M.I.T.
THE
GRADUATE
HOUSE

THE M.I.T. GRADUATE HOUSE *(see also previous page)* HAS COMFORTABLE LIVING, DINING, AND RECRATIONAL FACILITIES FOR SINGLE GRADUATE MEN.

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

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

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

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

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

RESIDENCE REQUIREMENTS

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

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

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

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

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

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

Financial Assistance to Graduate Students

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

In a typical recent year about 425 graduate students held fellowships and scholarships; over 300 held teaching appointments, and over 500 held research appointments.

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

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

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

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

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

FELLOWSHIP AND SCHOLARSHIP AWARDS

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

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

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

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

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

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

Applications from new students who are at the same time applying for admission to the Graduate School must be accompanied by the full credentials required with the admission application. Only applicants with very high credentials may expect favorable consideration of scholarship applications before they have completed at

least one term of residence as a graduate student. Recently twenty to thirty Whitney Fellowship awards have been granted annually to new students with outstanding qualifications.

Applications received at dates other than March 1 will be considered from time to time if funds are available.

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

JUNIOR STAFF APPOINTMENTS

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

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

In view of their full-time responsibilities on assigned research and corresponding non-academic 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 Graduate Student or of Limited Graduate Student.

Any D.S.R. appointee may, by written permission from the Director of the Division (or his designate), apply for enrollment as a student in one subject only per term (but not thesis), either as auditor or for academic credit; he will be accepted for such enrollment if, in the opinion of the instructor in the subject, he is qualified to undertake it and if section size permits. For this type of enrollment he will be assigned to an appropriate Registration Officer and will pay, whether as a student or listener, the fee established at the Special Student rate and will be recorded as a Special Student.

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

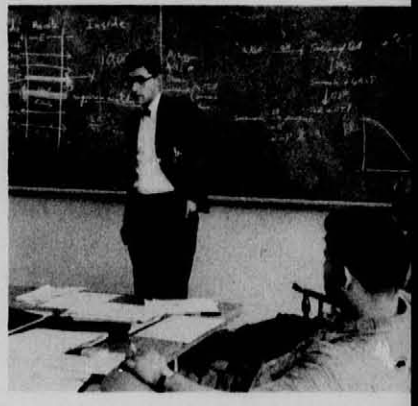
A D.S.R. appointee who at some previous time has held Regular Graduate Student status may, upon joint recommendation of a department Committee and the D.S.R. to the Dean of the Graduate School, be permitted to enjoy the status of Limited Graduate Student for the following purposes:

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

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

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

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



SCHOOL FOR ADVANCED STUDY 4.

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

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

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

INSTITUTE PROFESSORS

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

SLOAN FOREIGN POST-DOCTORAL FELLOWS

ROGER FREDERICK CHALLIS BROWN, PH.D.
RONALD JAMES GRIBBEN, PH.D.
JAN WILLEM KUIPER, SC.D.
AZRIEL LÉVY, PH.D.
MIHAJLO MESAROVIĆ, D.TECH.SC.
ALAN NEIL STROH, PH.D.
KENZO SUGIMOTO, PH.D.

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

SCHOOL OF ARCHITECTURE AND PLANNING

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

As the first institution to organize and develop formal architectural education in the United States, M.I.T. has steadily held to the belief that the basic prerequisites for the study of architecture are sympathy for human institutions, esthetic perception, and the ability to utilize effectively the methods of science. 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 have been more than ever 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 and that mastery of the parts is insufficient. 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.

The aim of our School is not 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 a groundwork of real 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 a great many fields of action in which architects are called upon to function. Similarly, we endeavor to convey to the planning student the importance of teamwork, of the coordinate function. It is in the approach to and understanding of problems rather than in their 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; in charge of the Department
HERBERT LYNES BECKWITH, M.ARCH.
Professor of Architecture
GYORGY KEPES, M.A.
Professor of Visual Design
PIETRO BELLUSCHI, DOTT. ING., LL.D.
Professor of Architecture; Dean of the School of Architecture and Planning
EDUARDO FERNANDO CATALANO, M.ARCH.
Professor of Architecture
LEWIS MUMFORD
Bemis Professor of Architecture (Visiting)
ERNEST NAPOLEON GELOTTE, S.B.
Associate Professor of Construction
WILLIAM HOSKINS BROWN, M.ARCH.
Associate Professor of Architecture
RICHARD FILIPOWSKI, B.A.
Associate Professor of Visual Design
ROBERT BRADFORD NEWMAN, M.A., M.ARCH.
Associate Professor of Architecture
ALBERT BUSH-BROWN, M.F.A.
Assistant Professor of Architectural History
MARVIN EDWARD GOODY, M.ARCH., M.C.P.
Assistant Professor of Architecture
ROBERT ORMEROD PREUSSER
Assistant Professor of Visual Design
IMRE HALASZ, DIPL.ARCH.
Assistant Professor of Architecture
BERNARD POLMER SPRING, A.B., M.ARCH.
Assistant Professor of Architecture

Lecturers

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

Technical Instructor

NISHAN BICHAJIAN

Research Associate

RICHARD WINFIELD HAMILTON, M.ARCH.

Professors Emeriti

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

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

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

THE UNDERGRADUATE PROGRAM

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 selected elements of science, mathematics, humanities, and basic engineering with a program of departmental studies designed to provide a generalized but thorough introduction to architecture. Supplemented by practical experience, this introduction serves as preparation for the responsibilities of independent practice.

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

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

The curriculum is as follows:

FIRST YEAR

First Term

8.01	PHYSICS	5–6
21.01	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
D 11	ENGINEERING DRAWING	4–2
M 11	CALCULUS	3–6
	Elective subjects (see next page)	*11*
		45

ARCHITECTURE

DEPARTMENT OF ARCHITECTURE

FIRST YEAR (continued)

Second Term

8.02	PHYSICS	5–6
21.02	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
D 12	DESCRIPTIVE GEOMETRY	4–2
M 12	CALCULUS	3–6
	Elective subjects (see below)	*11*
		45

ELECTIVE SUBJECTS

Students are required to earn 22 units of elective credits in their first two years. These may include Approved First-Year Elective Subjects, upper-class elective subjects, Military Science, or Air Science. Any part of this elective requirement taken in the second year will be in addition to the specified second-year curriculum of this Course. Students electing Military Science or Air Science subjects should refer to the Army and Air Force R.O.T.C. Programs in Section 2 of this Catalogue.

APPROVED FIRST-YEAR ELECTIVE SUBJECTS

The following subjects are approved as first-year electives. The number of students admitted to any one of these subjects will depend upon the facilities available.

First Term

5.01	GENERAL CHEMISTRY (6–5)
12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
20.00	MAN'S FOOD (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.005	PUBLIC SPEAKING (3–3)
AS 11	AIR SCIENCE (3–0)
D 111	GRAPHICS LABORATORY I (3–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 21	†SPOKEN GERMAN (3–3)
L 31	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 61	†INTRODUCTION TO SPOKEN FRENCH (3–3)
M 100	ELEMENTARY NUMBER THEORY (2–4)
MS 11	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

Second Term

1.002	TECHNOLOGY IN OUR CIVILIZATION (2–4)
4.00	STRUCTURE OF THE CITY (3–3)
5.02	GENERAL CHEMISTRY (6–5)
7.00	PERSPECTIVES IN LIFE SCIENCE (3–3)
12.00	EARTH SCIENCE (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) (2–4)
12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.006	PUBLIC SPEAKING (3–3)
AS 12	AIR SCIENCE (3–0)
D 121	GRAPHICS LABORATORY II (3–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 14	ELEMENTARY NOMOGRAPHY (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 22	†SPOKEN GERMAN (3–3)
L 32	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 62	†CONVERSATIONAL FRENCH (3–3)
M 101	TOPICS IN DISCRETE MATHEMATICS (2–4)
MS 12	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

† The prerequisite is 3 years of high school German or French, as the case may be, or the equivalent.

SECOND YEAR[1]

First Term

2.001	APPLIED MECHANICS I	3–5
4.02	[2]FORM AND DESIGN	9–11
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
		46

Second Term

2.04	STRENGTH OF MATERIALS	3–6
4.11	[2]ARCHITECTURAL DESIGN	9–11
8.04	PHYSICS	5–5
21.04	HUMANITIES	3–5
		47

THIRD YEAR

First Term

4.131	ARCHITECTURAL DESIGN	9–11
4.31	STRUCTURAL ANALYSIS	8–0
4.53	CITY PLANNING PRINCIPLES	2–4
4.65	INTRODUCTION TO ART AND ARCHITECTURE	3–5
	[3]*Humanities*	3–5
		50

Second Term

4.132	ARCHITECTURAL DESIGN	9–11
4.32	STRUCTURAL ANALYSIS	8–0
4.66	MODERN ART AND ARCHITECTURE	3–5
17.73	MATERIALS — WOOD, PLASTICS, FABRICS	3–3
	[3]*Humanities*	3–5
		50

FOURTH YEAR

First Term

2.661	HEATING AND VENTILATION	2–4
4.141	ARCHITECTURAL DESIGN	12–8
	[3]*Humanities*	3–5
	Elective subjects (see next page)	*14*
		48

Second Term

2.662	HEATING AND VENTILATION	2–4
4.142	[4]ARCHITECTURAL DESIGN	12–8
17.74	MATERIALS — MASONRY AND METALS	5–4
	[3]*Humanities*	3–5
	Elective subject (see next page)	*6 to 8*
		49 to 51

FIFTH YEAR

First Term

4.04	LIGHT AND COLOR	9–11
4.151	[5]ARCHITECTURAL DESIGN	12–8
	Elective subjects (see next page)	*8*
		48

FIFTH YEAR (continued)

Second Term

THESIS	20
Elective subjects (see below)	*28*
	48

[1] Students who have not already completed the 22-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] The Registration Officer will assign approximately one-half of the students to take 4.11 in the first term in place of 4.02. These students will take 4.02 in the second term.

[3] Concentration in Visual Arts (Field Ten) is not permitted in satisfaction of the humanities requirement. 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The required third- and fourth-year humanities may be distributed as desired in the last three years of Course IV-A, provided a schedule satisfactory to the Department can be arranged. The humanities requirement is described in Section 2 of this Catalogue.

[4] On the termination of 4.142 ARCHITECTURAL DESIGN, the student's total progress in architectural design will be appraised by his instructor. If this progress is deemed to be insufficient, the student may be required to register for subjects in architectural design beyond the stated curriculum before being allowed to register for thesis.

[5] 4.18 COLLABORATIVE DESIGN (9–11), may be substituted for 4.151.

UPPERCLASS ELECTIVE SUBJECTS

Each student is expected to plan a program of elective subjects with his Registration Officer. Such a program may have a broad coverage, but it should also develop some area close to professional interest, such as structures, environmental control, visual design, or city planning. The following electives are suggested, but additional humanities and subjects from other curricula may also be considered.

4.33	STRUCTURES SEMINAR (2–4)
4.34	STRUCTURES SEMINAR (2–4)
4.41	ARCHITECTURAL ACOUSTICS (3–5)
4.42	SPECIAL PROBLEMS IN ARCHITECTURAL ACOUSTICS*
4.67	THEORIES OF ARCHITECTURE*
4.68	ARCHITECTURAL CRITICISM*
4.70	URBAN SOCIOLOGY (2–4)
4.81	LAND ECONOMICS (2–6)
4.85	REAL ESTATE ECONOMICS (2–4)
6.16	ELECTRICITY (3–6)
6.17	ILLUMINATION (2–4)

* 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 met the requirements of the entire first two years of the architectural curriculum, provided his college transcript shows that he has completed the following:

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

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 special sections 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. Up to 24 units of such subjects which are at the professional level may contribute, if approved by the Department, toward the requirements for the Master's degree.

The Degree of 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 and a thesis of from 24 to 36 units. Completion ordinarily involves twelve months of residence for graduates of five-year professional courses.

Department of City and Regional Planning

JOHN TASKER HOWARD, M.C.P.
Professor of City Planning; in charge of the Department
FREDERICK JOHNSTONE ADAMS, B.ARCH.
Professor of City Planning
CHARLES ABRAMS, LL.B.
Professor of Land Economics (Visiting)
ROLAND BRADFORD GREELEY, A.B.
Associate Professor of Regional Planning
BURNHAM KELLY, A.B., LL.B., M.C.P.
Associate Professor of City Planning
LLOYD RODWIN, PH.D.
Associate Professor of Land Economics; Director, Center for Urban Studies
KEVIN ANDREW LYNCH, B.C.P.
Associate Professor of City Planning

Instructor
BERNARD JOEL FRIEDEN, M.A., M.C.P.

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

UNDERGRADUATE PREPARATION FOR CITY AND REGIONAL PLANNING

The Department does not offer an undergraduate degree. However, undergraduates who expect to do graduate work in the Department may, by a careful selection of elective subjects during their last two undergraduate years, reduce the time normally needed to complete the requirements for the Master's degree. Qualified students who have made full use of their elective time in Architecture (Course IV-A) may complete the requirements for the degree of Master in City Planning, except for thesis, in two academic terms. Civil Engineering (Course I) is also considered good preparation for graduate work in city planning, provided full advantage is taken of elective subjects to meet the prerequisites for graduate study in the Department. Other suitable undergraduate Courses are Economics 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 in city planning usually differs from that required for the scientific degrees. In place of the general requirements given in Section 3 of this Catalogue, the following are prerequisites for graduate study:

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

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

Professional Subjects in City Planning. Acceptable subjects of at least one term credit each in basic design or freehand drawing, sociology, transportation engineering, statistics, public administration, economics, and city planning principles.

Deficiencies in any of the above subjects may be removed by enrolling in special sections in subjects offered by the Institute. A majority of the students take several subjects classed as prerequisites during the first year of graduate registration in the Department. If these subjects are at the professional level they may be counted, up to the 24 units described in Section 3, toward the requirements for the Master's degree.

The Degree of Master in City Planning

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

The Degree of Doctor of Philosophy in City and Regional Planning

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

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

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

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

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

Upon successful completion of these examinations, students are required to prepare a written doctoral thesis evidencing the capacity to do independent, creative 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 will be closely associated with the research program of the Center for Urban and Regional Studies.

The Dean of the School of Engineering describes the School's objectives.

The object of an engineering education is to give expression, direction, and discipline to the urge, inherent in so many of us, to design, to build, and to participate in man's efforts to harness the forces of nature for his benefit. The essential qualities for a career in engineering are imagination, a sense of reality and logic, intellectual honesty, a flair for mathematical reasoning, a love for the understanding of physical phenomena of nature, and perhaps most important of all, strength of character and integrity to labor through the years necessary for training and indoctrination.

There are few professional fields which offer such wide scope of activity. The modern engineer is occasionally an independent professional practitioner, sometimes a teacher, sometimes an entrepreneur responsible for his own business, most frequently an employee of a corporation, and with increasing frequency a member or leader of management in industry. The educated engineer can enter all of these functions, and many others, with a unique set of professional tools and with a social outlook matured by the sense of social responsibility which is one of the important characteristics of the professional man.

The engineer is the latest among professional men to arrive at full status in modern society. He is the custodian of a major share of our heritage of applied science, continually enriched by inventions and new developments. He must carry out his work as a leader of men, conscious of the social and economic implications of his decisions. While he has to deal with facts and scientific principles, his real stature finds expression in those situations where judgment and wisdom shape the elements of scientific knowledge to achieve results which will benefit our society.

Engineering presents a bewildering array of specialties, and there is a corresponding variety of educational opportunities and emphasis. The program of undergraduate education in engineering at M.I.T. has in recent years become a program of general education with emphasis on science, the humanities, and the broad aspects of technology which are essential to modern society. The technical and professional subjects of application begin only in the later years of the undergraduate program. The mature professional education finds its full expression in the graduate years. Throughout this process, but particularly in the later years, the educational activity is enriched by association with research, with practical work, and with teaching.

The various curricula in the School of Engineering at M.I.T. are general enough so that the choice of specialty is never quite as momentous as it may at first appear. Indeed, the first-year programs for all Courses in the School of Engineering, outlined on the opposite page, are essentially similar. The basis of a choice among engineering fields lies within — rather than outside — each student's mind and personality. To find expression for one's gifts and to carry one's education as far as those gifts justify is the essential purpose. 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.

C. RICHARD SODERBERG

THE FIRST YEAR IN THE SCHOOL OF ENGINEERING

The first-year curriculum in the School of Engineering, essentially similar for all departments, includes fundamental subjects that provide freshmen with a strong foundation for their professional studies. Because this first-year curriculum is basic and broad, it meets the requirements of any engineering field. Thus, though the entering freshman is asked to indicate the Course in which he expects to study, this selection may be changed with minimum inconvenience at any time before the beginning of his second year.

The curriculum below shows the minimum requirements for the first year in all Courses in the School of Engineering.

First Term

5.01	GENERAL CHEMISTRY	6–5
8.01	PHYSICS	5–6
21.01	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 11	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

Second Term

5.02	GENERAL CHEMISTRY	6–5
8.02	PHYSICS	5–6
21.02	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 12	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

[1] Students accepted for the N.R.O.T.C. Program (see Section 2 of this Catalogue) omit the elective subjects and take in their place NS11 and NS12 ORIENTATION AND SEA POWER (4–5, 4–5) in the first and second terms, respectively.

ELECTIVE SUBJECTS

Students are required to earn 12 units of elective credits in their first two years. These may include Approved First-Year Elective Subjects, upper-class elective subjects, Military Science, or Air Science. Any part of this elective requirement taken in the second year will be in addition to the specified second-year curriculum of the Course elected. Students electing Military Science or Air Science subjects should refer to the Army and Air Force R.O.T.C. Programs in Section 2 of this Catalogue. The departments in the School of Engineering recommend a graphics subject as part of the elective requirement.

APPROVED FIRST-YEAR ELECTIVE SUBJECTS

The following subjects are approved as first-year electives. The number of students admitted to any one of these subjects will depend upon the facilities available.

First Term

12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
20.00	MAN'S FOOD (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.005	PUBLIC SPEAKING (3–3)
AS 11	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 111	GRAPHICS LABORATORY I (3–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 21	[1]SPOKEN GERMAN (3–3)
L 31	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 61	[1]INTRODUCTION TO SPOKEN FRENCH (3–3)
M 100	ELEMENTARY NUMBER THEORY (2–4)
MS 11	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

Second Term

1.002	TECHNOLOGY IN OUR CIVILIZATION (2–4)
4.00	STRUCTURE OF THE CITY (3–3)
7.00	PERSPECTIVES IN LIFE SCIENCE (3–3)
12.00	EARTH SCIENCE (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) (2–4)
12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.006	PUBLIC SPEAKING (3–3)
AS 12	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 121	GRAPHICS LABORATORY II (3–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 14	ELEMENTARY NOMOGRAPHY (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 22	[1]SPOKEN GERMAN (3–3)
L 32	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 62	[1]CONVERSATIONAL FRENCH (3–3)
M 101	TOPICS IN DISCRETE MATHEMATICS (2–4)
MS 12	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

[1] The prerequisite is 3 years of high school German or French, as the case may be, or the equivalent.

Department of Aeronautical Engineering

CHARLES STARK DRAPER, SC.D.
Professor of Aeronautical Engineering; in charge of the Department; Director of Instrumentation Laboratory

ROBERT LOUIS HALFMAN, S.M.
Associate Professor of Aeronautical Engineering; Executive Officer

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

OTTO CARL KOPPEN, S.B.
Professor of Aeronautical Engineering

EDWARD STORY TAYLOR, S.B.
Professor of Aircraft Engines

JOHN RAYMOND MARKHAM
Professor of Aeronautical Engineering

SHATSWELL OBER, S.B.
Professor of Aeronautical Engineering

RAYMOND LEWIS BISPLINGHOFF, SC.D.
Professor of Aeronautical Engineering

HORTON GUYFORD STEVER, PH.D.
Professor of Aeronautical Engineering; Associate Dean of the School of Engineering

WALTER WRIGLEY, SC.D.
Professor of Aeronautical Engineering

RENE HARCOURT MILLER, B.A.
Professor of Aeronautical Engineering

GEORGE PAUL SUTTON, M.S.
Jerome Clarke Hunsaker Professor of Aeronautical Engineering (Visiting)

WALTER McKAY, S.M.
Associate Professor of Aeronautical Engineering

JOSEPH BICKNELL, S.M.
Associate Professor of Aeronautical Engineering

PAUL EDWIN SANDORFF, S.B.
Associate Professor of Aeronautical Engineering

ROBERT KARL MUELLER, SC.D.
Associate Professor of Aeronautical Engineering

HOLT ASHLEY, SC.D.
Associate Professor of Aeronautical Engineering

YAO TZU LI, SC.D.
Associate Professor of Aeronautical Engineering

MORTON FINSTON, PH.D.
Associate Professor of Aeronautical Engineering

ERIK LEONARD MOLLÖ-CHRISTENSEN, SC.D.
Associate Professor of Aeronautical Engineering

LEON TRILLING, PH.D.
Associate Professor of Aeronautical Engineering

FRANK KINGSLEY BENTLEY
Assistant Professor of Aeronautical Engineering

JAMES WAH MAR, SC.D. (*Absent*)
Assistant Professor of Aeronautical Engineering

ELMER EUGENE LARRABEE, S.M.
Assistant Professor of Aeronautical Engineering

THEODORE HSUEH-HUANG PIAN, SC.D.
Assistant Professor of Aeronautical Engineering

MYRON ARNOLD HOFFMAN, SC.D. (*Absent*)
Assistant Professor of Aeronautical Engineering

JUDSON RICHARD BARON, SC.D.
Assistant Professor of Aeronautical Engineering

JOHN DUGUNDJI, SC.D.
Assistant Professor of Aeronautical Engineering

WINSTON ROSCOE MARKEY, SC.D.
Assistant Professor of Aeronautical Engineering

WALLACE EARL VANDER VELDE, SC.D.
Assistant Professor of Aeronautical Engineering

Lecturer

HENRY PHILIP WHITAKER, S.B.

Professor Emeritus

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

AERONAUTICAL ENGINEERING

Aeronautical engineering deals with the problems of manned or unmanned vehicles that operate above the earth's surface. These include fixed-wing aircraft, helicopters, ballistic missiles, guided missiles, and space vehicles. Successful realization of systems based on such devices requires that solutions be found for the static and dynamic problems of sustentation, fluid resistance to motion, propulsion, strength and elasticity of minimum-weight structures, and measurements under difficult environmental conditions. In addition it is necessary to understand and use the theory of rapid, precise, and reliable manual and automatic control of the direction and speed of massive bodies moving in space with many degrees of freedom under driving forces from very powerful and complex engines. It is the primary objective of the Aeronautical Engineering Department to give a clear understanding of all the basically important problems that occur in aeronautics and to provide students with a broad background of education in the art and science of applying sound judgment in achieving acceptable solutions for practical situations.

More than any other, the factor which influences the educational climate of the Department is the extensive, vigorous participation by every faculty member in the activities of one or more of the several departmental research laboratories. The Department is outstanding in the volume of sponsored and unsponsored research carried out by its staff. Except for flight testing and similar activities, all this work is done either on or in the immediate vicinity of the campus. Because all faculty members are actively interested in teaching, the aeronautical research problems of one day can and often do become the classroom examples or assignments of the next. Many undergraduates and a majority of graduate students find that part-time employment in one of the laboratories gives a source of income while providing experience that is an invaluable supplement to formal courses. Such experience commonly suggests thesis projects which place fundamental emphasis on a working relationship with the current problems of aeronautical engineering. The Department is proud that all of its extensive research facilities are available to its student body for thesis work or instruction, and that the utilization is high for both of these purposes. Of the many basic contributions to aeronautical science in such areas as automatic control, inertial navigation, turbojet engines, aeroelasticity and aerodynamic heating, a large proportion had their origins in student-faculty collaboration on thesis projects.

Major departmental laboratories are listed below, with a brief description of their activities:

AEROELASTIC AND STRUCTURES LABORATORY

Here a wide variety of investigations are conducted on the interrelation between aerodynamic and elastic forces. Model construction facilities are available, as are wind tunnels and a shock tube for low-speed or high-speed dynamic testing. The structural test facility contains equipment for static or dynamic loading of aircraft components and material samples. Electro-thermal furnaces permit study of high-temperature gradients and transient effects.

AIRCRAFT INSTRUMENTS LABORATORY

The Aircraft Instruments Laboratory operates extensive equipment for studying the performance of measuring and control systems, with particular emphasis on instructing students in the fundamentals of such systems and providing thesis facilities. Items available include an electronic simulator, harmonic synthesizer, environmental facility, and apparatus for measuring vibratory characteristics of instruments.

GAS TURBINE LABORATORY

The facilities of this Laboratory are devoted to the study of fluid-dynamic phenomena in turbines, compressors and combustion chambers, boundary-layer flow and mixing of jets. The Laboratory includes an 8 by 8 inch supersonic wind tunnel for testing turbine components, along with other experimental apparatus of all types related to aircraft propulsion research.

INSTRUMENTATION LABORATORY

The Instrumentation Laboratory is a defense research organization devoted to research and development on fire control and navigation systems. Its equipment includes several digital and analog computers and an extensive flight facility at Hanscom Air Force Base near Boston. Research projects are organized in such a way that students may obtain advanced professional experience, similar to an internship, in instrumentation and weapons systems. Valuable sources of thesis material are provided in these fields. Results of current research are being applied directly to graduate academic subjects

and ultimately to undergraduate teaching in the Department. The weapons systems curriculum provided for Air Force officers, Navy officers, and civilians is very largely based on the work of the Instrumentation Laboratory.

NAVAL SUPERSONIC LABORATORY

Here basic research is carried on in problems of high-speed flight — for example, loads on supersonic wings and bodies, aerodynamic heating, and hypersonic gas dynamics. The Laboratory centers on a 10,000-horsepower wind tunnel, with rectangular test section 18 by 24 inches, ambient pressures ¼ to 4 atmospheres, and velocities up to four times sonic speed. Associated facilities include a small tunnel capable of operating above 10 times sonic speed.

WRIGHT BROTHERS WIND TUNNEL

Here there is a 2,000-horsepower low-speed wind tunnel, with elliptic throat 7½ by 10 feet and operating pressures ¼ to 4 atmospheres. This tunnel also serves as the reservoir for an intermittent transonic wind tunnel with an 18-inch slotted-wall test section, and for an intermittent supersonic tunnel with continuously variable Mach number between 1.2 and 2.0. The latter facility is particularly adapted for the measurement of oscillatory air loads and aeroelastic stability.

OTHER RESEARCH GROUPS

The Fluid Dynamics Research Group and the Aerophysics Research Group are organized so that interested students and staff members may work in these areas. These groups are not directly associated with any one facility but take advantage of the staff and equipment of any and all departmental laboratories that are able to make contributions to their research.

THE UNDERGRADUATE PROGRAMS

Aeronautical Engineering (Course XVI)

Building on the firm grounding in basic science and mathematics provided by the first two years of Institute work, the undergraduate Course in Aeronautical Engineering adds the advanced subjects required to apply engineering science in working out optimum designs for aeronautical systems. The program is broad and flexible, with education not only in peculiarly aeronautical sciences such as three-dimensional gas dynamics but also in the areas of generalized rigid-body mechanics, elasticity, structures, thermodynamics, vector field theory, complex linear systems, applied electronics, measurements, stability of physical systems, servomechanisms, and automatic controls. The essential unity of the curriculum formed from these subjects is emphasized by sequences of coordinated subjects that bridge the gap between basic science and mathematics and the comprehensive subjects in the principles of aeronautical engineering.

These comprehensive subjects are taken in the senior year and include the major steps required for a preliminary study of a chosen manned or unmanned aeronautical vehicle. In the course of this work, essential subsystems and components are considered and integrated into an over-all design. Methods of checking the expected performance of a vehicle based on such a design are studied by laboratory tests on aerodynamic performance, structural behavior, and the operation of various subsystems including automatic control components. During parts of the fourth-year program students work together in teams similar to those commonly used by industry for large projects. As a result, each student receives interesting and rewarding experiences in the technical aspects of his chosen profession, and he also becomes aware of the great importance of personal relationships in modern engineering. In his professional work with comprehensive problems, the student has continuous contacts with a number of senior faculty members who are familiar with current practice in the aeronautical industry. Each student is given personal attention, since it is the Department's aim to prepare him for his first job with the breadth of vision and ability required of potential chief engineers. In addition, his qualifications in basic science, mathematics, and applied science give him an excellent preparation for starting advanced study toward a career in research.

The curriculum not only provides the coordinated education described above but offers the flexibility of choice among several advanced professional electives in many fields. In addition, subjects in the regular curriculum may be replaced by equivalent subjects, if the substitutions are approved by the Registration Officer.

The Course leads to the degree of Bachelor of Science in Aeronautical Engineering. The curriculum for the first year is shown on page 77; the curriculum for the second, third, and fourth years is shown on the next page.

SECOND YEAR[1]

First Term

2.001	APPLIED MECHANICS I	3–5
8.03	PHYSICS	5–5
16.70	AIRCRAFT DETAIL DESIGN	8–0
16.82	INTRODUCTORY AERONAUTICAL ENGINEERING	3–3
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		49

Second Term

2.37	MECHANICAL BEHAVIOR OF MATERIALS	5–4
8.04	PHYSICS	5–5
16.00	AEROMECHANICS	4–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		45

THIRD YEAR

First Term

2.40	HEAT ENGINEERING	4–5
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	4–6
16.01	AEROMECHANICS	5–5
16.11	AIRCRAFT PERFORMANCE AND STABILITY	4–8
	[2]*Humanities*	3–5
		49

Second Term

16.02	AERODYNAMICS	6–6
16.20	STRUCTURES	4–6
16.30	PRINCIPLES OF AUTOMATIC CONTROL	3–9
16.53	AIRCRAFT PROPULSION	3–6
	[2]*Humanities*	3–5
		51

FOURTH YEAR

First Term

16.302	AERONAUTICAL SYSTEMS	3–6
16.71T	AERONAUTICAL ENGINEERING	12–0
	[2]*Humanities*	3–5
	Laboratory elective subject	*10*
	Professional elective subject or humanities (see next column)	*8*
		47

Students registered in the fourth year, first term, 1958–59: omit 16.302 and 16.71T. Add 16.30 PRINCIPLES OF AUTOMATIC CONTROL (3–9) and 16.71 AERONAUTICAL ENGINEERING (10–0).

Second Term

16.72	AERONAUTICAL ENGINEERING THESIS OR PROJECT	9–3 9
	[2]*Humanities*	3–5
	Professional elective subject (see next column)	9
	Professional elective subject or humanities (see next column)	*8*
		46

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2 of this Catalogue.

PROFESSIONAL ELECTIVE SUBJECTS

The following are suggested as professional electives:

2.48T	GAS TURBINES AND JET PROPULSION (3–6)
2.79	ELEMENTARY INTERNAL COMBUSTION ENGINES (3–6)
6.19	FUNDAMENTALS OF ELECTRONICS (4–6)
16.03	PRINCIPLES OF AERODYNAMICS (4–5)
16.21	STRUCTURAL ANALYSIS (4–6)
16.23	AIRCRAFT STRUCTURAL DESIGN (3–5)
16.302	AERONAUTICAL SYSTEMS (3–6) (*1958–59 only*)
16.76	ORBITAL VEHICLES (3–6)
M 351	ADVANCED CALCULUS FOR ENGINEERS (3–6)
M 352	ADVANCED CALCULUS FOR ENGINEERS (3–6)

Other subjects may be chosen as electives if approved by the Registration Officer.

The Honors Course

Students who wish to pursue a coordinated schedule of studies through their senior and graduate years may apply for an 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 Aeronautical Engineer 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 Aeronautical Engineering and either the degree of Master of Science in Aeronautical Engineering or the degree of Aeronautical Engineer, awarded simultaneously at the end of the graduate program.

Aeronautical Engineering (Cooperative Course) (Course XVI-B)

The cooperative program for Aeronautical Engineering undergraduates provides the opportunity for about six 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 pro-

gram does not interfere with the student's academic progress nor with his extracurricular activities in association with his classmates.

The cooperating companies of the aircraft industry pay the students at prevailing rates during their period of employment. The students pay their own transportation and living 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 March 1 of their sophomore year. These forms should be completed and returned by March 15, with an added statement specifying the location where the student prefers to work.

Representatives of the cooperating companies come to the Institute to interview interested students and to determine, together with the Department representative, the distribution of those selected for employment. Students who are thus 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 Aeronautical Engineering.

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

The Cooperative Course leads to the degree of Bachelor of Science in Aeronautical Engineering. The curriculum is shown below.

FIRST AND SECOND YEARS

Same as Aeronautical Engineering (Course XVI)

THIRD YEAR

Summer

	At M.I.T., first 6 weeks:	
2.40	HEAT ENGINEERING	4–5
16.01	AEROMECHANICS	5–5
		19
	Vacation, approximately 2 weeks	
	At plants, remainder of summer:	
16.851	INDUSTRIAL PRACTICE	40 h.p.w.

First Term

	At plants:	
16.852	INDUSTRIAL PRACTICE	40 h.p.w.

Second Term

	At M.I.T.:	
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	4–6
16.02	AERODYNAMICS	6–6
16.30	PRINCIPLES OF AUTOMATIC CONTROL	3–9
16.53	AIRCRAFT PROPULSION	3–6
	[1]*Humanities*	3–5
		51

FOURTH YEAR

Summer

	At M.I.T.:	
16.11	AIRCRAFT PERFORMANCE AND STABILITY	4–8
16.20	STRUCTURES	4–6
	[1]*Humanities*	3–5
		30

First and Second Terms

Same as Aeronautical Engineering (Course XVI)

[1] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2 of this Catalogue.

GRADUATE STUDY IN AERONAUTICAL ENGINEERING

In contrast with undergraduate work, where some specialization is possible but is not encouraged, advanced study in the Department of Aeronautical Engineering usually follows a program directed toward some particular part of the aeronautical field. Commonly selected major fields include air vehicle design, aerodynamics, structures, propulsion, instrumentation, and automatic control. For successful graduate work in any of these fields, most students discover that strong preparation and aptitude in applied mathematics are necessary supplements for the other undergraduate fundamentals. Students frequently elect subjects given by other departments which bear a useful relation to their aeronautical subject.

Advanced study in the Department leads to the degrees of Master of Science in Aeronautical Engineering, Aeronautical Engineer, or Doctor of Science in Aeronautical Engineering.

Entrance Requirements for Graduate Study

All degree applicants must have preparation substantially equivalent to fundamental undergraduate subjects in heat engineering, aeromechanics, aerodynamics, aircraft structures, basic electrical engineering, and automatic control. Certain additional background education is needed for professional specialization in particular fields.

The Master of Science Degree

For this degree, at least one year of an approved graduate program is required, including thesis. Two terms of advanced mathematics beyond DIFFERENTIAL EQUATIONS (M22) must be included. This degree is awarded simultaneously with the Bachelor of Science in Aeronautical Engineering 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 Aeronautical Engineer degree.

The Aeronautical Engineer Degree

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 science and its engineering applications. The program must include advanced subjects in theoretical and applied aerodynamics, propulsion, design, structures, and automatic control.

Requirements for admission to candidacy for the degree of Aeronautical Engineer are more rigorous than for the degree of Master of Science in Aeronautical Engineering.

The Doctor of Science in Aeronautical Engineering

For this degree the student must complete an approved program, including thesis, more extensive than that required for the degree of Aeronautical Engineer. The General Examination includes both written and oral parts. The thesis must demonstrate the student's ability to carry out independent original research of high quality on a problem of aeronautical science or engineering.

The 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 Aeronautical Engineering (Instrumentation and Weapons Systems Divisions), Electrical Engineering, Mechanical Engineering, Mathematics, and Physics. The program is administered, for registration purposes, by the Department of Aeronautical Engineering. 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.

Language Requirement

No language requirement is made for candidates for the Master of Science or Engineer degrees. A candidate for the Doctor of Science degree must demonstrate competence in reading two foreign languages in his major field; German is specified, and the second language is arranged in consultation with each student's Graduate Registration Officer.

Financial Assistance for Graduate Study

The Department offers several fellowships for full-time study in aeronautical engineering; 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)

WALTER GORDON WHITMAN, SC.D.
Professor of Chemical Engineering; in charge of the Department

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

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

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

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

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

EDWIN RICHARD GILLILAND, SC.D., D.ENG.
Professor of Chemical Engineering

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

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

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

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

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

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

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

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

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

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

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

THOMAS WILLIAM MIX, S.M.
Assistant Professor of Chemical Engineering

ALLAN HARDY BONNELL, SC.D.
Assistant Professor of Chemical Engineering; Director, Bayway Station, School of Chemical Engineering Practice

DAVID HAMPTON KLIPSTEIN, S.M.
Assistant Professor of Chemical Engineering; Director, Bound Brook Station, School of Chemical Engineering Practice

CHARLES MICHAEL MOHR, S.M.
Assistant Professor of Chemical Engineering; Director, Engineering Practice School at Oak Ridge

Technical Instructors

HENRY CHASEN
HAROLD HAVNER CARTER

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; Lecturer

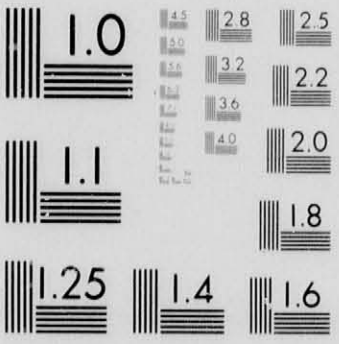
STATIONS OF THE SCHOOL OF CHEMICAL ENGINEERING PRACTICE

Directors

ALLAN HARDY BONNELL, SC.D., *Bayway*
DAVID HAMPTON KLIPSTEIN, S.M., *Bound Brook*

Assistant Directors

EDWARD LYDIG HOYT, S.M., *Bayway*
NICHOLAS JAMES STEVENS, JR., S.M., *Bound Brook*



MICROCOPY RESOLUTION TEST CHART
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M.I.T. ANNUAL CATALOGUES AND BULLETINS
1958/59

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04

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 into 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 its 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 to exercise considerable selectivity in the more advanced phases of undergraduate work and in graduate study.

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

THE UNDERGRADUATE PROGRAMS

The undergraduate Courses provide basic studies in physics and mathematics, a major concentration in chemistry, and a strong core of chemical engineering. The four-year undergraduate programs, designed to develop judgment, initiative, and responsibility, give each student considerable latitude in arranging a selection of subjects that will best fit his needs and develop his aptitudes. Those who expect to go on to Graduate School may therefore elect subjects which will strengthen their preparation for advanced professional work.

The student takes a significant professional minor, equivalent to about 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, metallurgy, pregraduate nuclear engineering, and properties of materials. In addition to work in science and engineering, students take an integrated sequence of subjects in the humanities and social studies. The chemical engineer's progress and accomplishments are not determined solely by technological competence; fully as important is his breadth of outlook and his understanding of society.

These curricula give undergraduates a sound basis for further developing their aptitudes and interests through industrial work, self-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 for the first year is shown on page 77; the balance of the curriculum is as follows:

SECOND YEAR[1]

First Term

5.41	ORGANIC CHEMISTRY I	4–4
5.416	ORGANIC PREPARATIONS I	6–0
8.03	PHYSICS	5–5
10.17	INDUSTRIAL CHEMISTRY	3–4
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		48

Second Term

8.04	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	Elective subjects (see next page)	*19*
		46

THIRD YEAR

First Term

	Elective subjects (see next page)	*48*

Second Term

	Elective subjects (see next page)	*48*

FOURTH YEAR

First Term

10.15	THESIS REPORTS	3–0
	Elective subjects (see below)	*45*
		48

Second Term

	THESIS	12
	Elective subjects (see below)	*36*
		48

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

ELECTIVE SUBJECTS

The elective subjects shown in the above program for students in Chemical Engineering (Course X) must include the following:

1. At least four subjects in humanities that satisfy the sequence and breadth requirements given in Section 2 of this Catalogue.
2. At least 35 units of subjects in chemistry.
3. At least 60 units of subjects in chemical engineering.
4. At least 25 units of an integrated professional minor in departments other than chemistry and chemical engineering.
5. Within or in addition to these requirements, students must take 23 units of laboratory work.

Students should also note the elective subject requirements for Chemical Engineering Practice (Course X-B), given on the opposite page.

Undergraduate elective requirements for Course X would be satisfied, for example, by the following sequence of electives:

SECOND YEAR

Second Term

5.42	ORGANIC CHEMISTRY II (4–4)
5.426	QUALITATIVE ORGANIC ANALYSIS (6–0)
10.11	CHEMICAL ENGINEERING (2–3)

THIRD YEAR

First Term

2.001	APPLIED MECHANICS I (3–5)
	or
M 351	ADVANCED CALCULUS FOR ENGINEERS (3–6)
5.03	PRINCIPLES OF INORGANIC CHEMISTRY (3–3)
5.61	PHYSICAL CHEMISTRY I (4–4)
10.18	INDUSTRIAL CHEMISTRY (3–6)
10.28	CHEMICAL ENGINEERING THERMODYNAMICS (4–6)
	Humanities (3–5)

Second Term

2.002	APPLIED MECHANICS II (3–5)
	or
M 352	ADVANCED CALCULUS FOR ENGINEERS (3–6)
5.14	ANALYTICAL CHEMISTRY I (3–3)
5.141	ANALYTICAL CHEMISTRY LABORATORY I (9–0)
5.62	PHYSICAL CHEMISTRY II (4–4)
10.29	CHEMICAL ENGINEERING (4–6)
	Humanities (3–5)

FOURTH YEAR

First Term

10.21	INDUSTRIAL CHEMISTRY (3–6)
10.26	INDUSTRIAL CHEMISTRY LABORATORY (10–0)
	or
10.27	CHEMICAL ENGINEERING LABORATORY (10–0)
10.31	CHEMICAL ENGINEERING (4–6)
	Humanities (3–5)
	Elective subject (8)

Second Term

6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING (4–6)
10.32	CHEMICAL ENGINEERING (4–6)
	Humanities (3–5)
	Elective subject (8)

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 for Chemical Engineering Practice is the same as that for Chemical Engineering through the third year. The fourth year is as follows:

FOURTH YEAR

First Term

	Elective subjects (see below)	*48*

Second Term

	School of Chemical Engineering Practice:	
10.83T	BAYWAY STATION	18–0
10.84T	BOUND BROOK STATION	18–0
	THESIS	12
		48

ELECTIVE SUBJECTS

Each student in Chemical Engineering Practice (Course X-B) must take the following as part of his elective program:

1. At least four subjects in humanities that satisfy the sequence and breadth requirements given in Section 2 of this Catalogue.
2. At least 35 units of subjects in chemistry.

(continued on the next page)

3. At least 45 units of subjects in chemical engineering.

4. At least 15 units of an integrated professional minor in departments other than chemistry and chemical engineering.

5. Within or in addition to these requirements, students must take 13 units of laboratory work.

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, and Doctor of Science in Chemical 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 degree of Chemical Engineer and for the Doctor of Science degree is more specific in character, and the Department offers coordinated programs in three fields: engineering operations, applied chemistry, and fuel engineering. Special programs are developed for individual cases.

Entrance Requirements for Graduate Study

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

Requirements for Advanced Degrees

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

Fields of Study

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

ENGINEERING OPERATIONS (PROCESS ENGINEERING)

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

Relevant subjects offered by the Department include:

ANALYTICAL TREATMENT OF CHEMICAL ENGINEERING PROCESSES (10.33)
CHEMICAL ENGINEERING THERMODYNAMICS (10.40)
DISTILLATION (10.41)
SEPARATION PROCESSES (10.43)
ABSORPTION AND EXTRACTION (10.46)
ION EXCHANGE (10.47)
HEAT TRANSMISSION (10.50)
CHEMICAL ENGINEERING II (10.52)
CHEMICAL ENGINEERING DESIGN (10.53)
ECONOMIC BALANCE IN CHEMICAL INDUSTRY (10.55)
PRINCIPLES OF COMBUSTION (10.70)

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

APPLIED CHEMISTRY

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

research activity falls into these areas, and unique laboratory facilities are provided.

Relevant subjects offered by the Department include:

INDUSTRIAL CHEMISTRY (10.25)
ION EXCHANGE (10.47)
ADVANCED THERMODYNAMICS (10.62)
MOLECULAR FORCES AND PROPERTIES OF MATTER (10.63)
APPLIED CHEMICAL KINETICS (10.65)
COLLOID CHEMISTRY (10.66T)
APPLIED SURFACE CHEMISTRY (10.67)
HIGH POLYMER TECHNOLOGY (10.69)

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

FUEL ENGINEERING

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

Subjects commonly taken are:

CHEMICAL ENGINEERING THERMODYNAMICS (10.40)
CHEMICAL ENGINEERING II (10.52)
APPLIED CHEMICAL KINETICS (10.65)
PRINCIPLES OF COMBUSTION (10.70)
SELECTED COMBUSTION PROBLEMS (10.72)
PRINCIPLES OF FURNACE DESIGN (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 (10.81T and 10.82T) until the end of January, and then return to the Institute to complete the program for the Master's degree during the spring term.

A similar Practice School program at the field stations starts early in February and extends to early June.

The Engineering Practice School at Oak Ridge, described in Section 1 of this Catalogue, is similar in educational philosophy and technique to the School of Chemical Engineering Practice and operates on the same schedule. For chemical engineering students it may be regarded as an alternative experience to that of the School of Chemical Engineering Practice.

For students who have graduated in chemical engineering from other institutions, the usual program of study for the Master's degree in Chemical Engineering Practice involves one or two terms at the Institute followed by the field station work in the Practice School. Graduates in chemistry from other institutions normally require an additional term. Students are usually not admitted to the Practice School until they have spent at least one term at the Institute.

Department of Civil and Sanitary Engineering

JOHN BENSON WILBUR, SC.D.
Professor of Civil Engineering; in charge of the Department

CHARLES HEAD NORRIS, SC.D.
Professor of Structural Engineering; Executive Officer

JOHN BRAZER BABCOCK, 3D, S.B.
Professor of Railway Engineering, Emeritus; Lecturer

WILLIAM EDWARD STANLEY, C.E.
Professor of Sanitary Engineering, Emeritus; Lecturer

ARTHUR THOMAS IPPEN, PH.D.
Professor of Hydraulics

ROLF ELIASSEN, SC.D.
Professor of Sanitary Engineering

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

JAMES WALLACE DAILY, PH.D.
Professor of Hydraulics

GORDON RYERSON WILLIAMS, S.B.
Professor of Hydraulic Engineering

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

LAURITS BJERRUM, DR.SC.
Professor of Soil Mechanics (Visiting)

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

EUGENE MIRABELLI, S.B.
Associate Professor of Structural Design

ALEXANDER JAMIESON BONE, S.M.
Associate Professor of Transportation Engineering

JAMES ALBERT MURRAY, S.B.
Associate Professor of Materials

THOMAS WILLIAM LAMBE, SC.D.
Associate Professor of Soil Mechanics

JOHN MELVIN BIGGS, S.M.
Associate Professor of Structural Engineering

HOWARD SIMPSON, SC.D.
Associate Professor of Structural Engineering

DONALD ROBERT FERGUSSON HARLEMAN, SC.D.
Associate Professor of Hydraulics

ROSS ERWIN McKINNEY, SC.D.
Associate Professor of Sanitary Engineering

ROBERT VAN DUYNE WHITMAN, SC.D.
Assistant Professor of Soil Mechanics

VINCENT JACOB ROGGEVEEN, M.B.A., S.M.
Assistant Professor of Transportation Engineering

PETER STURGES EAGLESON, SC.D.
Assistant Professor of Hydraulic Engineering

FRANK JOSEPH HEGER, JR., S.M.
Assistant Professor of Structural Design

FREDERICK JEROME McGARRY, A.B., S.M.
Assistant Professor of Materials

CHARLES LESLIE MILLER, S.M.
Assistant Professor of Surveying

SAUL NAMYET, S.B.
Assistant Professor of Structural Engineering

ALBERT SCHEFFER LANG, S.B.
Assistant Professor of Transportation Engineering

RONALD ELLIOTT NECE, SC.D.
Assistant Professor of Hydraulics

JAMES EDWIN ROBERTS, S.B.
Assistant Professor of Soil Mechanics

JAMES MARTIN SYMONS, SC.D.
Assistant Professor of Sanitary Engineering

Lecturers

GEORGE WILLIAM McCREERY, S.B.
Construction Management

KARL TERZAGHI, DR. ING.
Soil Mechanics

Instructors

CHARLES CUSHING LADD, A.B., S.M.
DANIEL RITTENHOUSE SCHURZ, B.A., S.B.
MARTIN WOHL, S.B.

Technical Instructor

ALBERT JOSEPH O'NEILL, S.B.

Research Associates

JACOB JOSEPH BIKERMAN, PH.D.
ROBERT TORRENCE MARTIN, PH.D.

Professors Emeriti

CHARLES MILTON SPOFFORD, S.B.
Hayward Professor of Civil Engineering, Emeritus

CHARLES BLANEY BREED, S.B.
Professor of Civil Engineering, Emeritus

JOHN BRAZER BABCOCK, 3D, S.B.
Professor of Railway Engineering, Emeritus; Lecturer

WALTER CHARLES VOSS, S.M.
Professor of Building Construction, Emeritus

WILLIAM EDWARD STANLEY, C.E.
Professor of Sanitary Engineering, Emeritus; Lecturer

CIVIL AND SANITARY ENGINEERING

Civil engineering, as its name implies, is the branch of engineering most directly concerned with the betterment of modern civilization. The civil engineer changes the geography of the earth as he conceives, engineers, and executes the construction of the structures and ground facilities that comprise systems for transportation, water control, and improved environment for living, working, and recreation. This is systems engineering on its largest scale; other branches of engineering have their unquestioned place in segments of these systems, but no engineer is better equipped to embrace the systems as a whole than is the civil engineer.

Civil engineering centers on the construction industry, which represents an annual expenditure of well over one-tenth of our national income. In the over-all economy, it is the most stable branch of the engineering profession; it flourishes not only in a time of gigantic defense expenditures but also in periods when a greater proportion of our national resources can be turned to peaceful pursuits.

For those who seek an outdoor life and the fascination of distant places, civil engineering in the many underdeveloped areas of the world may be appealing. Even greater opportunities lie in our own country, especially in our cities, where slum areas, building shortages, water shortages, industrial waste pollution, and traffic strangulation all demand attention. There are some who believe that the future trend is toward decentralization of our cities. Should this be so, there will be new communities to build and new networks of transportation to link them.

While many civil engineers are employed by private and governmental organizations, the opportunities for establishing a business of one's own — either as a consulting engineer or as a contractor — are more favorable than in the other branches of the engineering profession.

Facilities

The Department of Civil and Sanitary Engineering has excellent facilities for work in all phases of the field. The Structural Analysis Laboratory offers facilities for instruction and research in the static and dynamic behavior of structures. The Soil Mechanics Laboratory is available for instruction in experimental technique and for investigations of soils of various kinds. The Hydrodynamics Laboratory has facilities for fundamental studies in fluid mechanics and special investigations on hydraulic models. A newly equipped Transportation Laboratory and a new Photogrammetry Laboratory offer research facilities in these areas. The Sedgwick Laboratories of Sanitary Science are devoted to instruction and research in the scientific discipline comprising sanitary engineering. The Building Materials Laboratory has facilities for investigating the fundamental properties of engineering materials including concrete; cementitious materials; timber products; and plastics and laminates, the new synthetics.

THE UNDERGRADUATE PROGRAM

Civil Engineering (Course I)

The undergraduate curriculum in Civil Engineering is arranged so that all students receive training in the basic principles of mathematics and science; in the humanities; in engineering science, such as the mechanics of solids, fluids, and soils; and in civil engineering subjects such as surveying, engineering construction, structural engineering, and foundation engineering. A system of fourth-year electives permits some degree of specialization in such areas as construction, structural and foundation engineering, sanitary engineering, hydraulic engineering, or transportation engineering; or if the student prefers, his fourth-year program may be continued on a more general basis.

The Department believes that students should be introduced to actual engineering projects at an early stage in the educational program and has therefore introduced a two-term sequence called CIVIL ENGINEERING PROJECTS I and II (1.901 and 1.902) into the second year. The purpose of this is not to transmit a technician's skill and specialized method of approach but to develop the attributes which lie beyond the capacity of pure analysis and which are essential to the profession: imaginative power of conception and intuitive reasoning circumscribed by good judgment and practicality.

Students are also encouraged to spend their summers on actual engineering jobs, and the Department maintains a placement program especially directed toward that objective. Second-year subjects in surveying are helpful in connection with summer employment as well as with the entire educational program.

Much of the Institute's work in Sanitary Engineering (Course XI) and Building Engineering and Construction (Course XVII) is given

at the graduate level. However, undergraduates may gain a foundation in these branches through the electives within the Course in Civil Engineering (Course 1).

The Course leads to the degree of Bachelor of Science in Civil Engineering. The curriculum for the first year is shown on page 77; the curriculum for the second, third, and fourth years is shown below.

SECOND YEAR[1]

First Term

1.01	SURVEYING I	8–0
1.901	CIVIL ENGINEERING PROJECTS I	6–4
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		45

Second Term

1.02	SURVEYING II	8–0
1.40	STATICS AND DYNAMICS	3–5
1.902	CIVIL ENGINEERING PROJECTS II	4–2
8.04	PHYSICS	5–5
21 04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		49

THIRD YEAR

First Term

1.41	MATERIALS AND MECHANICS	6–6
1.601	FLUID MECHANICS	2–4
1.911	ENGINEERING CONSTRUCTION	5–4
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	4–6
12.321	ENGINEERING GEOLOGY	4–2
	[2]*Humanities*	3–5
		51

Second Term

1.30	SOIL MECHANICS	6–6
1.42	MATERIALS AND MECHANICS	6–6
1.44	ELEMENTARY STRUCTURAL ENGINEERING	6–2
1.602	FLUID MECHANICS	3–6
	[2]*Humanities*	3–5
		49

FOURTH YEAR

First Term

1.441	[3]STRUCTURAL DESIGN	6–0
1.451	STRUCTURAL ANALYSIS	3–6
	THESIS	2
	[2]*Humanities*	3–5
	Elective subjects (see next column)	*24*
		49

Second Term

1.442	[3]REINFORCED CONCRETE DESIGN	6–0
2.41	HEAT ENGINEERING	4–5
	THESIS	7
	[2]*Humanities*	3–5
	Elective subjects (see next column)	*18*
		48

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2.

[3] 1.443 STRUCTURAL DESIGN (7–2) and 1.444 REINFORCED CONCRETE DESIGN (7–2) may be substituted for 1.441 and 1.442.

ELECTIVE SUBJECTS

Approved fourth-year elective subjects are listed below. Students may, if they wish, choose two additional one-term subjects in humanities in lieu of other electives.

First Term

1.06	PHOTOGRAMMETRIC ENGINEERING (4–4)
1.201	TRANSPORTATION PLANNING (6–3)
1.31	SOIL ENGINEERING (3–6)
1.43	ADVANCED MATERIALS (2–4)
1.443	[1]STRUCTURAL DESIGN (7–2)
1.621	FLUID MECHANICS LABORATORY (6–0)
1.701	HYDROLOGY AND HYDRAULIC ENGINEERING (3–6)
1.781	SANITARY SCIENCE (3–6)
1.921	BUILDING CONSTRUCTION (3–3)
1.931	DWELLING HOUSE CONSTRUCTION (3–3)
15.11	INTRODUCTION TO INDUSTRIAL MANAGEMENT (3–6)
15.41	FINANCIAL MANAGEMENT (3–6)
15.50	ACCOUNTING (5–4)
15.61	BUSINESS LAW (3–6)

Second Term

1.04	APPLIED SURVEYING (5–4)
1.202	TRANSPORTATION ENGINEERING (6–3)
1.444	[1]REINFORCED CONCRETE DESIGN (7–2)
1.452	STRUCTURAL ANALYSIS (3–6)
1.702	HYDROLOGY AND HYDRAULIC ENGINEERING (3–6)
1.782	SANITARY ENGINEERING (3–6)
1.922	CONSTRUCTION MANAGEMENT (3–3)
15.11	INTRODUCTION TO INDUSTRIAL MANAGEMENT (3–6)
15.41	FINANCIAL MANAGEMENT (3–6)
15.61	BUSINESS LAW (3–6)

For students interested in specific fields of civil engineering, the subjects listed below are suggested. To these may be added other subjects of the student's choice, as time permits.

CONSTRUCTION ENGINEERING

First Term

1.43	ADVANCED MATERIALS (2–4)
1.443	[1]STRUCTURAL DESIGN (7–2)
1.921	BUILDING CONSTRUCTION (3–3)
1.931	DWELLING HOUSE CONSTRUCTION (3–3)

Second Term

1.444	[1]REINFORCED CONCRETE DESIGN (7–2)
1.452	STRUCTURAL ANALYSIS (3–6)
1.922	CONSTRUCTION MANAGEMENT (3–3)

HYDRAULIC ENGINEERING

First Term

1.621	FLUID MECHANICS LABORATORY (6–0)
1.701	HYDROLOGY AND HYDRAULIC ENGINEERING (3–6)

Second Term

1.702	HYDROLOGY AND HYDRAULIC ENGINEERING (3–6)

SANITARY ENGINEERING

First Term

1.621 FLUID MECHANICS LABORATORY (6–0)
1.701 HYDROLOGY AND HYDRAULIC ENGINEERING (3–6)
1.781 SANITARY SCIENCE (3–6)

Second Term

1.702 HYDROLOGY AND HYDRAULIC ENGINEERING (3–6)
1.782 SANITARY ENGINEERING (3–6)

STRUCTURAL AND FOUNDATION ENGINEERING

First Term

1.31 SOIL ENGINEERING (3–6)
1.443 [1]STRUCTURAL DESIGN (7–2)

Second Term

1.444 [1]REINFORCED CONCRETE DESIGN (7–2)
1.452 STRUCTURAL ANALYSIS (3–6)

TRANSPORTATION ENGINEERING

First Term

1.201 TRANSPORTATION PLANNING (6–3)
1.31 SOIL ENGINEERING (3–6)

Second Term

1.04 APPLIED SURVEYING (5–4)
1.202 TRANSPORTATION ENGINEERING (6–3)

[1] 1.443 STRUCTURAL DESIGN (7–2) and 1.444 REINFORCED CONCRETE DESIGN (7–2) may be substituted for 1.441 and 1.442 in the Course I curriculum.

THE GRADUATE PROGRAMS

The Department of Civil and Sanitary Engineering provides opportunity for graduate study and research leading to the degrees of Master of Science in Civil Engineering, Civil Engineer, and Doctor of Science in Civil Engineering. It also offers graduate programs in Sanitary Engineering (Course XI) and in Building Engineering and Construction (Course XVII).

Students may undertake graduate study either on a full-time basis or on a part-time basis in connection with a junior staff appointment. Financial aid is available to full-time students in the form of fellowships, scholarships, or loans. (See Section 3 and Appendix A.)

Civil Engineering (Course I)

Programs of study in civil engineering may be selected from the following fields:

Structural Engineering: advanced subjects dealing with analysis and design of statically indeterminate and other complex structures.

Soil Engineering: theoretical and experimental work dealing with soils and soil structures.

Hydraulics: theoretical and experimental work in fluids and hydraulic engineering.

Transportation Engineering and Surveying: design and operation of highways and airports; advanced surveying and photogrammetry.

Students may supplement their programs in these fields with approved subjects in sanitary engineering and building engineering and construction, and with approved subjects in related fields, such as mathematics, mechanics, materials, geology, nuclear engineering, and industrial management.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

In addition to the general requirements set forth in Section 3 of this Catalogue, applicants must present evidence of training in professional subjects considered essential for all civil engineers and corresponding substantially to the following Institute subjects:

SURVEYING (1.01 and 1.02)
STATICS AND DYNAMICS (1.40)
MATERIALS AND MECHANICS (1.41 and 1.42)
ELEMENTARY STRUCTURAL ENGINEERING (1.44)
STRUCTURAL DESIGN (1.441)
or
REINFORCED CONCRETE DESIGN (1.442)
STRUCTURAL ANALYSIS (1.451)
FLUID MECHANICS (1.601)

In addition, applicants must have sufficient undergraduate training to prepare them for the advanced subjects which they wish to take.

Further specific professional requirements prerequisite for graduate study in the various branches of civil engineering are given below.

For Fluid Mechanics and Hydraulic Engineering:
FLUID MECHANICS (1.602)
For Soil Engineering:
SOIL MECHANICS (1.30)
For Structural Engineering:
STRUCTURAL ANALYSIS (1.452)
For Transportation Engineering:
TRANSPORTATION PLANNING (1.201)
TRANSPORTATION ENGINEERING (1.202)

Students may make up deficiencies in prerequisites while pursuing a program of graduate work; they must remove any deficiencies before proceeding with advanced subjects dependent upon the prerequisites.

MASTER OF SCIENCE IN CIVIL ENGINEERING

At the discretion of the Department, up to 24 units of the more advanced subjects in the undergraduate curricula may be accepted in partial fulfillment of the requirements for the degree of Master of Science.

CIVIL ENGINEER

Programs of study leading to the degree of Civil Engineer provide opportunities for a broader training than that required for the Master's degree and better preparation for professional practice in civil engineering. The rigor of the

program and the quality of academic performance required are substantially those demanded of students working toward the Master's degree or those preparing for the General Examination for the Doctor's degree. The normal period of study for this degree is two full years beyond the Bachelor's degree.

DOCTOR OF SCIENCE IN CIVIL ENGINEERING

Only students who have shown promise of outstanding performance in work of a creative nature are encouraged to study for the doctorate. Students beginning graduate work whose records do not show this ability are usually advised to qualify first for the Master's degree. The thesis research for the doctorate is expected to make a contribution to professional knowledge in the field of civil engineering.

General requirements for the Doctor's degree are given in Section 3 of this Catalogue.

Each applicant for the doctorate in civil engineering is required to demonstrate his ability to read scientific literature in English and in two other modern languages, with German and French usually specified.

Sanitary Engineering (Course XI)

The Department offers graduate study and research in sanitary engineering as Course XI, to satisfy the requirements for the degrees of Master of Science in Sanitary Engineering, Sanitary Engineer, and Doctor of Science in Sanitary Engineering.

Special sanitary engineering subjects are offered dealing with: water resources and treatment; sewage, refuse and industrial waste processing and disposal; air pollution control; sanitary chemistry and chemical examination of water, sewage and industrial wastes; sanitary microbiology and other applications of biochemistry; environmental sanitation; radiological health; and public health engineering.

Civil engineering subjects of value to sanitary engineers are also offered, such as advanced hydraulics, soil mechanics and foundations, structural theory and design, and others. In addition, a number of closely related subjects in other departments may be pursued to complete a particular plan of study.

Programs of study may be arranged to provide the fundamental training required for professional careers in the special fields of sanitary engineering, including: engineering design and construction of sanitary facilities, and consulting engineering practice; process or functional design for water, sewage, and industrial waste treatment, refuse disposal and stream sanitation; operation and management of waterworks, sewage treatment plants and other sanitary facilities and services; and environmental sanitation with private corporations or in public health agencies.

SANITARY ENGINEERING LABORATORIES

The Sedgwick Laboratories of Sanitary Science provide well-equipped facilities for instruction and research in sanitary chemistry; sanitary biology and biochemistry; environmental sanitation in relation to nuclear energy; and engineering problems relating to water, sewage, and industrial waste treatment.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

In general, graduates of approved programs in civil engineering will have the necessary undergraduate background for graduate study leading to a career in any of the special fields of sanitary engineering. Graduates of approved programs in chemical engineering will be well prepared to take up sanitary engineering in the fields of industrial wastes and environmental sanitation; but if they desire to prepare for sanitary engineering design and construction, they should include additional studies in hydraulics and structural theory as part of their graduate programs. A graduate in any other field of engineering or in chemical or biological science will need additional undergraduate preparation, depending upon his previous training and the program of study proposed; or, he may qualify for study leading to a degree without specification of a field.

The general requirements are those given in Section 3 of this Catalogue, except that the requirement for DIFFERENTIAL EQUATIONS (M22) may be omitted.

In addition to the foregoing general requirements, the applicant for a degree in sanitary engineering must have the undergraduate training considered essential for all sanitary engineers and substantially equivalent to the following Institute subjects:

SURVEYING (1.01 and 1.02)
STATICS AND DYNAMICS (1.40)
MATERIALS AND MECHANICS (1.41 and 1.42)
ELEMENTARY STRUCTURAL ENGINEERING (1.44)
FLUID MECHANICS (1.601 and 1.602)
HYDROLOGY AND HYDRAULIC ENGINEERING (1.701)
SANITARY SCIENCE (1.781)
SANITARY ENGINEERING (1.782)

Students whose undergraduate training has been in some other field, such as chemical engineering, may substitute for the above subjects, required for civil engineering, other subjects well adapted to preparing a sanitary engineer for process work such as the treatment of industrial wastes.

MASTER OF SCIENCE IN SANITARY ENGINEERING

Up to 24 units of certain of the subjects listed above may be accepted, at the discretion of the Department, in partial fulfillment of the requirements for the degree of Master of Science in Sanitary Engineering. Students with proper undergraduate preparation normally complete the requirements for the degree in two terms.

SANITARY ENGINEER

Programs of study leading to the degree of Sanitary Engineer provide opportunities for a broader education than that required for the Master's degree and better preparation for professional practice in sanitary engineering. The quality of academic performance required is substantially that demanded of students working toward the Master's degree or preparing for the General Examination for the Doctor's degree. The normal period of study for this degree is two full years beyond the Bachelor's degree.

DOCTOR OF SCIENCE IN SANITARY ENGINEERING

Only students who have shown promise of outstanding performance in work of a creative nature are encouraged to study for the doctorate. Students beginning graduate work whose records do not yield evidence of this ability are usually advised to qualify first for the Master's degree. The thesis research for the doctorate is expected to make an original contribution to professional knowledge in the field of sanitary engineering.

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

Each applicant for the doctorate in sanitary engineering is required to demonstrate his ability to read scientific literature in English and in two other modern languages, with German and French usually preferred.

Building Engineering and Construction (Course XVII)

The Department of Civil and Sanitary Engineering offers in Course XVII opportunities for graduate study and research in building engineering and construction, leading to the degrees of Master of Science in Building Engineering and Construction, and Building Engineer.

Programs for graduate study are flexible, and students are encouraged to work out individual plans with Registration Officers. These may include, in addition to subjects in Building Engineering and Construction described on pages 248 and 249 of this Catalogue, graduate subjects in such related fields as soil mechanics, foundations, structural mechanics, statically indeterminate structures, structural engineering, mathematics, theory of elasticity, economics, finance, industrial management, labor relations, air conditioning, and certain subjects in the undergraduate curricula.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

The general requirements for all graduate students given in Section 3 of this Catalogue are applicable, except that the requirement for DIFFERENTIAL EQUATIONS (M22) may in certain instances be waived. In addition to these general requirements, and except as noted below, candidates should have completed subjects approximately the equivalent of the following:

SURVEYING I (1.01)
STATICS AND DYNAMICS (1.40)
MATERIALS AND MECHANICS (1.41 and 1.42)
ELEMENTARY STRUCTURAL ENGINEERING (1.44)
STRUCTURAL DESIGN (1.441)[1]
REINFORCED CONCRETE DESIGN (1.442)[1]
ENGINEERING CONSTRUCTION (1.911)
BUILDING CONSTRUCTION (1.921)[1]
CONSTRUCTION MANAGEMENT (1.922)[1]

[1] Up to a total of 24 units of these subjects may count for credit toward either Master's or Engineer's degree, if they have not already been accepted for credit toward the Bachelor's degree.

In special instances, suitable professional experience may be accepted in lieu of formal training in certain of the above subjects. Otherwise, the student may make up prerequisites during attendance as a graduate student.

MASTER OF SCIENCE IN BUILDING ENGINEERING AND CONSTRUCTION

Subject to Department approval, up to 24 units of the more advanced undergraduate subjects may be accepted in partial fulfillment of the requirements for the degree of Master of Science.

BUILDING ENGINEER

Programs of study leading to the degree of Building Engineer provide opportunities for a broader training than that required for the Master's degree and better preparation for professional practice in building engineering and construction, and in management. The rigor of the program and the quality of academic performance required are substantially those demanded of students working toward the Master's degree. The normal period of study is two full years beyond the Bachelor's degree.

Department of Electrical Engineering

GORDON STANLEY BROWN, SC.D., D.ENG.
Professor of Electrical Engineering; in charge of the Department

CARLTON EVERETT TUCKER, S.B.
Professor of Electrical Engineering; Executive Officer

HAROLD LOCKE HAZEN, SC.D.
Professor of Electrical Engineering; Dean of the Graduate School

MURRAY FRANK GARDNER, S.M.
Professor of Electrical Engineering

ERNST ADOLPH GUILLEMIN, PH.D.
Professor of Electrical Communications

SAMUEL HAWKS CALDWELL, SC.D.
Professor of Electrical Engineering

ARTHUR ROBERT VON HIPPEL, PH.D.
Professor of Electrophysics

HAROLD EUGENE EDGERTON, SC.D., D.ENG.
Professor of Electrical Measurements

EUGENE WHEELOCK BOEHNE, D.ENG.
Professor of Electrical Engineering

JEROME BERT WIESNER, PH.D.
Professor of Electrical Engineering; Director of Research Laboratory of Electronics

WILLIAM HENRY RADFORD, D.ENG.
Professor of Electrical Communications; Associate Director of Lincoln Laboratory

LAN JEN CHU, SC.D.
Professor of Electrical Engineering

JOHN GEORGE TRUMP, SC.D.
Professor of Electrical Engineering

RICHARD HENRY BOLT, PH.D. (*Absent*)
Professor of Acoustics

KARL LELAND WILDES, S.M.
Professor of Electrical Engineering

HENRY JOSEPH ZIMMERMANN, S.M.
Professor of Electrical Engineering; Associate Director of Research Laboratory of Electronics

CLAUDE ELWOOD SHANNON, PH.D.
Professor of Communication Sciences

ROBERT MARIO FANO, SC.D.
Professor of Electrical Communications

WALTER ALTER ROSENBLITH, ING.RAD.
Professor of Communications Biophysics

PAUL FRANKLIN CHENEA, PH.D.
Edwin Sibley Webster Professor of Electrical Engineering (Visiting)

LAUREL JONES LEWIS, PH.D.
Professor of Electrical Engineering (Visiting)

NATHANIEL ROCHESTER, S.B.
Professor of Communications Sciences (Visiting)

DAVID CALVIN WHITE, PH.D.
Professor of Electrical Engineering

RICHARD DUDLEY FAY, A.B., S.B.
Associate Professor of Electrical Communications, Emeritus; Lecturer

RICHARD HENRY FRAZIER, S.M.
Associate Professor of Electrical Engineering

PARRY MOON, S.M.
Associate Professor of Electrical Engineering

TRUMAN STRETCHER GRAY, SC.D.
Associate Professor of Engineering Electronics

CHARLES KINGSLEY, JR., S.M.
Associate Professor of Electrical Engineering

YUK-WING LEE, SC.D.
Associate Professor of Electrical Engineering

GEORGE CHENEY NEWTON, JR., SC.D.
Associate Professor of Electrical Engineering

WILLIAM KIRBY LINVILL, SC.D. (*Absent*)
Associate Professor of Electrical Engineering

JOHN FRANCIS REINTJES, M.E.E.
Associate Professor of Electrical Engineering

SAMUEL JEFFERSON MASON, SC.D.
Associate Professor of Electrical Engineering

RICHARD BROOKS ADLER, SC.D.
Associate Professor of Electrical Engineering

LOUIS DIJOUR SMULLIN, S.M.
Associate Professor of Electrical Engineering

PETER ELIAS, PH.D.
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EWAN WATTS FLETCHER, PH.D.
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ROBERT LOUIS KYHL, PH.D.
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DAVID ALBERT HUFFMAN, SC.D.
Associate Professor of Electrical Engineering

WILLIAM WALTHER SEIFERT, SC.D.
Associate Professor of Electrical Engineering

KENNETH NOBLE STEVENS, SC.D.
Associate Professor of Electrical Engineering

HERMANN ANTON HAUS, SC.D.
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MARCY EAGER, S.B.
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WILLIAM McCONWAY SIEBERT, SC.D.
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LEONARD ABRAHAM GOULD, SC.D.
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MAHMOUD RIAZ, SC.D.
Assistant Professor of Electrical Engineering

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JOHN GRANLUND, SC.D.
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BERNARD WIDROW, SC.D.
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MOISE HERBERT GOLDSTEIN, JR., SC.D.
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AMAR GOPAL BOSE, SC.D.
Assistant Professor of Electrical Engineering

DENYS OSMUND AKHURST, PH.D.
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EDWARD ARTHURS, SC.D.
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PERRY AMBROSE MILES, PH.D.
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CAMPBELL LEACH SEARLE, S.M.
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RICHARD DOUGLAS THORNTON, SC.D.
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JOHN McREYNOLDS WOZENCRAFT, SC.D.
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ELIAS PANAYIOTIS GYFTOPOULOS, SC.D.
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WILLIAM DAVID JACKSON, B.SC.
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Lecturers

JORDAN JAY BARUCH, SC.D.
LEO LEROY BERANEK, SC.D.
WESLEY ALLISON CLARK, JR., A.B.
GODFREY THOMAS COATE, M.S.
ALEXANDER KUSKO, SC.D.

Instructors

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DUDLEY ALLEN BUCK, S.M.
WILLIAM TOWER PEAKE, S.M.
JAMES FREDERICK KAISER, S.M.
DAVID REMPFER WHITEHOUSE, SC.D.
PAUL EDWARD GRAY, S.M.
LAWSON PARKS HARRIS, S.M.
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ABRAHAM BERS, S.M.
JOHN BLAIR, S.M.
JOSÉ MARIA BORREGO-LARRALDE, S.M.
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LEO JEDYNAK, S.M.
ROBERT PENDLETON RAFUSE, S.M.

Assistant to Head of Department

JOHN AVERY TUCKER, M.ENG.

Non-Resident Instructors

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JAMES RICHARDSON BELFORD, B.A.
ARAM BOYAJIAN, A.B., E.E.
IRWIN DORROS, S.M.
RICHARD KARL GARDNER, S.M.
SORAB KHUSHRO GHANDI, PH.D.
LEO HELLERMAN, M.A., B.E.E.
STANLEY REID HURST, SC.D.
EARLE BERNARD MULLEN, M.A.
LEONARD RABINS, M.S.E.E.
MANDAKINI SANÉ ROHATGI, PH.D.
JOHN PARKER RUNYON, M.E., DIPL.MATH.
ARTHUR P. STERN, M.S.
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JEROME JOSEPH SURAN, B.S.E.E.
WILLIAM RUSSELL THICKSTUN, JR., PH.D.
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JOHN WELLINGTON IRWIN, M.D.
LEROY ALLEN SCHALL, SC.B.
ALEXANDER SMAKULA, PH.D.
FRANCIS LEE WEILLE, M.D.
PATRICK YOUTZ, A.B., S.M.

Professors Emeriti

RALPH RESTIEAUX LAWRENCE, S.B.
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WILLIAM HENRY TIMBIE, A.B.
Professor of Electrical Engineering and Industrial Practice, Emeritus
HERBERT BRISTOL DWIGHT, D.SC.
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RALPH GORTON HUDSON, S.B.
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RICHARD DUDLEY FAY, A.B., S.B.
Associate Professor of Electrical Communications, Emeritus; Lecturer
LYMAN MINER DAWES, S.B.
Assistant Professor of Industrial Applications, Emeritus

ELECTRICAL ENGINEERING

Starting from a relatively modest beginning about one hundred years ago, the field of electrical engineering has become one of great variety and scope. Today its products and services influence the daily living of most of the world's population, and the tempo of growth and change continues. Because new concepts and developments are steadily appearing in the field, professional study and training must give more than a competence to handle the problems of the present. Students should not merely seek to acquire specific skills and methods; they must search for deep understanding of their work and direct it toward the future.

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

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

THE UNDERGRADUATE PROGRAMS

The Department offers three principal degree programs: Electrical Engineering (Course VI), a four-year program leading to the Bachelor of Science degree; the Cooperative Course in Electrical Engineering (Course VI-A), which interweaves industrial or research experience with education; and Electrical Science and Engineering (Course VI-B), which emphasizes a broad and deep mastery of the engineering sciences. Courses VI-A and VI-B both terminate with the Master of Science degree after five years of study.

The common objective of all three Courses 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 eight 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.

Laboratory work is coordinated with classroom work in each of the eight core subjects. 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. Individual 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)

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. About one-half of the senior year program — in addition to the humanities electives — may be engineering or science electives, at the free choice of the individual student. His selection of subjects, made in consultation with his Registration Officer, 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 Course leads to the degree of Bachelor of Science in Electrical Engineering.

The curriculum for the first year of Course VI is given on page 77; the curriculum for the second, third, and fourth years is shown below.

SECOND YEAR[1,2]

First Term

2.001	APPLIED MECHANICS I	3–5
6.00	INTRODUCTORY CIRCUIT THEORY	7–5
8.031	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		47

Second Term

2.002	APPLIED MECHANICS II	3–5
6.01	INTRODUCTORY CIRCUIT THEORY	7–5
8.041	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		47

THIRD YEAR

First Term

6.02	ELECTRONIC DEVICES AND CIRCUITS	7–5
6.03	FIELDS, ENERGY, AND FORCES	7–5
M 351	ADVANCED CALCULUS FOR ENGINEERS	3–6
	[3]*Humanities*	3–5
	[4]*Elective subject*	*9*
		50

Second Term

6.05	ELECTRONIC CIRCUITS AND SIGNALS	7–5
6.06T	ELECTROMECHANICAL ENERGY CONVERSION	7–5
	[3]*Humanities*	3–5
	[5]*Elective subjects*	*18*
		50

FOURTH YEAR

First Term

6.07	ENERGY TRANSMISSION AND RADIATION	6–6
6.08	MOLECULAR ENGINEERING	7–5
	THESIS	2
	[3]*Humanities*	3–5
	[6]*Elective subjects*	*12*
		46

Second Term

THESIS	7
[3]*Humanities*	3–5
[6]*Elective subjects or additional* THESIS	*30*
	45

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] See footnote 3.

[3] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2. Students are urged to consider a modern language sequence in the Humanities. Plans for such a program should begin in the first or second year, depending upon the previous language background.

[4] This subject must be selected from the following:

2.40 HEAT ENGINEERING (4–5)
8.051 ATOMIC AND NUCLEAR PHYSICS I (4–5)

[5] Subjects should be selected from the following or from equivalent out-of-Department subjects:

2.07 DYNAMICS (3–6)
2.42 HEAT ENGINEERING (3–6)
8.052 ATOMIC AND NUCLEAR PHYSICS II (4–5)
M 352 ADVANCED CALCULUS FOR ENGINEERS (3–6)

[6] Registration Officers should be consulted for suitable elective subjects. A total of 16 units of additional humanities or language may be elected.

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

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

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

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

The manufacturing companies — such as the General Electric Company, International Business Machines Corporation, Raytheon Manufacturing Company, General Radio Company, and Philco Corporation — provide experience in production and manufacturing, testing, design, development, and research in various areas of the electronics, power, communications, control, and computation fields. The utility companies — including the American Electric Power Corporation and the Boston Edison Company — provide experience related to the technical operation, system planning, administration, and supporting research of a large electric utility system. The Bell Telephone Laboratories afford the opportunity for industrial practice in the development of communication apparatus, circuits, and equipment for the Bell Telephone System. The government service laboratories, such as the Naval Ordnance Laboratory and the Air Force Cambridge Research Center, provide opportunities for students to learn about and to experience, with progressively increased responsibility, the many skills and technical disciplines which are brought together in a large laboratory that is concerned with basic and applied research and creative engineering covering a wide range of electrical technology.

Students are divided into two groups, one of which studies at the Institute while the other works at the plants of the cooperating companies. Students in training at the plants are subject to the usual company regulations. They receive

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

The Course leads to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year. The curriculum for the two groups is shown below.

GROUP A			GROUP B		
FIRST AND SECOND YEARS					
Same as Electrical Engineering (Course VI)			*Same as Electrical Engineering (Course VI)*		
THIRD YEAR					
Summer Term					
	At M.I.T.:			*At Plants:*	
6.02	ELECTRONIC DEVICES AND CIRCUITS	7–5	6.021	ELECTRONIC DEVICES AND CIRCUITS	4–4
6.03	FIELDS, ENERGY, AND FORCES	7–5		INDUSTRIAL PRACTICE	40 h.p.w.
	[1]*Elective subject*	*9*		*(Students register for one of the following:* 6.901, 6.905, 6.911, 6.931, 6.941, 6.951, 6.961, 6 971, 6.981, *or* 6.991)	
		33			
First Term					
	At Plants:			*At M.I.T.:*	
M 351	ADVANCED CALCULUS FOR ENGINEERS	3–6	6.022	ELECTRONIC DEVICES AND CIRCUITS LABORATORY	3–1
	INDUSTRIAL PRACTICE	40 h.p.w.	6.03	FIELDS, ENERGY, AND FORCES	7–5
	(Students register for one of the following: 6.901, 6.905, 6.911, 6.931, 6.941, 6.951, 6.961, 6.971, 6.981, *or* 6.991)		14.01	[2]ECONOMIC PRINCIPLES I — *Humanities*	3–5
			M 351	ADVANCED CALCULUS FOR ENGINEERS	3–6
				[2]*Humanities*	3–5
				[1]*Elective subject*	*9*
					50
Second Term					
	At M.I.T.:			*At Plants:*	
6.05	ELECTRONIC CIRCUITS AND SIGNALS	7–5	M 352	ADVANCED CALCULUS FOR ENGINEERS	3–6
6.06T	ELECTROMECHANICAL ENERGY CONVERSION	7–5		INDUSTRIAL PRACTICE	40 h.p.w.
14.01	[2]ECONOMIC PRINCIPLES I — *Humanities*	3–5		*(Students register for one of the following:* 6.902, 6.906, 6.912, 6.932, 6.942, 6.952, 6.962, 6.972, 6.982, *or* 6.992)	
	[2]*Humanities*	3–5			
	[3]*Elective subject*	*9*			
		49			
FOURTH YEAR					
Summer Term					
	At Plants:			*At M.I.T.:*	
M 352	ADVANCED CALCULUS FOR ENGINEERS	3–6	6.05	ELECTRONIC CIRCUITS AND SIGNALS	7–5
	INDUSTRIAL PRACTICE	40 h.p.w.	6.06T	ELECTROMECHANICAL ENERGY CONVERSION	7–5
	(Students register for one of the following: 6.902, 6.906, 6.912, 6.932, 6.942, 6.952, 6.962, 6.972, 6.982, *or* 6.992)			*Professional elective subject*	*9*
					33

GROUP A			GROUP B		
FOURTH YEAR (*continued*)					
First Term					
	At M.I.T.:			*At Plants:*	
6.07	ENERGY TRANSMISSION AND RADIATION	6–6	6.071	ENERGY TRANSMISSION AND RADIATION	3–6
6.08	MOLECULAR ENGINEERING	7–5		INDUSTRIAL PRACTICE	40 h.p.w.
	[2]*Humanities*	3–5		(*Students register for one of the following:* 6.903, 6.907, 6.913, 6.933, 6.943, 6.953, 6.963, 6.973, 6.983, *or* 6.993)	
	[2]*Humanities*	3–5			
	Professional elective subject	*9*			
		49			
Second Term					
	At Plants:			*At M.I.T.:*	
	Elective subject	*9*	6.072	ENERGY TRANSMISSION AND RADIATION LABORATORY	3–0
	INDUSTRIAL PRACTICE	40 h.p.w.	6.08	MOLECULAR ENGINEERING	7–5
	(*Students register for one of the following:* 6.903, 6.907, 6.913, 6.933, 6.943, 6.953, 6.963, 6.973, 6.983, *or* 6.993)			[2]*Humanities*	3–5
				[2]*Humanities*	3–5
				Professional elective subject	*9*
				[3]*Elective subject*	*9*
					49
GRADUATE YEAR					
Summer Term					
	At Plants:			*At Plants:*	
	Elective subject	*9*		*Elective subject*	*9*
	INDUSTRIAL PRACTICE	40 h.p.w.		INDUSTRIAL PRACTICE	40 h.p.w.
	(*Students register for one of the following:* 6.904, 6.908, 6.914, 6.934, 6.944, 6.954, 6.964, 6.974, 6.984, *or* 6.994)			(*Students register for one of the following:* 6.904, 6.908, 6.914, 6.934, 6.944, 6.954, 6.964, 6.974, 6.984, *or* 6.994)	
First Term					
	At M.I.T.:			*At M.I.T.:*	
	Graduate study and thesis	*48*		*Graduate study and thesis*	*48*
		48			48
Second Term					
	At M.I.T.:			*At M.I.T.:*	
	Graduate study and thesis	*48*		*Graduate study and thesis*	*48*
		48			48

[1] This subject must be selected from the following:
2.40 HEAT ENGINEERING (4–5)
8.051 ATOMIC AND NUCLEAR PHYSICS I (4–5)

[2] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken, as specified. The humanities requirement is described in Section 2.

[3] The subject should be selected from the following or from equivalent out-of-Department subjects:
2.07 DYNAMICS (3–6)
2.42 HEAT ENGINEERING (3–6)
8.052 ATOMIC AND NUCLEAR PHYSICS II (4–5)

Electrical Science and Engineering (Course VI-B)

This five-year 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 Course is distinguished from Courses VI and VI-A 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 Course VI-B 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 Course VI curriculum may be admitted at the beginning of the junior year. It is expected that students who elect Course VI-B 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 Course to spend at least one and preferably two summers gaining practical experience in some industrial activity before graduation. Registration Officers will assist them with this.

The Course leads to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year. The curriculum for the first year is shown on page 77; for the later years, it is as follows:

SECOND YEAR

First Term

2.001	APPLIED MECHANICS I	3–5
6.00	INTRODUCTORY CIRCUIT THEORY	7–5
8.031	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		47

Second Term

2.002	APPLIED MECHANICS II	3–5
6.01	INTRODUCTORY CIRCUIT THEORY	7–5
8.041	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		47

THIRD YEAR

First Term

6.02	ELECTRONIC DEVICES AND CIRCUITS	7–5
6.03	FIELDS, ENERGY, AND FORCES	7–5
8.051	ATOMIC AND NUCLEAR PHYSICS I	4–5
M 351	ADVANCED CALCULUS FOR ENGINEERS	3–6
	[2]*Humanities*	3–5
		50

Second Term

6.05	ELECTRONIC CIRCUITS AND SIGNALS	7–5
6.063	ELECTRICAL ENERGY CONVERSION	7–5
8.052	ATOMIC AND NUCLEAR PHYSICS II	4–5
M 76	PROBABILITY	3–6
	[2]*Humanities*	3–5
		50

FOURTH YEAR

First Term

6.073	ENERGY TRANSMISSION AND RADIATION	6–6
6.11	SEMINAR	2–4
	[2]*Humanities*	3–5
	Mathematics elective subject	*9*
	Elective subjects	*12*
		47

Second Term

6.083	MOLECULAR SCIENCE AND ENGINEERING	7–5
6.12	SEMINAR	2–4
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4–6
	[2]*Humanities*	3–5
	Elective subject	*9*
		45

GRADUATE YEAR

First Term

	Graduate study and thesis	*48*

Second Term

	Graduate study and thesis	*48*

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2 of this Catalogue.

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 mathe-

matics, 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 program for the degree of Electrical Engineer requires a much broader two-year graduate program for students preparing for engineering practice. The three-year program for the degree of Doctor of Science or Doctor of Philosophy includes about one year of intensive research and leads toward careers in teaching or research. These one-, two-, and three-year periods are full-time minima for qualified Bachelors in Electrical Engineering.

There are no fixed programs of study for these degrees. Particular effort is made with each student to develop his program of graduate study along the lines of his individual special interest. Such a procedure provides him with a strong incentive for a high level of accomplishment and gives him a specialized ability that is immediately useful. This specialized ability, however, is deemed a less significant result of graduate study than is the clearer insight into and better integration of fundamental principles so generally gained by the graduate student. Soundly conceived advanced work rarely fails to send the student back to deepen his understanding of elementary but basic principles. These ideas are evidenced by the methods of approach used in graduate engineering subjects and by the fact that students usually include in their programs further formal study of mathematics and physics.

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

Advanced network analysis and synthesis
Pulse circuits
Microwave circuits
Electronic circuits
Switching circuits
Engineering electronics
Instrumentation
Transient analysis
Applied field theory
Antennas
Transistors and other solid-state control devices
Information theory
Nonlinear circuit theory
Noise theory
Communications theory and systems
Analog and digital computers
Pulsed-data systems
Feedback and process control systems
Energy conversion and control devices and systems
Hearing, speech, and language
Acoustics
Electro-neurophysiology
Solid-state materials
Nonlinear system analysis
Molecular engineering

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

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

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

In the *Research Laboratory of Electronics*, sponsored jointly by the Departments of Electrical Engineering and Physics, particular attention is currently given to microwave electronics and its applications in modern communication systems and devices, network theory and network synthesis, the generation of high-energy radiation, electronic computation, microwave gaseous discharges and their role in providing high-density

plasmas, atomic beams in relation to the development of time standards and the determination of electric and magnetic moments, processing and transmitting information, language translation, switching logic, statistical theory of communication, transistor circuitry and applications, and communications biophysics.

In *energy conversion and control*, a group is concerned with understanding, developing, and controlling processes by which energy is converted between electrical and other forms — specifically energy conversion utilizing the interaction of electromagnetic energy and semiconductor materials, electromechanical energy conversion utilizing both magnetohydromagnetic principles and the physics of interaction between moving material bodies and electromagnetic fields, heat transfer in electrical conversion devices, dynamics of and analog representations for generating and regulating portions of electrical systems for air vehicles, analysis of nonlinear continuous and pulsed-data-type systems, and the analysis of magnetic and semiconductor power-type control devices.

In *computer components and systems*, a group is concerned with basic research in computer design and application. Digital computer components involving transistors, ferrites, and other new materials are being devised. One group is developing a computer component called a "cryotron," whose valve action utilizes control of superconductivity by a magnetic field at temperatures near absolute zero. Microminiaturization via evaporative-film techniques are becoming increasingly effective in component development. Of interest also are general mathematical techniques such as linear system analysis, probability theory, linear programming, and Monte Carlo methods which lead to formulations requiring large-scale digital computation. These activities coordinate with the *M.I.T. Computation Center*, which has as its objective the encouragement and training of students, engineers, and scientists in the use of modern computing machines in their research efforts.

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

In the *Laboratory for Insulation Research* a new approach to the synthesis of engineering materials, termed "molecular engineering," is being pioneered. Of current interest are investigations of the behavior of matter, at high electric field strengths; the magnetic behavior of matter at microwave frequencies; the study of the formation and behavior of ferroelectric domains and their dependence on electric field, temperature, and pressure and frequency; and the potentialities and limitations of ferromagnetic semiconductors.

In *acoustics*, research deals with sound waves from sub-audible to high-ultrasonic frequencies in solids, liquids, and gases, covering a wide range of topics relevant to communications, speech synthesis, physical acoustics, and techniques for the use of sound and ultrasound in engineering and science.

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

From the emphasis given to the graduate student's association with active projects, it is evident that his graduate study is to be conceived as a coordinated whole, culminating in thesis research, affording the student an opportunity to develop his ability to do constructive reasoning and to contribute to the advancement of engineering.

Studies toward an advanced degree can be pursued either as a full-time student or in combination with a graduate assistantship, of which about sixty are offered each year beginning in the summer or in the fall. These assistantships provide the opportunity for participation in one of the sponsored research laboratories associated with the Electrical Engineering Department, or participation in the teaching program of the Department, or both. All assistantships in the Department of Electrical Engineering are full time and permit carrying about 40 per cent of a full-time graduate study program. Thus, a degree requires about twice the minimum time, but holders of the appointments find the additional educational experience associated with them quite as valuable as the formal study. For the doctorate especially, candidates often desire both teaching and research experience. The financial assistance given by these appointments is frequently an important additional consideration.

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

Entrance Requirements for Graduate Study

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

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:

APPLIED MECHANICS (2.001, 2.002)
HEAT ENGINEERING (2.40)
or
ATOMIC AND NUCLEAR PHYSICS I (8.051)
or
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)
INTRODUCTORY CIRCUIT THEORY (6.00, 6.01)
ELECTRONIC DEVICES AND CIRCUITS (6.02)
FIELDS, ENERGY, AND FORCES (6.03)
ELECTRONIC CIRCUITS AND SIGNALS (6.05)
ELECTROMECHANICAL ENERGY CONVERSION (6.06T)
ENERGY TRANSMISSION AND RADIATION (6.07)
MOLECULAR ENGINEERING (6.08)
ADVANCED CALCULUS FOR ENGINEERS (M351)

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 to be 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 Master of Science Degree

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, and experimental aspects of electrical engineering.

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

The Electrical Engineer Degree

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 degree. Programs for this degree are elective except for the thesis and seminar and ordinarily require at least four terms of graduate study beyond the Bachelor's degree level.

The required seminar gives students an opportunity to report orally on some phase of work or on a case study in the field of his specialty. In this seminar each student is expected to demonstrate competence in recognizing and appraising key issues in the orderly and creative application of science and technology in engineering.

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

The Doctorate

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

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

The General Examination is divided into two parts, of which the first is both written and oral. This first part, which should be taken within one year after beginning graduate study, is designed to determine whether the candidate is qualified, in terms of command of the basic sciences and practices of electrical engineering, to take advanced study and research of doctoral caliber. The second part of the General Examination is wholly oral and is taken after the problem for the thesis research has been chosen and the related preparatory program of specialized graduate study has been completed.

Each applicant for the doctorate in electrical engineering is required to demonstrate his ability to read scientific literature in English and in two other modern languages selected from German, Russian, and French.

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

Department of Mechanical Engineering

JOSEPH HENRY KEENAN, S.B.
Professor of Mechanical Engineering; in charge of the Department

JAMES HOLT, S.B.
Professor of Mechanical Engineering; Executive Officer

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

EDWARD ROBINSON SCHWARZ, M.S.
Professor of Textile Technology; in charge of Textile Technology

CARL RICHARD SODERBERG, TEKN.D., D.ENG.
Professor of Mechanical Engineering; Dean of the School of Engineering

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

JOHN THOMAS RULE, S.B.
Professor of Engineering Graphics; Dean of Students

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

EGON OROWAN, D.ENG.
George Westinghouse Professor of Mechanical Engineering

ASCHER HERMAN SHAPIRO, SC.D.
Professor of Mechanical Engineering

MILTON CLAYTON SHAW, SC.D.
Professor of Mechanical Engineering

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

JOSEPH KAYE, PH.D.
Professor of Mechanical Engineering

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

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

ARTHUR LAWRENCE TOWNSEND, S.B.
Associate Professor of Mechanical Engineering, Emeritus; Lecturer Director of the Lowell Institute School

CARL LOUIS SVENSON, S.M.
Associate Professor of Heat Engineering

ALVIN SLOANE, B.S.
Associate Professor of Applied Mechanics; Secretary of the Faculty

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

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

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

AUGUST LUDWIG HESSELSCHWERDT, JR., S.M.
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BRANDON GARNER RIGHTMIRE, SC.D.
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Associate Professor of Mechanical Engineering

KENNETH ROBERT WADLEIGH, SC.D.
Associate Professor of Mechanical Engineering

STANLEY BACKER, SC.D.
Associate Professor of Mechanical Engineering

JAMES ALAN FAY, PH.D.
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FRANK AMBROSE MCCLINTOCK, PH.D.
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MAURICE EDWIN SHANK, SC.D.
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TAU-YI TOONG, SC.D.
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OSMAN KAMEL MAWARDI, PH.D.
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JAMES BIGELOW RESWICK, SC.D.
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ROBERT HAMILTON CANNON, JR., SC.D.
Associate Professor of Mechanical Engineering

JESSE LOWEN SHEARER, SC.D.
Associate Professor of Mechanical Engineering

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

DAVID SHOTWELL WOOD, PH.D.
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WALTER CARL EBERHARD, S.B.
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DEANE LENT, A.B.
Assistant Professor of Engineering Drawing

GERALD PUTNAM, S.B.
Assistant Professor of Engineering Graphics

HENRY MARTYN PAYNTER, SC.D.
Assistant Professor of Mechanical Engineering

STEVEN ANSON COONS
Assistant Professor of Engineering Graphics

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

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

THOMAS PAUL RONA, SC.D.
Assistant Professor of Mechanical Engineering

THOMAS PATON GOODMAN, SC.D.
Assistant Professor of Mechanical Engineering

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

GEORGE ARTHUR BROWN, S.M.
Assistant Professor of Mechanical Engineering
ALVE JOHN ERICKSON, MECH.E.
Assistant Professor of Mechanical Engineering
FREDDIE DAVID EZEKIEL, SC.D. (*Absent*)
Assistant Professor of Mechanical Engineering
MIGUEL ANGEL SANTALO, MECH.E.
Assistant Professor of Mechanical Engineering
GEORGE NICKOLAS HATSOPOULOS, SC.D.
Assistant Professor of Mechanical Engineering
ROBERT RAYMOND ARCHER, PH.D.
Assistant Professor of Mechanical Engineering
PETER GRIFFITH, SC.D.
Assistant Professor of Mechanical Engineering
RICHARD JOSEPH NICKERSON, SC.D.
Assistant Professor of Mechanical Engineering
GEORGE SHERIDAN REICHENBACH, SC.D.
Assistant Professor of Mechanical Engineering
S. WILLIAM GOUSE, JR., S.M.
Assistant Professor of Mechanical Engineering
DAVID CLIFFORD PRIDMORE-BROWN, PH.D.
Assistant Professor of Mechanical Engineering
JOHN CLARK CHATO, M.S.
Assistant Professor of Mechanical Engineering
PHILIP GRAHAM HILL, S.M.
Assistant Professor of Mechanical Engineering
LAWRENCE CLAY HOAGLAND, MECH. E.
Assistant Professor of Mechanical Engineering
HERBERT HEATH RICHARDSON, S.M.
Assistant Professor of Mechanical Engineering
YASUTOSHI SENOO, DR.ENG.
Assistant Professor of Mechanical Engineering
JOSEPH LeCONTE SMITH, JR., M.S.
Assistant Professor of Mechanical Engineering

Lecturer

VICTOR EZRA HOWES, B.S.

Instructors

WARREN GEORGE NELSON, S.M.
THOMAS BROWN SHERIDAN, M.S.
JOHN ANDREW WELSH, S.M.
JEROME CATZ, S.M.
DWIGHT MAYLON BILLY BAUMANN, S.M.
PIERRE JOSEPH BROSENS, S.M.
DOUGLAS ALFRED EAST, A.B., S.M.
JOHN ERDMOND MAYER, JR., S.M.
PAUL JEROME BERENSON, S.M.
FRED WILLIAM BERG, B.M.E.
FORBES TAYLOR BROWN, S.M.
ZDENEN JAN JAROSLAV STEKLY, S.M.

Technical Instructors

RALPH JOHN BOWLEY
CLARENCE WILLIAM CHRISTIANSEN
FREDERICK HAROLD ANDERSON
JOHN LEACH
EVANS GRAVES ARNOLD

Research Associate

EDWARD PHIPPS KINGSBURY, SC.D.

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
GEORGE WRIGHT SWETT, S.B.
Professor of Machine Design, Emeritus
EARLE BUCKINGHAM
Professor of Mechanical Engineering, Emeritus
GORDON BALL WILKES, S.B.
Professor of Heat Engineering, Emeritus
THEODORE HOWARD TAFT, S.B.
Associate Professor of Heat Engineering, Emeritus
LAWRENCE SOUTHWICK SMITH, S.B.
Associate Professor of Applied Mechanics, Emeritus
WALTER HERMAN JAMES, S.B.
Associate Professor of Mechanical Engineering, Emeritus
ARTHUR LINDSAY GOODRICH, S.B.
Associate Professor of Drawing and Descriptive Geometry, Emeritus
IRVING HENRY COWDREY, S.B.
Associate Professor of Testing Materials, Emeritus
JOHN MOYES LESSELLS, B.SC.
Associate Professor of Mechanical Engineering, Emeritus
ARTHUR LAWRENCE TOWNSEND, S.B.
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ROY GIBSON BURNHAM, S.B.
Assistant Professor of Drawing and Descriptive Geometry, Emeritus
WALTER CARL EBERHARD, S.B.
Assistant Professor of Engineering Graphics, Emeritus; Lecturer

MECHANICAL ENGINEERING

Mechanical engineering is concerned with the invention, development, design, and manufacture of machines and equipment of many different types. As such, it embraces a wide range of interests and activities. The technological areas in which mechanical engineers are prominent include power production, industrial machinery, process equipment, automation of production processes, and propulsion systems and structures for aircraft, ships, and ground vehicles. Within these areas, however, an individual's effort may involve research in fundamentals, the development of advanced devices or systems, the synthesis of a complete device or system which works reliably and efficiently, or the management of groups working in research, development, design, or production. Mechanical engineers continue to make important contributions to such varied fields as aircraft engines and structures; nuclear power plants; rockets; steam, gasoline, and hydroelectric power plants; automatic control systems; production methods; materials of construction; ship design; and textile technology — in fact, in almost every major technological field. The broad capabilities of mechanical engineers are universally required.

Obviously a field of this width and diversification cannot be mastered in all its details in four college years — or even in a lifetime. Forty or fifty years ago a college graduate was supposed to understand the whole field in a general way and to be immediately useful to his first employer. Now the objective of education is rather to provide well-planned programs which develop strength in subjects basic to all or most of these applications. The aim is to graduate men with the versatility to advance with confidence in many possible directions and the adaptability to meet our rapidly changing technology.

A successful mechanical engineer possesses a combination of creative ingenuity and analytical understanding of mathematics and science. A man with creative ingenuity — for example, a prolific inventor — gains in effectiveness if he can distinguish which of his ideas are important and which are not. The man with analytical ability gains in effectiveness if he has original ideas worth analyzing. The most effective engineer is good in both directions, and the educational program of the Department aims at such a balanced development.

The Department believes that the formal undergraduate and graduate educational programs thrive best in an atmosphere of active research and development. This environment is provided by a faculty engaged in pressing forward on new ideas and by excellent laboratories where students are welcomed as young colleagues in the exciting job of trying to understand, to improve, and to innovate. The diverse interests of the Department are exemplified by the research groups active in such fields as thermodynamics, heat and mass transfer, fluid dynamics and high-speed gas dynamics, magnetohydrodynamics, control systems, metal cutting and processing, cryogenics, lubrication, friction and wear, vibrations, elastic and plastic behavior of materials and structures, photoelasticity and experimental stress analysis, refrigeration and air conditioning, textile technology, combustion, gas turbines, turbomachinery, internal-combustion engines, systems design, and machine design.

Enthusiasm for good ideas, whether new or old, provides the inspiration for good teaching and research. Starting with this premise, the Department provides programs designed to stimulate each student to excel in some aspects of mechanical engineering while developing a good general background. These programs provide not only a challenging intellectual experience but a sound preparation for a long and effective engineering career.

THE UNDERGRADUATE PROGRAMS

Mechanical Engineering (Course II)

The work in the first two years of this Course lays a thorough foundation in mathematics, physics, and chemistry. It includes four terms of humanities and two terms of introductory subjects in engineering, all of which is prescribed. In the succeeding two years each student has a wide area of choice and may follow his natural interests, restrained only by the necessity of a balanced and logical program, which must have the approval of the professor who is his Registration Officer. While the Registration Officer will consider any program a student may propose, the Department has worked out four general types of curricula. These four programs center around power and propulsion; engineering science; materials; and design, manufacturing, and controls.

POWER AND PROPULSION

Power may be produced by gasoline engines, steam cycles, gas turbines, jets, or as yet unde-

veloped devices like the hydrogen-fusion power plant. The subjects offered in this program in power and propulsion give the student experience in the scientific approach to the engineering problems which arise in power-producing machines. Since power machinery involves every branch of technology, the student has an opportunity to employ basic analytical methods drawn from a wide variety of disciplines — including thermodynamics, combustion, fluid mechanics, strength of materials, and machine design — and to apply them to the analysis and design of engines and power plants.

ENGINEERING SCIENCE

In recent years the world of science has seen revolutionary changes which have advanced man's understanding of nature far beyond the dreams of only a generation ago. These new concepts have opened fertile fields of knowledge whose practical exploitation has only been touched. This requires men broadly trained, to participate in almost any new technological development.

The program in engineering science prepares students for such a career by providing a course of study covering two general fields. The first includes physics, chemistry, and mathematics. The second constitutes what are generally called the engineering sciences: the dynamics of particles and solids, fluid dynamics, thermodynamics, and the dynamics of systems. This program differs from the others in that it incorporates more study in mathematics, physics, and applied science. Mastery of these fields provides the engineering scientist with a broad understanding of the present basis of science and technology and equips him with a solid foundation on which he may build a special competence in any of a wide variety of activities.

MATERIALS

Many advances in engineering design and technology are limited by the performance of materials available for any particular application. One of the important aspects of materials performance is the basic understanding of why materials behave mechanically in the way they do and what measures can be employed to take advantage of, or to improve on, 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 mechanical engineering and materials fields, depending upon the particular electives which they choose. These activities may range from the engineering aspects of advanced technological developments, where the problems are far from being understood, to the manufacturing, processing and development of new materials and to the technology of textiles.

DESIGN, MANUFACTURING, AND CONTROLS

Design and manufacturing are at the very core of all engineering projects, and by far the largest number of graduate mechanical engineers are engaged in these activities.

The starting point for work in this area is the invention of a useful device or process based upon sound scientific principles. The most effective of several possible methods of putting the basic idea into practice must next be selected. An efficient, reliable, and economical machine must then be designed, with careful consideration given to the methods of fabrication which will be employed. These are activities which call for sound engineering judgment.

The educational program emphasizes this reiterative process — science, visualization, design, and fabrication — in order to develop the student's engineering judgment and his confidence in attacking new and different problems, both essential qualities for his future professional career.

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

The Course based on any one of these four programs leads to the degree of Bachelor of Science in Mechanical Engineering.

The curriculum for the first year is shown on page 77; ENGINEERING DRAWING (D11) is recommended as one of the elective subjects. The undergraduate program for the second, third, and fourth years is shown on the next page.

SECOND YEAR[1]

First Term

2.001	APPLIED MECHANICS I	3–5
2.861	ENGINEERING DESIGN AND MANUFACTURE	8–4
8.03	PHYSICS	
	or	5–5
8.031	[2]PHYSICS	
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		47

Second Term

2.002	APPLIED MECHANICS II	3–5
3.11	ENGINEERING MATERIALS	6–4
8.04	PHYSICS	
	or	5–5
8.041	[2]PHYSICS	
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		45

THIRD YEAR

First Term

2.003	APPLIED MECHANICS III	4–8
2.403	THERMODYNAMICS I	4–8
	[3]*Humanities*	3–5
	Elective subjects	16 to 21
		48 to 53

Second Term

2.25	FLUID MECHANICS	4–8
2.37	MECHANICAL BEHAVIOR OF MATERIALS	5–4
	[3]*Humanities*	3–5
	Elective subjects	18 to 23
		47 to 52

FOURTH YEAR

First Term

	[3]*Humanities*	3–5
	[4]THESIS *or elective subject*	9
	[5]*Elective subjects*	29
		46

Second Term

2.082T	MECHANICAL ENGINEERING PROBLEMS	2–4
	[3]*Humanities*	3–5
	[4]THESIS *or elective subject*	9
	[5]*Elective subjects*	27
		50

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] Students planning to elect 8.051 ATOMIC AND NUCLEAR PHYSICS I should take 8.031 PHYSICS and 8.041 PHYSICS.

[3] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2.

[4] A minimum of 9 units of THESIS is required. Students are encouraged to fulfill this requirement by registering for 9 units of THESIS during the first term, or 3 units of THESIS during the first term and 6 more units during the second term. Additional units of THESIS above 9 units must be approved by the Registration Officer.

[5] The electives must include at least one 8-unit laboratory subject to be chosen from 2.126 EXPERIMENTAL STRESS ANALYSIS (5–4), 2.68 ENGINEERING LABORATORY (4–4), 2.7941 INTERNAL COMBUSTION ENGINE LABORATORY (2–2), 2.7942 INTERNAL COMBUSTION ENGINE LABORATORY (2–2), 2.863 EXPERIMENTAL TECHNIQUES (3–5), or 3.50 X-RAY METALLURGY (4–4) and may include two additional humanities subjects. The entire program must be approved by the Registration Officer.

ELECTIVE PROGRAMS

The Department presents four recommended programs, designated as (1) Power and Propulsion; (2) Engineering Science; (3) Materials; and (4) Design, Manufacturing, and Controls. The following lists indicate the subjects recommended. Within each program the student is required to take the indicated third-year subjects, and he must choose at least four of the fourth-year elective subjects, including laboratory, unless another suitable program is arranged with the Registration Officer.

***1.* POWER AND PROPULSION**

THIRD YEAR

First Term

2.73	MACHINE DESIGN (4–2)
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING (4–6)

Second Term

2.421	HEAT ENGINEERING (3–6)
2.731	MACHINE DESIGN (5–4)
2.862	MACHINE TOOL FUNDAMENTALS (3–2)

FOURTH YEAR ELECTIVE SUBJECTS

First Term

2.252	FLUID MECHANICS (3–6)
2.28T	FLUID MACHINERY (3–6)
2.43	HEAT ENGINEERING (3–6)
2.58	HEAT TRANSFER (3–6)
2.581	NUCLEAR POWER PLANT ENGINEERING I (3–6)
2.663	AIR CONDITIONING (3–6)
2.68	ENGINEERING LABORATORY (4–4)
2.79	ELEMENTARY INTERNAL COMBUSTION ENGINES (3–6)
2.791	INTERNAL COMBUSTION ENGINES (3–6)
2.7941	INTERNAL COMBUSTION ENGINE LABORATORY (2–2)
2.821	COMBUSTION AERODYNAMICS (3–9)
2.863	EXPERIMENTAL TECHNIQUES (3–5)
22.10	INTRODUCTION TO NUCLEAR TECHNOLOGY I (3–6)
M 351	ADVANCED CALCULUS FOR ENGINEERS (3–6)

Second Term

2.252	FLUID MECHANICS (3–6)
2.48T	GAS TURBINES AND JET PROPULSION (3–6)
2.43	HEAT ENGINEERING (3–6)
2.56T	POWER PLANT ENGINEERING (3–6)

2.582 NUCLEAR POWER PLANT ENGINEERING II (6–3)
2.621 REFRIGERATION (3–6)
2.68 ENGINEERING LABORATORY (4–4)
2.693 REFRIGERATION AND AIR CONDITIONING LABORATORY (3–6)
2.792 INTERNAL COMBUSTION ENGINES (3–6)
2.7942 INTERNAL COMBUSTION ENGINE LABORATORY (2–2)
2.80 AUTOMOTIVE VEHICLES (3–6)
2.863 EXPERIMENTAL TECHNIQUES (3–5)
22.11 INTRODUCTION TO NUCLEAR TECHNOLOGY II (3–6)
M 352 ADVANCED CALCULUS FOR ENGINEERS (3–6)

2. ENGINEERING SCIENCE

THIRD YEAR

First Term

6.10 ELEMENTARY ELECTRIC CIRCUIT THEORY (4–8)
M 351 ADVANCED CALCULUS FOR ENGINEERS (3–6)

Second Term

2.404 THERMODYNAMICS II (3–6)
M 352 ADVANCED CALCULUS FOR ENGINEERS (3–6)

FOURTH YEAR ELECTIVE SUBJECTS[1]

First Term

2.081 STRENGTH OF MATERIALS (3–6)
2.252 FLUID MECHANICS (3–6)
2.405 THERMODYNAMICS OF RATE PROCESSES (3–6)
2.58 HEAT TRANSFER (3–6)
2.68 ENGINEERING LABORATORY (4–4)
2.782 INTRODUCTION TO AUTOMATIC CONTROL (3–6)
2.821 COMBUSTION AERODYNAMICS (3–9)
3.31 PHYSICAL METALLURGY I (7–4)
6.02 ELECTRONIC DEVICES AND CIRCUITS (7–5)

Second Term

2.06 VIBRATIONS (3–6)
2.081 STRENGTH OF MATERIALS (3–6)
2.252 FLUID MECHANICS (3–6)
2.68 ENGINEERING LABORATORY (4–4)
6.02 ELECTRONIC DEVICES AND CIRCUITS (7–5)
8.052 ATOMIC AND NUCLEAR PHYSICS II (4–5)

[1] In the fourth year, the student must take 8.051 ATOMIC AND NUCLEAR PHYSICS I (4–5) in place of 9 units of elective subjects.

3. MATERIALS

THIRD YEAR

First Term

2.73 MACHINE DESIGN (4–2)
3.31 PHYSICAL METALLURGY I (7–4)

Second Term

2.404 THERMODYNAMICS II (3–6)
3.32 PHYSICAL METALLURGY II (6–6)

FOURTH YEAR ELECTIVE SUBJECTS[1]

First Term

2.081 STRENGTH OF MATERIALS (3–6)
2.126 EXPERIMENTAL STRESS ANALYSIS (5–4)
2.68 ENGINEERING LABORATORY (4–4)
2.732 MACHINE DESIGN (4–5)
2.863 EXPERIMENTAL TECHNIQUES (3–5)
2.901 PRINCIPLES OF FABRIC STRUCTURE (3–6)
2.903 ELEMENTS OF TEXTILE MANUFACTURING (3–6)
3.396 NUCLEAR METALLURGY (2–4)
3.50 X-RAY METALLURGY (4–4)
3.70 CERAMICS (2–4)
8.051 ATOMIC AND NUCLEAR PHYSICS I (4–5)
M 351 ADVANCED CALCULUS FOR ENGINEERS (3–6)

Second Term

2.081 STRENGTH OF MATERIALS (3–6)
2.126 EXPERIMENTAL STRESS ANALYSIS (5–4)
2.32T MECHANICAL PROPERTIES OF NON-METALLICS (3–6)
2.68 ENGINEERING LABORATORY (4–4)
2.863 EXPERIMENTAL TECHNIQUES (3–5)
2.904 PRINCIPLES OF TEXTILE MANUFACTURING (3–6)
8.052 ATOMIC AND NUCLEAR PHYSICS II (4–5)
M 352 ADVANCED CALCULUS FOR ENGINEERS (3–6)

[1] In the fourth year, the student must take 2.731 MACHINE DESIGN, 2.862 MACHINE TOOL FUNDAMENTALS and 6.18 FUNDAMENTALS OF ELECTRICAL ENGINEERING in place of 23 units of elective subjects.

4. DESIGN, MANUFACTURING, AND CONTROLS

THIRD YEAR

First Term

2.73 MACHINE DESIGN (4–2)
6.18 FUNDAMENTALS OF ELECTRICAL ENGINEERING (4–6)

Second Term

2.421 HEAT ENGINEERING (3–6)
2.731 MACHINE DESIGN (5–4)
2.862 MACHINE TOOL FUNDAMENTALS (3–2)

FOURTH YEAR ELECTIVE SUBJECTS

First Term

2.081 STRENGTH OF MATERIALS (3–6)
2.126 EXPERIMENTAL STRESS ANALYSIS (5–4)
2.68 ENGINEERING LABORATORY (4–4)
2.732 MACHINE DESIGN (4–5)
2.751 ANALYSIS AND DESIGN OF ENGINEERING SYSTEMS I (3–9)
2.78 HYDRAULIC AND PNEUMATIC CONTROLS (5–4)
2.782 INTRODUCTION TO AUTOMATIC CONTROL (3–6)
2.855 THEORY OF METAL CUTTING (3–6)
2.863 EXPERIMENTAL TECHNIQUES (3–5)
3.18 PLASTIC WORKING OF METALS (2–4)
M 351 ADVANCED CALCULUS FOR ENGINEERS (3–6)

Second Term

2.06 VIBRATIONS (3–6)
2.081 STRENGTH OF MATERIALS (3–6)
2.126 EXPERIMENTAL STRESS ANALYSIS (5–4)
2.261 LUBRICATION AND FRICTION (2–4)
2.68 ENGINEERING LABORATORY (4–4)
2.735 HUMAN FACTORS IN DESIGN (6–3)
2.855 THEORY OF METAL CUTTING (3–6)
2.859 MANUFACTURING TECHNOLOGY (3–6)
2.863 EXPERIMENTAL TECHNIQUES (3–5)
3.18 PLASTIC WORKING OF METALS (2–4)
15.71 PRODUCTION MANAGEMENT (3–6)
M 32 ELEMENTARY STATISTICS (3–6)

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.

The Undergraduate Honors Course

Towards the end of the junior year an opportunity is offered to a limited 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 graduate year. The program must satisfy all the unit requirements for both degrees, including the time allotted to the Bachelor's thesis, and must include a thesis of not less than 30 units in the graduate year.

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 schedule of subjects taken in the junior year. The academic program is 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.

The Course leads to the degree of Bachelor of Science in Mechanical Engineering. The curriculum for the third year, and for the summers immediately preceding and following it, is given at the top of the next page. Members of the Cooperative Course are divided into two groups, as shown.

(*See the next page for the Course II-B curriculum.*)

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, and Doctor of Science in Mechanical Engineering.

In addition to its own extensive facilities for graduate research, the Department cooperates with other departments of the Institute in operating the Engineering Practice School at Oak Ridge, Tennessee. Here a number of graduate students take a four-month course under the supervision of resident M. I. T. staff members, enjoying all of the technical facilities available at Oak Ridge. The School is described more fully by the Department of Chemical Engineering, under whose administration it is operated.

Entrance Requirements for Graduate Study

The general admission requirements are those given in Section 3 of this Catalogue. Graduate students entering from other universities may be required to take undergraduate subjects in certain fields, in order that they should have approximately the same background as students with Bachelor's degrees from the Mechanical Engineering Department at M.I.T. However, they are encouraged to take the most advanced

(*Text continues on page 114.*)

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

GROUP A

FIRST AND SECOND YEARS

Same as Mechanical Engineering (Course II*)*

THIRD YEAR

Summer

Vacation (approximately 7 weeks)

At plants (remainder of summer):

2.951	INDUSTRIAL PRACTICE	40 h.p.w.

First Term

At plants:

2.952	INDUSTRIAL PRACTICE	40 h.p.w.

Second Term

At M.I.T.:

2.003	APPLIED MECHANICS III	4–8
2.403	THERMODYNAMICS I	4–8
2.73	MACHINE DESIGN	4–2
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	4–6
	[1]*Humanities*	3–5
		48

FOURTH YEAR

Summer

At M.I.T.:

2.25	FLUID MECHANICS	4–8
2.421	HEAT ENGINEERING	3–6
2.731	MACHINE DESIGN	5–4
2.862	MACHINE TOOL FUNDAMENTALS	3–2
		35

First and Second Terms

Same as Course II*, except that students must include in their fourth-year programs* 2.37 MECHANICAL BEHAVIOR OF MATERIALS (5–4) *and additional* [1]*Humanities* (3–5).

GROUP B

Same as Mechanical Engineering (Course II*)*

At M.I.T.:

2.003	APPLIED MECHANICS III	4–8
2.403	THERMODYNAMICS I	4–8
2.73	MACHINE DESIGN	4–2
2.862	MACHINE TOOL FUNDAMENTALS	3–2
		35

At M.I.T.:

2.25	FLUID MECHANICS	4–8
2.421	HEAT ENGINEERING	3–6
2.731	MACHINE DESIGN	5–4
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	4–6
	[1]*Humanities*	3–5
		48

At plants:

2.952	INDUSTRIAL PRACTICE	40 h.p.w.

At plants (first 7 weeks):

2.951	INDUSTRIAL PRACTICE	40 h.p.w.

Vacation (remainder of summer)

Same as Course II*, except that students must include in their fourth-year programs* 2.37 MECHANICAL BEHAVIOR OF MATERIALS (5–4) *and additional* [1]*Humanities* (3–5).

[1] 14.01 ECONOMIC PRINCIPLES (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2 of this Catalogue.

subjects which their previous training justifies. Satisfactory grades in a graduate subject will remove undergraduate deficiencies in subjects which cover the same field at the undergraduate level. Experience shows that the majority of transfer students without previous graduate training should take one or more of the following, or their equivalents:

STRENGTH OF MATERIALS (2.081)
FLUID MECHANICS (2.25)
HEAT ENGINEERING (2.43)

The Master of Science in Mechanical Engineering

The degree of Master of Science in Mechanical Engineering is awarded for a program of graduate study which is principally intended to provide a broad background of engineering science. Consisting of at least 96 units, it is planned individually by the student in conference with his faculty adviser. It must include a thesis of from 20 to 40 units, two subjects in mechanics or nuclear engineering, one subject in heat, and two in mathematics. 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 advisers.

The Master of Science in Textile Technology

Candidates for the Master's degree in Textile Technology should have either the training offered by the Institute in the fields of chemical engineering, chemistry, mechanical engineering, business and engineering administration, or industrial physics, or a training which is equivalent. 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.

The Mechanical Engineer Degree

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, and which does not include the emphasis on creative research which is characteristic of the doctoral program. The requirements for the degree include those of the Master's degree, a qualifying examination, and an additional year of advanced study for further development of engineering competence.

The Doctor of Science in Mechanical 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 he has received his Master's degree. The requirements for the Doctor's degree include a Major program, a Minor program, a thesis, and proficiency in two foreign languages, with French, German, or 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 Students. While no fixed number of units is prescribed, the usual program includes a substantial number of courses 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 two terms of work.

The Minor program must be approved by the student's Doctoral Committee. It must conform to the provisions for the Graduate School in general, given in Section 3.

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 will be under the supervision of a Doctoral Committee selected by the student and his thesis supervisor. This Committee will make an annual evaluation of the candidate's progress and will conduct a final examination based on the thesis.

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.

Department of Metallurgy

JOHN CHIPMAN, PH.D., SC.D.
Professor of Metallurgy; in charge of the Department

THOMAS BURNESS KING, PH.D.
Associate Professor of Metallurgy; Executive Officer

ANTOINE MARC GAUDIN, SC.D.
Richards Professor of Mineral Engineering

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

FREDERICK HARWOOD NORTON, SC.D.
Professor of Ceramics

MORRIS COHEN, SC.D.
Professor of Physical Metallurgy

JOHN WULFF, D.SC.
Professor of Metallurgy

CARL FREDERICK FLOE, SC.D.
Professor of Metallurgy; Administrative Vice Chancellor

HOWARD FLOYD TAYLOR, M.S.
American Brake Shoe Company Professor of Foundry Metallurgy

HERBERT HENRY UHLIG, PH.D.
Professor of Metallurgy

MICHAEL BERLINER BEVER, DR. IUR., SC.D.
Professor of Metallurgy

NICHOLAS JOHN GRANT, SC.D.
Professor of Metallurgy

BENJAMIN LEWIS AVERBACH, SC.D.
Associate Professor of Metallurgy

JOHN FRANK ELLIOTT, SC.D.
Associate Professor of Metallurgy

PHILIP LOUIS DE BRUYN, SC.D.
Associate Professor of Mineral Engineering

WILLIAM DAVID KINGERY, SC.D.
Associate Professor of Ceramics

WALTER ALAN BACKOFEN, SC.D.
Associate Professor of Metallurgy

CLYDE MELVIN ADAMS, JR., SC.D.
Associate Professor of Metallurgy

GEORGE ECONOMOS, SC.D.
Assistant Professor of Metallurgy

ROBERT EDWARD OGILVIE, SC.D.
Assistant Professor of Metallurgy

MERTON CORSON FLEMINGS, JR., SC.D.
Assistan. Professor of Metallurgy

FRANK BERTRAM CUFF, JR., SC.D.
Assistant Professor of Metallurgy

HENRY STEPHEN SPACIL, S.M.
Assistant Professor of Metallurgy

ROBERT LOUIS FLEISCHER, PH.D.
Assistant Professor of Metallurgy

JAMES HERBERT BROWN, SC.D.
Assistant Professor of Mineral Engineering

DAVID ALDEN THOMAS, SC.D.
Assistant Professor of Metallurgy

JOSE NAVARRO, PH.D.
Assistant Professor of Metallurgy

Lecturer

ALBERT RUDOLPH KAUFMANN, SC.D.

Instructors

WILLIAM GORDON MOFFATT, S.M.
GEORGE KRAUSS, JR., B.S.
GORDON EDWARD AGAR, B.A.SC.
DONALD PRATT FERRISS, M.S.
WILLIAM FULLER HOSFORD, JR., M.E.
MARC HERBERT RICHMAN, S.B.
DAVID LYTLE MCBRIDE, III, S.B.

Technical Instructors

PAUL FREDERICK HUGHES
WALTER ROLAND JOHNSON

Research Associates

ARTHUR STANLEY APPLETON, PH.D.
ARUP RATAN CHAUDHURI, PH.D.
KEN-ICHI HIRANO, SC.D.
SAMUEL VICTOR RADCLIFFE, PH.D.

Professors Emeriti

ROBERT SEATON WILLIAMS, PH.D.
Professor of Physical Metallurgy, Emeritus

MAURICE DEKAY THOMPSON, PH.D.
Professor of Electrochemistry, Emeritus

CARLE REED HAYWARD, S.B.
Professor of Process Metallurgy, Emeritus

VICTOR OLIVER HOMERBERG, SC.D.
Professor of Physical Metallurgy, Emeritus

METALLURGY

Metallurgy is the engineering science which deals with the production and utilization of metals and alloys and with the properties of metallic materials. It is a broad field, founded on the basic sciences of physics and chemistry and closely related to several branches of engineering. For many reasons it is a field of great importance to science and industry. Metals are of immense interest as basic components of our world, since they comprise about three-fourths of all the elements. Equally important is the fact that they are available in the earth's crust in large quantity and in such a form that they can be produced at a reasonable cost. Metals also have remarkable properties, which can often be modified to make them of particular use to man. They can be combined in an almost limitless number of ways, so that new alloys are constantly being developed to meet new needs or to serve old needs more adequately. As a result of their usefulness and availability, metals are now the working substance of modern engineering. The efficient operation of gas turbines, nuclear reactors, and many electrical devices of the future depends critically on metals as materials of construction.

The metallurgical engineer finds his services in great demand. Industries which are producing metals and converting them into useful products offer opportunities in plant operation and management to metallurgists with a Bachelor's degree. Metallurgists also play a prominent role in research on the nature and properties of metals and in the development of new processes and alloys to meet the increasingly severe demands of modern technology. While opportunities for this work exist for those with basic training, the demand is particularly active for persons who have taken graduate study. Preparation for graduate work may be an undergraduate major in metallurgy, physical science, or a field of engineering.

The Department of Metallurgy offers a wide range of subjects in metallurgy, mineral engineering, and ceramics, together with excellent opportunities for research. Brief descriptions of the major research facilities are given below.

The Physical Metallurgy Laboratories provide facilities for research on the constitution of metals and alloys, diffusion and reactions in the solid state, phase transformations, equilibrium diagrams of alloy systems, and the physical and mechanical properties of metals and alloys. The facilities include metallographic equipment, X-ray units for diffraction studies and radiography, testing apparatus, heat treating furnaces, and such specialized equipment as dilatometers, magnetometers, and an electron microscope.

The Process Metallurgy Laboratories provide a wide variety of facilities for investigations on roasting, extraction, reduction, smelting, distillation, refining, and the many chemical reactions involved in these processes. The steelmaking laboratory has facilities for preparation of experimental steels and for studies of the chemical reactions of molten iron and steel with gases, slags, and refractories.

The Metals Processing Laboratories are equipped for instruction and research in various aspects of the forming and joining of metals. Modern facilities for the study of melting, casting, brazing, welding, powder metallurgy, and plastic deformation are available. Research programs in progress include the mechanical as well as metallurgical aspects of the subject.

In the *Mineral Engineering Laboratories*, facilities are available for research on comminution, sizing, dewatering, and the various separation methods of ores, minerals, and fuels. A modern laboratory is equipped for a detailed study of flotation. Complete microscopic equipment is available for mineral identification. The equipment is designed not only for the study of batch or continuous operations of the various processes, but also for the analysis of the basic physical and chemical phenomena on which the processes rest.

The Ceramics Laboratories are well equipped to carry out advanced research in the field which includes abrasives, cermets, coatings, electrical ceramics, glass, heavy clay products, pottery, and refractories. Facilities are available for process ceramics studies in fields such as raw material properties, forming processes, drying, melting, phase equilibria, chemical reactions, firing and sintering of ceramic materials. Facilities are also available for physical ceramics studies in fields such as thermal properties, diffusion, surface properties, solid state reactions, physical and mechanical properties, and electrical and magnetic properties of ceramic materials.

The High-Temperature Metals Laboratory is concerned with the behavior of metals at elevated temperatures, and especially the effects of stress and time on this behavior. Other research is

concerned with structural stability, deformation, fracture phenomena, and alloy development. Facilities for the preparation of complex alloys and for creep and stress rupture testing are available as well as equipment for measuring various physical and mechanical properties.

Research is carried out in the *Corrosion Laboratory* on general mechanisms of corrosive attack, leading to a better understanding of the various available methods for controlling corrosion and oxidation damage to metals and to formulation of new corrosion-resistant alloys. The Laboratory is equipped with a vacuum furnace, and with modern facilities for electrochemical measurements and reaction rate studies.

Work on applied thermodynamics and kinetics is done in various laboratories of the Department and is concerned with such topics as calorimetry of metals and alloys, stability of metal sulfides and halides, and the electrochemistry of metallic systems.

To aid its research activities, the Department maintains an analytical laboratory and machine and instrument shops.

THE UNDERGRADUATE PROGRAM

Metallurgy (Course III)

The Course in Metallurgy offers opportunity for study in all phases of the science and engineering of metals. Because metallurgy is such a broad field, the curriculum contains a core of basic science and engineering and, in the junior and senior years, a wide choice of elective subjects.

The core consists primarily of mathematics, physics, chemistry, and the humanities, along with an introduction to metal science and the engineering principles involved in the extraction and application of metals. Students learn the basic thermodynamics, unit processes, and mechanical operations which underlie the making and shaping of metals; they also study the structure of metals, in preparation for understanding their properties and for selecting the right materials to meet service requirements. Students are introduced to the laws governing the alloying of metals and the principles by which new alloys may be developed.

The large amount of elective time permits students to pursue studies in related fields or to take additional subjects in metallurgical engineering, metal processing, or physical metallurgy. For example, those who are interested in ores and their beneficiation may elect subjects in mineral engineering and geology. A combined program of metallurgical and chemical engineering is suggested for those who wish to concentrate on the production of metals. For some students the curriculum may include a substantial amount of mathematics and physics. Still others may choose to direct their programs towards the study of machine design, stress analysis, and metal forming. There are also opportunities to combine a curriculum in metallurgy with the study of subjects in electrical engineering, nuclear engineering, business administration, or the humanities. The study of metallurgy may also lead into a program of materials engineering.

The planning of programs is begun under faculty supervision during the latter part of the second year. Faculty counseling in the selection of electives during the third and fourth years is readily available, but each student must assume the responsibility for planning his own program. A brochure describing the many possible programs may be obtained from the Department.

The Course leads to the degree of Bachelor of Science in Metallurgy. The curriculum for the first year is given on page 77; the curriculum for the second, third, and fourth years is given below.

SECOND YEAR[1]

First Term

2.001	APPLIED MECHANICS I	3–5
3.11	ENGINEERING MATERIALS	6–4
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		45

Second Term

2.002	APPLIED MECHANICS II	3–5
3.00	EXTRACTIVE METALLURGY	6–4
8.04	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		45

THIRD YEAR

First Term

3.31	PHYSICAL METALLURGY I	7–4
5.61	PHYSICAL CHEMISTRY I	4–4
	[2]*Humanities*	3–5
	[3]*Elective subjects* (*see next page*)	*23*
		50

THIRD YEAR (continued)

Second Term

3.01	METALLURGICAL ENGINEERING I	4–4
3.011	METALLURGICAL ENGINEERING LABORATORY I	3–1
5.62	[4]PHYSICAL CHEMISTRY II	4–4
	[2]*Humanities*	3–5
	[3]*Elective subjects (see below)*	*20*
		48

Summer

3.10	METALLURGICAL PLANT VISITS	3–1

FOURTH YEAR

First Term

3.20	METALLURGICAL THERMODYNAMICS	4–4
3.50	X-RAY METALLURGY	4–4
	THESIS	2
	[2]*Humanities*	3–5
	[5]*Elective subjects (see below)*	*24*
		50

Second Term

	THESIS	10
	[2]*Humanities*	3–5
	[5]*Elective subjects or additional* THESIS	*27*
		45

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2 of this Catalogue.

[3] It is recommended that 3.02 METALLURGICAL ENGINEERING II (4–4) and 3.021 METALLURGICAL ENGINEERING LABORATORY (3–1) or 3.32 PHYSICAL METALLURGY II (6–6) be among the elective subjects.

[4] 8.07 STATISTICAL MECHANICS AND THERMODYNAMICS (4–6) may be substituted for 5.62.

[5] Up to 6 units of additional THESIS may be substituted for elective subjects in the second term of the fourth year. Students may, if they wish, elect two additional subjects in the humanities in lieu of elective subjects.

ELECTIVE SUBJECTS

Each student is expected to plan his own schedule of elective subjects in cooperation with a faculty adviser, whose approval is required. The elective program is expected to include subjects both within and without the Department of Metallurgy. The following are among elective subjects offered within the Department:

3.02 METALLURGICAL ENGINEERING II (4–4)
3.021 METALLURGICAL ENGINEERING LABORATORY II (3–1)
3.03 METALLURGICAL ENGINEERING III (3–6)
3.13 FOUNDRY ENGINEERING (2–4)
3.15 WELDING ENGINEERING (2–4)
3.16 POWDER METALLURGY (2–4)
3.18 PLASTIC WORKING OF METALS (2–4)
3.32 PHYSICAL METALLURGY II (6–6)
3.33 PHYSICAL METALLURGY III (6–4)
3.42 ELECTROCHEMISTRY (2–4)
3.51 PHYSICS OF METALS (2–4)
3.61T ELECTRIC AND MAGNETIC MATERIALS (2–4)
3.70 CERAMICS (2–4)
3.701 CERAMICS LABORATORY (3–0)
3.81 MINERAL ENGINEERING I (6–6)
3.82 MINERAL ENGINEERING II (6–6)
3.83 MINERAL ENGINEERING III (3–6)
3.85 QUANTITATIVE MINERAGRAPHY (5–2)
3.87 ORE TESTING (10–0)

GRADUATE STUDY IN METALLURGY, MINERAL ENGINEERING, AND CERAMICS

Graduate work in the Department of Metallurgy comprises advanced studies and research on a selected topic. Laboratory investigations occupy a central position in all graduate programs. The descriptions of the laboratories given above have already introduced the various fields in which investigations may be carried out.

The Department offers the following graduate degrees: Master of Science in Metallurgy; Master of Science in Ceramics; Metallurgical Engineer; Mineral Engineer; Doctor of Science in Metallurgy; and Doctor of Science in Ceramics.

Requirements for Graduate Study

The general admission requirements are those given in Section 3 of this Catalogue. As a basic preparation for research work in this Department, it is required that all incoming graduate students register for 3.25 EXPERIMENTAL METHODS IN METALLURGY in the first term in which it is scheduled. This requirement may be waived upon presentation of evidence of similar training elsewhere.

FOR STUDENTS IN METALLURGY

Students whose preparation does not include the following subjects or their equivalents are expected to complete them in the early part of their graduate work:

METALLURGICAL ENGINEERING I (3.01)
PHYSICAL METALLURGY I (3.31)
PHYSICAL CHEMISTRY I (5.61)
PHYSICAL CHEMISTRY II (5.62)
or
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)

For students who are graduates of mechanical engineering or physics and who wish to specialize in mechanical metallurgy or physical metallurgy, a special program will be arranged in

lieu of the above requirements in chemistry and metallurgical engineering.

FOR STUDENTS IN MINERAL ENGINEERING

Students whose preparation does not include the following subjects or their equivalents are expected to complete them in the early part of their graduate work:

METALLURGICAL ENGINEERING I (3.01)
MINERAL ENGINEERING I (3.81)
PHYSICAL CHEMISTRY I AND II (5.61, 5.62)

FOR STUDENTS IN CERAMICS

There are no special prerequisites for graduate study in ceramics — each applicant will be considered individually. In general, graduates of courses in ceramics, ceramic engineering, chemistry, chemical engineering, mechanical engineering, metallurgy, or physics will be qualified. All entering graduate students are required to register for 3.70 CERAMICS in the first term in which it is scheduled, or present evidence of similar training elsewhere.

The Graduate Degrees

The specifications for the degrees of Master of Science in Metallurgy, Master of Science in Ceramics, Metallurgical Engineer, Mineral Engineer, Doctor of Science in Metallurgy, and Doctor of Science in Ceramics are as set forth in Section 3 of this Catalogue.

Candidates for the doctorate in metallurgy or ceramics are required to demonstrate their ability to read scientific literature in German and in one other foreign language in which a significant metallurgical literature exists.

Assistantships and Fellowships

The Department offers assistantships and fellowships for graduate study. Research and teaching assistantships are available, on a full- or half-time basis, in all of the fields in which the Department is active. Further information about assistantships and fellowships may be obtained from the chairman of the Departmental Committee on Graduate Students.

Department of Naval Architecture and Marine Engineering

LAURENS TROOST, IR.
Professor of Naval Architecture; in charge of the Department
FRANK MENDELL LEWIS
Professor of Marine Engineering
EDWARD SENTMAN ARENTZEN, S.M.
Captain, U. S. N.
Professor of Naval Construction
EVERS BURTNER, S.B.
Associate Professor of Naval Architecture and Marine Engineering, Emeritus; Lecturer
JOHN HARVEY EVANS, B.ENG.
Associate Professor of Naval Architecture
SHANNON CURTIS POWELL, DOTT.ING.
Associate Professor of Marine Engineering
MARTIN AARON ABKOWITZ, PH.D.
Associate Professor of Naval Architecture
JOE WARREN THORNBURY, NAV.E.
Commander, U. S. N.
Associate Professor of Naval Engineering
PHILIP MANDEL, B.S.
Associate Professor of Naval Architecture
ELMER EUGENE ALLMENDINGER, S.M.
Assistant Professor of Naval Architecture

Instructor
JUSTIN ELLIOT KERWIN, S.M.

Professors Emeriti
GEORGE OWEN, S.B.
Professor of Naval Architecture, Emeritus
HENRY EASTIN ROSSELL, S.M.
Professor of Naval Construction, Emeritus
LAWRENCE BOYLSTON CHAPMAN, S.B.
Professor of Marine Transportation and Marine Engineering, Emeritus
GEORGE CHARLES MANNING, SC.D.
Professor of Naval Architecture, Emeritus
EVERS BURTNER, S.B.
Associate Professor of Naval Architecture and Marine Engineering, Emeritus; Lecturer

NAVAL ARCHITECTURE AND MARINE ENGINEERING

The design of ships is both an art and a science. The construction of ships is engineering in action. The operation of ships requires a knowledge of problems which are found only in the case of floating bodies and the sea. Undergraduate instruction in these fields, therefore, requires a curriculum which is broad in its scope, fundamental in its nature, and which stimulates original thinking; a substantial part of the undergraduate curriculum is prescribed to insure that the student gets at least a speaking acquaintance with most aspects of the fascinating activity of ship design and construction, by study in a wide range of scientific and engineering disciplines. Graduate study may be more restricted, because the postgraduate student has generally found a specific area in the field which is of particular interest to him.

The Department of Naval Architecture and Marine Engineering has a comparatively small enrollment of undergraduates, but it has many graduate students. This makes necessary a faculty with both substantial industrial experience and adequate professional knowledge. 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 postgraduate study. In addition, it offers a graduate program for selected officers of the U.S. Navy, U.S. Coast Guard, and accredited foreign navies. This is designated as Naval Construction and Engineering (Course XIII-A).

THE UNDERGRADUATE PROGRAMS

Naval Architecture and Marine Engineering (Course XIII)

This curriculum is customarily followed by those interested in the technical aspects of the marine industry — both naval architects and marine engineers. Both take the same required subjects in mathematics, science, engineering fundamentals, and humanities, in addition to introductory subjects in the various phases of ship design, construction, and marine engineering. Specialization, in the form of elective subjects,

is largely reserved for the last year. A thesis — a report of an independent research or study project — is required of every student before he graduates. Throughout the curriculum the emphasis is on developing logic and originality, so that graduates may make an orderly attack on engineering problems and may make the proper engineering decisions.

The curriculum of the undergraduate Course is given in tabular form below, but the substitution of subjects other than those given in this table is acceptable provided the breadth and depth of the coverage is the same. Since much of the design information in regard to ships is delineated on drawings, a naval architect or marine engineer must have a working knowledge of the theory of engineering drawing and a modicum of skill in visual presentation. This requires a certain amount of experience, but the time in the drawing room is not by any means spent entirely to this end. A substantial part of this time is used in performing the computations and engineering which underlie design work. Further, since both naval architecture and marine engineering are essentially specializations in the general field of mechanical engineering, students spend almost as much of their class time in the Department of Mechanical Engineering as in the Department of Naval Architecture and Marine Engineering. In addition, the curriculum includes instruction in the nature of metals and the fundamentals of electrical engineering. Basic acquaintance with these fields is essential to any engineer.

This four-year Course leads to the degree of Bachelor of Science in Naval Architecture and Marine Engineering. The curriculum for the first year is given on page 77, the curriculum for the second, third, and fourth years is given below.

SECOND YEAR[1,2]

First Term

2.001	APPLIED MECHANICS I	3–5
2.861	ENGINEERING DESIGN AND MANUFACTURE	8–4
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		47

Second Term

2.002	APPLIED MECHANICS II	3–5
3.11	ENGINEERING MATERIALS	6–4
8.04	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		45

THIRD YEAR[2]

First Term

2.25	FLUID MECHANICS	4–8
2.403	THERMODYNAMICS I	4–8
13.01T	NAVAL ARCHITECTURE I	4–5
13.61	MARINE ENGINEERING DESIGN III	5–0
	[3]*Humanities*	3–5
		46

Second Term

2.37	MECHANICAL BEHAVIOR OF MATERIALS	5–4
2.421	HEAT ENGINEERING	3–6
13.02	NAVAL ARCHITECTURE II	4–5
13.45	SHIP STRUCTURES	3–6
13.52T	MARINE ENGINEERING I	2–4
	[3]*Humanities*	3–5
		50

FOURTH YEAR[2] ***(1958–59 only)***

First Term

13.43	SHIP STRUCTURAL DRAWING	3–0
13.53	MARINE ENGINEERING II	3–5
13.61	MARINE ENGINEERING DESIGN III	5–0
	THESIS	2
	[3]*Humanities*	3–5
	[4]*Professional elective subjects*	*14*
	Elective subject	*8*
		48

Second Term

13.46	SHIP DESIGN	9–2
13.54	MARINE ENGINEERING DYNAMICS	2–4
13.62	MARINE ENGINEERING DESIGN IV	5–0
	THESIS	7
	[3]*Humanities*	3–5
	Elective subject	*8*
		45

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] Substitution is not permitted for professional subjects in the second, third, and fourth years unless the proposed subject has practically the same subject content and objectives.

[3] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and may be used in partial fulfillment of the humanities requirement. Students planning to register in Course XIII-B in the fourth year are not permitted concentration in Economics (Field Six) or Labor Relations (Field Eight) in satisfaction of the humanities requirement. The humanities requirement is described in Section 2.

[4] The professional electives must include 2.37 MECHANICAL BEHAVIOR OF MATERIALS (5–4) or 2.68 ENGINEERING LABORATORY (4–4) or 2.863 EXPERIMENTAL TECHNIQUES (3–5).

Shipping and Shipbuilding Management (Course XIII-B)

This Course is intended to satisfy the formal educational requirements of students primarily interested in the business and management phases of the marine industry. Students entering this new and challenging field must have a firm technical background; hence essentially all the requirements of the Naval Architecture and Marine Engineering curriculum must be satisfied prior to graduation. In the last two years of this five-year program, students for the most part take subjects of their own choice. According to their interests, they select areas of concentration in business and management and study undergraduate and graduate subjects in M.I.T.'s Department of Economics and Social Science and School of Industrial Management. Students may also broaden their experience by electing advanced subjects offered by other departments at the Institute.

This five-year program leads to two degrees: the Bachelor of Science in Naval Architecture and Marine Engineering and the Master of Science in Shipping and Shipbuilding Management, awarded simultaneously at the end of the graduate (fifth) year. The curriculum is the same as that for Naval Architecture and Marine Engineering (Course XIII) through the third year; the curriculum for the fourth and graduate years is shown below.

FOURTH YEAR[1] (*1958–59 only*)

First Term		
13.43	SHIP STRUCTURAL DRAWING	3–0
13.53	MARINE ENGINEERING II	3–5
13.61	MARINE ENGINEERING DESIGN III	5–0
	[2]*Humanities*	3–5
	[3]*Professional elective subjects (see below)*	*14*
	Elective subject	*8*
		46
Second Term		
13.46	SHIP DESIGN	9–2
13.54	MARINE ENGINEERING DYNAMICS	2–4
13.62	MARINE ENGINEERING DESIGN IV	5–0
	[2]*Humanities*	3–5
	[3]*Professional elective subject (see below)*	*9*
	Elective subject	*8*
		47

GRADUATE YEAR

First Term		
	THESIS	5
	Graduate study (see "Elective subjects" below)	43
		48
Second Term		
	THESIS	24
	Graduate study (see "Elective subjects" below)	24
		48

[1] Substitution is not permitted for professional subjects in the fourth year unless the proposed subject has practically the same subject content and objectives.

[2] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and may be used in partial fulfillment of the humanities requirement. Students are not permitted concentration in Economics (Field Six) or Labor Relations (Field Eight) in satisfaction of the humanities requirement. The humanities requirement is described in Section 2.

[3] The professional electives must include 2.37 MECHANICAL BEHAVIOR OF MATERIALS (5–4) or 2.68 ENGINEERING LABORATORY (4–4) or 2.863 EXPERIMENTAL TECHNIQUES (3–5).

ELECTIVE SUBJECTS

The coordinated program of professional electives and graduate study for Course XIII-B will be approved after consultation with and concurrence of the Department of Economics and Social Science and the School of Industrial Management, as appropriate. Compliance with all regulations of the Graduate School is required. Graduate study in the fifth year may include up to a total of 11 units of additional THESIS.

GRADUATE STUDY IN NAVAL ARCHITECTURE AND MARINE ENGINEERING

The Department of Naval Architecture and Marine Engineering offers four graduate degrees in this field: Master of Science, Naval Architect, Marine Mechanical Engineer, and Doctor of Science. In addition, the Course in Naval Construction and Engineering (Course XIII-A) offers the degree of Naval Engineer.

A program of graduate study in the Department is almost entirely under the control of the student. He is assisted in his planning by the Graduate Registration Officer who is his faculty adviser. An acceptable graduate program of 96 credit units, which is usually completed in one academic year if based on an undergraduate curriculum equivalent in scope to that offered by this Department, leads to the degree of Master of Science in Naval Architecture and Marine Engineering; a two-year program leads to the degree of Naval Architect or Marine Mechanical Engineer. Students with a less broad undergraduate background usually require

more time; or they may follow a program leading to a Master of Science without specification, which requires the same standards of academic performance.

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

Subjects offered in this Department which are available to civilian graduate students include the following:

PRINCIPLES OF SHIP DESIGN (13.03)
PRELIMINARY DESIGN OF SHIPS (13.031)
ADVANCED SHIP DESIGN (13.04)
ADVANCED HYDROMECHANICS OF SHIP DESIGN (13.05)
SPECIAL PROBLEMS IN NAVAL ARCHITECTURE AND MARINE ENGINEERING (13.06)
MARINE ENGINEERING ECONOMICS (13.56)
SHIP MACHINERY DESIGN I AND II (13.711, 13.721)
MECHANICAL VIBRATION (13.73, 13.74)
MARINE PROPELLERS (13.791)
PROBLEMS IN SHIPYARD MANAGEMENT (13.92)

Subjects offered by other departments which are recommended for the consideration of graduate students in this Department include the following: 1.41, 1.42, 1.551, 1.552, 1.561, 1.562, 1.571, 1.572, 1.63, 1.683, 2.082T, 2.125, 2.211, 2.212, 2.213, 2.215, 2.216, 2.221, 2.28T, 2.451, 2.452, 2.49, 2.491, 2.492, 2.521, 2.522, 2.78, 2.797, 3.43, 3.44, 6.19, 6.25T, 6.581, 8.051, 8.531, 16.21, 16.31, M351, M352, M39, M411, M42, M421, M422, 22.10 and 22.11.

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 and quantity, 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 and engineering design

If undergraduate preparation has been significantly less intensive in any of these areas, the deficiencies must be removed prior to the award of any of the degrees implying specification. This may be accomplished concurrently with graduate work if the deficiencies are not extensive. Undergraduate subjects so required will in some cases be accepted by the Department in partial fulfillment of the advanced degree requirements. Accepted subjects will generally be restricted to those offered by this Department in the normal fourth-year program. A strictly limited number of subjects, in no case exceeding 24 units of registration, will be accepted on this basis. Somewhat less intensive undergraduate work in areas represented by subjects of instruction given in this Department is appropriate for candidates for the degree of Master of Science without specification, if accompanied by correspondingly increased competence in other areas.

Departmental Requirements for Advanced Degrees

The program of studies for an advanced degree is largely under control of the student, acting with the advice of his Registration Officer. It must meet the general requirements specified in Section 3 of this Catalogue and must be acceptable to the Departmental Committee on Graduate Students.

Unless special approval is given by this Committee, candidates for any graduate degree other than the Master of Science in Shipping and Shipbuilding Management will be expected to include at least two terms of advanced mathematics in their programs; a program for an Engineer degree should also include two subjects in the area of economics or industrial management, and at least 20 units of comprehensive design, such as PRELIMINARY DESIGN OF SHIPS (13.031), or equivalent. A single thesis will generally be acceptable for both the Master of Science and Engineer degrees, provided it is appropriate to the specification of the latter degree. A reading knowledge of technical material in two foreign languages is required for the Doctor of Science degree.

The Department interprets the field of naval architecture and marine engineering rather broadly in connection with the requirements for a degree with or implying specification. Thus a program for a degree with specification usually includes considerable work in other departments, such as mathematics and mechanical engineering, and the thesis may be in another department if it is directly applicable to naval architecture and marine engineering.

Assistantships and Scholarships

A limited number of part-time assistantships in connection with teaching and research duties are available each year. In addition to the M.I.T. fellowships and scholarships, some industrial fellowship aid is available, generally to students who are graduates of this Department or who have completed some graduate work in the Department. Fellowships are also awarded each year by the Society of Naval Architects and Marine Engineers. These latter are valid for study at any institution of the recipient's choice and are usually awarded to applicants who have previously evidenced strong interest in the field of naval architecture and marine engineering, either through their education or their professional work. Prospective students are invited to communicate with the Head of the Department regarding any of these educational and financial opportunities. Applications for the Society of Naval Architects and Marine Engineers Awards are made directly to that Society. Inquiries for the fall term should be made early in the preceding spring term.

Naval Construction and Engineering (Course XIII-A)

This Course was originally set up at the request of the United States Navy to provide appropriate academic background for officers who would later supervise the design and construction of combat vessels. It has more recently been somewhat broadened in scope and now provides four specialized curricula in the field of ship engineering. The subjects which are common to all curricula are given below.

1.612 FLUID MECHANICS (3–6)
2.046 STRENGTH OF MATERIALS AND DYNAMICS (6–8)
2.081 STRENGTH OF MATERIALS (3–6)
2.402 HEAT ENGINEERING (4–8)
2.501 HEAT TRANSFER (3–3)
3.391 PROPERTIES OF METALS (3–3)
3.392 PROPERTIES OF METALS (3–3)
8.03S PHYSICS (4–6)
13.012 NAVAL ARCHITECTURE (5–7)
13.12 WARSHIP GENERAL ARRANGEMENTS (3–5)
13.13 WARSHIP STRUCTURE THEORY I (3–6)
13.15T WARSHIP BASIC DESIGN I (6–5)
13.16 WARSHIP BASIC DESIGN II (3–6)
13.17 HISTORY OF WARSHIPS (3–4)
13.20 ELEMENTARY WARSHIP DESIGN (8–2)
13.22 WARSHIP GENERAL DESIGN (5–0)
13.241 WARSHIP STRUCTURE DESIGN I (3–0)
13.26 PRELIMINARY DESIGN OF WARSHIPS (9–0)
13.54 MARINE ENGINEERING DYNAMICS (2–4)
13.75 WARSHIP PROPULSION I (5–6)
13.76 WARSHIP PROPULSION II (6–4)
13.791 MARINE PROPELLERS (3–6)
13.90 WARSHIP ELECTRICAL ENGINEERING (3–4)
13.92 PROBLEMS IN SHIPYARD MANAGEMENT (3–6)
22.10 INTRODUCTION TO NUCLEAR TECHNOLOGY I (3–6)
22.11 INTRODUCTION TO NUCLEAR TECHNOLOGY II (3–6)
M 351 ADVANCED CALCULUS FOR ENGINEERS (3–6)
M 352 ADVANCED CALCULUS FOR ENGINEERS (3–6)
M 73 REVIEW OF MATHEMATICS (8–12)
THESIS (25–0)

In addition to study at the Institute for seven terms, the Course includes experience during the summers after the first and second years at a naval shipyard and a naval research institution.

The Course leads to the degree of Master of Science in Naval Architecture and Marine Engineering and the degree of Naval Engineer, awarded simultaneously at the end of the program of study.

Admission to the Course is subject to the approval of the U.S. Navy and requires undergraduate preparation equivalent to that offered by the U.S. Naval and Coast Guard Academies.

Department of Nuclear Engineering

MANSON BENEDICT, PH.D.
Professor of Nuclear Engineering; in charge of the Department
IRVING KAPLAN, PH.D.
Professor of Nuclear Engineering
THEOS JARDIN THOMPSON, PH.D.
Professor of Nuclear Engineering; Director of M.I.T. Reactor
EDWARD ARCHIBALD MASON, SC.D.
Associate Professor of Nuclear Engineering
MELVILLE CLARK, JR., PH.D.
Associate Professor of Nuclear Engineering
ALAN HUGH STENNING, SC.D.
Assistant Professor of Nuclear Engineering
GORDON LEE BROWNELL, PH.D.
Assistant Professor of Nuclear Engineering
NORMAN CARL RASMUSSEN, PH.D.
Assistant Professor of Nuclear Engineering

Research Associates
THOMAS CANTWELL, S.M., M.B.A.
DAVID DAYTON LANNING, B.A.
AMADEUS EDWARD PROFIO, JR., S.B.
DANIEL SCHWARTZ, S.M.

Assistant to Head of Department
LINCOLN CLARK, JR., A.B.

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.

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 both graduate students who wish to specialize in nuclear engineering and 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. No undergraduate degree is offered.

Registration in the Department and all subjects of instruction are open to all students with the requisite prior training, with the exception of the Engineering Practice School at Oak Ridge. Attendance at this Practice School is limited to United States citizens approved by the U.S. Atomic Energy Commission.

THE M.I.T. RESEARCH REACTOR

The M.I.T. Research Reactor is a 1000 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 will serve as a source of radiations for use in laboratory instruction on radiation detection and measurement methods. A variety of research projects will make use of the intense sources of neutrons and gamma rays produced by the reactor. Areas of research which the reactor has opened up include: neutron physics, cross-section measurements, reactor physics, solid-state studies based on neutron diffraction, radiochemistry of the fission products, physics of neutron-capture processes, activation analysis, research with short-lived radioisotopes, radiation-catalyzed chemical reactions, radiation-induced biological effects, radiation therapy, and radiation-damage studies of materials.

OTHER FACILITIES IN CAMBRIDGE

The Department also has a well-equipped nuclear instrumentation laboratory and a subcritical reactor built of graphite and natural uranium. Laboratory space and shop facilities are available for research in all areas of nuclear engineering. M.I.T.'s I.B.M. Type 704 electronic computer is used extensively in research and graduate instruction.

OAK RIDGE ENGINEERING PRACTICE SCHOOL

The Engineering Practice School at Oak Ridge, Tennessee, (described in Section 1) is of special interest to graduate students in nuclear engineering. Students enrolled in the School are assigned technical problems which have arisen in the design, development, and operation of the plants which are operated for the Atomic Energy Commission by the Union Carbide Nuclear Company. Under the direction of resident M.I.T. faculty, students learn to apply their technical skills and engineering judgment to the solution of problems encountered in all phases of the atomic energy field, from the production and refining of fissionable fuel to the design and operation of nuclear reactors.

UNDERGRADUATE PREPARATION FOR NUCLEAR ENGINEERING (COURSE XXII)

An undergraduate degree in physics, chemistry, or metallurgy, or in chemical, civil, mechanical, or electrical engineering offers suitable preparation for graduate study in nuclear engineering, provided the following M.I.T. undergraduate subjects or their equivalent have been included.

Physics — three years, including atomic and nuclear physics
Mathematics — three years, including ADVANCED CALCULUS FOR ENGINEERS (M351, M352)
Thermodynamics — (2.40, 2.403, 3.20, 8.07, or 10.28)
Heat Transfer — (2.43, 2.50, 2.58, or 10.31)

Prospective graduate students should make every effort to take these subjects before starting graduate study. Students deficient in one or more of them may make up their deficiencies after admission to graduate study, but they will need more time to complete the graduate program.

Students who expect to apply for admission to the graduate Course in Nuclear Engineering should discuss their undergraduate programs with the Department's Registration Officer, preferably before the end of their junior year.

GRADUATE STUDY IN NUCLEAR ENGINEERING

Details of the requirements for graduate degrees are given in the following paragraphs.

The Master of Science Degree

The general requirements for this degree are listed in Section 3. Subjects desirable for candidates for the Master of Science in Nuclear Engineering are:

BIOLOGICAL EFFECTS OF NUCLEAR RADIATION (22.20)
NUCLEAR REACTOR PHYSICS I (22.21)
NUCLEAR REACTOR PHYSICS II (22.22)
NUCLEAR REACTOR ENGINEERING (22.23)
NUCLEAR REACTOR PHYSICS LABORATORY (22.41)
NUCLEAR PHYSICS FOR ENGINEERS I (8.531)
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 may expect to complete the requirements for the Master of Science degree in a fall and a spring term, except perhaps for completion of the thesis.

Work in the Engineering Practice School at Oak Ridge may be accepted in place of a thesis for candidates for the Master of Science degree. Students with adequate undergraduate preparation who elect to attend this Practice School will ordinarily require a minimum of fifteen months to obtain the degree. Normally the student completes his program of studies at the Institute during a fall and spring term and attends the Practice School during the following fall term.

The Doctor of Science Degree

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. Before the student may start his doctoral research, he is required to pass a comprehensive general examination demonstrating competence in physics, mathematics, engineering fundamentals, and the aspects of nuclear engineering related to his field of undergraduate training.

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

NUCLEAR REACTOR PHYSICS I (22.21)
NUCLEAR REACTOR PHYSICS II (22.22)
NUCLEAR REACTOR ENGINEERING (22.23)
NUCLEAR REACTOR PHYSICS LABORATORY (22.41)
NUCLEAR PHYSICS FOR ENGINEERS (8.531, 8.532)

Doctoral research may be undertaken either in nuclear engineering or in a related field in another department. Appropriate areas of research include: reactor statics and dynamics, cross-section measurements, neutron diffraction studies, plasma physics, magnetohydrodynamics, nuclear metallurgy, feedback control, heat transfer, nuclear instrumentation, shielding, transport theory, nuclear chemistry, chemical and biological effects of radiation, effect of radiation on reactor materials, fuel cycles for nuclear reactors, solvent extraction of metals, isotope separation, and treatment of radioactive wastes.

The student's Minor subjects should be in some field other than that of his undergraduate specialization. Language requirements for the doctorate are a reading knowledge of scientific literature in German and either Russian or French.

General Engineering (Course IX-B)

Under Special Administration

The Course in General Engineering (Course IX-B) has been discontinued except for members of the Class of 1959 who are already enrolled in it. Students in the Course follow this curriculum in their fourth year, leading to the degree of Bachelor of Science in General Engineering.

FOURTH YEAR ***(1958–59 only)***

First Term

THESIS	4
Humanities (see Section 2)	3–5
Elective subjects	*36*
	48

Second Term

THESIS	5
Humanities (see Section 2)	3–5
Elective subjects	*35*
	48

SCHOOL OF HUMANITIES AND SOCIAL STUDIES

The Dean of the School of Humanities and Social Studies describes its many activities in serving M.I.T. Courses and granting M.I.T. degrees.

The School of Humanities and Social Studies embraces the work of a faculty divided into three cross-disciplinary departments. The Department of Economics and Social Science includes the faculty interested in economics, political science, psychology, labor relations, and sociology; the Department of Humanities includes the faculty concerned with history, literature, music, and philosophy; the Department of Modern Languages numbers those whose interest is in modern languages, literature in foreign languages, comparative literature, and linguistics.

This faculty has three complementary missions. The School is in the first place responsible for much of the general education required of every undergraduate at M.I.T., regardless of his area of specialization. In this role members of the faculty, mostly, though not all, drawn from the Department of Humanities, guide every freshman and sophomore through the common core curriculum in the humanities; later, all of the faculties of the School meet their share of juniors or seniors, as these upperclassmen are required to elect one field for concentrated study in the humanities and social sciences. The core curriculum and fields for subsequent study are described in Section 2 of this Catalogue.

A second mission of the School involves offerings leading to the degree of Bachelor of Science. There are currently five such programs, two in the Department of Economics and three in the Department of Humanities. These five 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 Studies require the same rigor in science and engineering — though not the depth of accomplishment — that is required of scientists and engineers; the programs include these subjects as a fundamental part of contemporary culture. Far from regarding the scientific study as antithetical to the humanistic, they recognize the essential unity of serious study in any area. Thus these programs may be particularly well fitted to prepare the right kind of young man or woman for living in the modern world.

The student whose formal education is completed with his four-year degree is likely to find that the preparation for modern life afforded by these Courses in economics, political science, or humanities is unique and effective; if he intends to continue to higher degrees, he will find that he is well prepared for study in a law school, medical school, or graduate school of industrial management; he will also find it possible to continue at once in graduate work in either of the two majors he has carried as an undergraduate. Thus the curriculum is an unusually flexible and open-ended one.

The School of Humanities and Social Studies 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 and in political science.

The extent of the graduate work and research is perhaps the feature which most distinguishes the School of Humanities and Social Studies at M.I.T. from those to be found in other technological institutions. The extent to which the members of this faculty are in close contact with the faculties of science and engineering is perhaps what most distinguishes it from those of non-technological institutions. We believe this to be a happy pair of circumstances, a pair which makes every part of our student offering richer.

JOHN E. BURCHARD

THE FIRST YEAR IN THE SCHOOL OF HUMANITIES AND SOCIAL STUDIES

The first-year curriculum is identical for all five undergraduate Courses in the School of Humanities and Social Studies. It demonstrates clearly the strong competence in the sciences which is expected of students who will major in the Department of Humanities and the Department of Economics and Social Science. Indeed, this curriculum meets the requirements for the first year in all Courses in the School of Science and (except for one recommended elective) in the School of Engineering. Although students may indicate a tentative choice of Course early in their freshman year, this selection may be changed with minimum inconvenience at any time before the beginning of the second year.

The curriculum below shows the minimum requirements for the first year in all Courses in the School of Humanities.

First Term

5.01	GENERAL CHEMISTRY	6–5
8.01	PHYSICS	5–6
21.01	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 11	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

Second Term

5.02	GENERAL CHEMISTRY	6–5
8.02	PHYSICS	5–6
21.02	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 12	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

[1] Students accepted for the N.R.O.T.C. Program (see Section 2 of this Catalogue) omit the elective subjects and take in their place NS11 and NS12 ORIENTATION AND SEA POWER (4–5, 4–5) in the first and second terms, respectively.

ELECTIVE SUBJECTS

Students are required to earn 12 units of elective credits in their first two years. These may include Approved First-Year Elective Subjects, upper-class elective subjects, Military Science, or Air Science. Any part of this elective requirement taken in the second year will be in addition to the specified second-year curriculum of the Course elected. Students electing Military Science or Air Science subjects should refer to the Army and Air Force R.O.T.C. Programs in Section 2 of this Catalogue.

APPROVED FIRST-YEAR ELECTIVE SUBJECTS

The following subjects are approved as first-year electives. The number of students admitted to any one of these subjects will depend upon the facilities available.

First Term

12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
20.00	MAN'S FOOD (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.005	PUBLIC SPEAKING (3–3)
AS 11	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 111	GRAPHICS LABORATORY I (3–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 21	[1]SPOKEN GERMAN (3–3)
L 31	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 61	[1]INTRODUCTION TO SPOKEN FRENCH (3–3)
M 100	ELEMENTARY NUMBER THEORY (2–4)
MS 11	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

Second Term

1.002	TECHNOLOGY IN OUR CIVILIZATION (2–4)
4.00	STRUCTURE OF THE CITY (3–3)
7.00	PERSPECTIVES IN LIFE SCIENCE (3–3)
12.00	EARTH SCIENCE (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) (2–4)
12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.006	PUBLIC SPEAKING (3–3)
AS 12	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 121	GRAPHICS LABORATORY II (3–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 14	ELEMENTARY NOMOGRAPHY (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 22	[1]SPOKEN GERMAN (3–3)
L 32	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 62	[1]CONVERSATIONAL FRENCH (3–3)
M 101	TOPICS IN DISCRETE MATHEMATICS (2–4)
MS 12	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

[1] The prerequisite is 3 years of high school German or French, as the case may be, or the equivalent.

For students who expect to enroll in one of the Courses in the Department of Humanities or the Department of Economics and Social Science, the following electives are recommended as particularly relevant to later work:

1.002	TECHNOLOGY IN OUR CIVILIZATION (2–4)
4.00	STRUCTURE OF THE CITY (3–3)
7.00	PERSPECTIVES IN LIFE SCIENCE (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)

Any language subject for which the student is prepared.

Department of Economics and Social Science

ROBERT LYLE BISHOP, PH.D.
Professor of Economics; in charge of the Department
RALPH EVANS FREEMAN, M.A., B.LITT.
Professor of Economics
WILLIAM RUPERT MACLAURIN, D.C.S.
Professor of Economics
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 (Visiting)
WILFRED MALENBAUM, PH.D.
Professor of Economics (Visiting)
EVERETT EINAR HAGEN, PH.D.
Professor of Economics (Visiting)
BENJAMIN HOWARD HIGGINS, PH.D.
Professor of Economics (Visiting)
WALT WHITMAN ROSTOW, PH.D. *(Absent)*
Professor of Economic History
EVSEY DAVID DOMAR, PH.D.
Professor of Economics
DANIEL LERNER, PH.D.
Professor of Sociology
EDGAR CARY BROWN, PH.D.
Professor of Economics
ERIK HOMBURGER ERIKSON, PH.D.
Professor of Communications (Visiting)
ITHIEL DE SOLA POOL, PH.D.
Professor of Political Science
ROBERT MERTON SOLOW, PH.D.
Professor of Economics
ROBERT HENRY STROTZ, PH.D.
Professor of Economics (Visiting)
PAUL PIGORS, PH.D.
Associate Professor of Industrial Relations
MORRIS ALBERT ADELMAN, PH.D.
Associate Professor of Economics
ROGER WILLIAM BROWN, PH.D.
Associate Professor of Social Psychology
LUCIAN WILMOT PYE, PH.D.
Associate Professor of Political Science
ELSPETH DAVIES ROSTOW, A.M. *(Absent)*
Assistant Professor of History
DAVIS HUMPHREY HOWES, 3D, PH.D.
Assistant Professor of Psychology
LAURENCE WOODWARD MARTIN, PH.D.
Assistant Professor of Political Science
ABRAHAM J. SIEGEL, M.A.
Assistant Professor of Industrial Relations
JOHN ARTHUR SWETS, PH.D.
Assistant Professor of Psychology
FRANCIS MICHEL BATOR, PH.D.
Assistant Professor of Economics
ROBERT COLDWELL WOOD, PH.D.
Assistant Professor of Political Science
ALBERT KEINOSUKE ANDO, PH.D.
Assistant Professor of Economics
DAVID MARVIN GREEN, PH.D.
Assistant Professor of Psychology
RALPH CLAYBOURNE JAMES, JR., M.A.
Assistant Professor of Industrial Relations
SETH PHILLIP TILLMAN, M.A.
Assistant Professor of Political Science
GEORGE OAKLEY TOTTEN, PH.D.
Assistant Professor of Political Science

Lecturers

LINCOLN PALMER BLOOMFIELD, PH.D.
FREDERICK GEORGE LESIEUR
LOUIS C. SCHAW, PH.D.
JOHN TREXLER URBAN, B.A.

Professors Emeriti

FLOYD ELMER ARMSTRONG, LL.D.
Professor of Economics and Finance, Emeritus
DONALD SKEELE TUCKER, PH.D.
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. Three sections have now been developed within the Department: Industrial Relations, Political Science, and Psychology. These different approaches to the study of human behavior complement each other and afford a number of programs from which students may choose. An examination of the curricula listed below will reveal considerable flexibility within each program.

THE UNDERGRADUATE PROGRAMS

Economics, Politics, and Engineering (Course XIV-A)

Economics, Politics, and Science (Course XIV-B)

The Courses in Economics, Politics, and Engineering and in Economics, Politics, and Science combine basic training in either engineering or science with the social sciences. This combination emphasizes the relationships among scientific, engineering, economic, political, and human relations problems, thus giving insight into both the technical and nontechnical aspects of an industrial society. Students may prepare for a wide range of careers, particularly in the research, engineering, economics, personnel, sales, production, and international departments of business and in governmental and labor organizations.

Students concentrating in political science will be equipped with knowledge and skills for dealing with the increasing range of problems which arise between business and government and which involve the activities of governmental agencies and political groups in matters of direct concern to scientists and engineers. The Courses also provide a broad undergraduate preparation for graduate work in such fields as economics, engineering, science, business administration, law, and medicine.

Students in Course XIV-A elect an area of engineering concentration which corresponds to one of the established engineering fields at M.I.T. Each student works out an individual program of studies which includes the core subjects required of those majoring in that engineering field, as recommended by the particular engineering department. Social science subjects are substituted for the more specialized subjects offered after the sophomore year 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.

ECONOMICS

Subjects in economics in both Courses stress the economic and social structure within which business is conducted and technological change takes place. The objectives here are threefold: (1) to convey an understanding of human behavior, particularly in industrial settings; (2) to analyze the organization and operation of our economic system; and (3) to develop an understanding of broad questions of social policy. In this way the range of the student's insight is broadened, so that he is able to recognize a maximum number of administrative choices in any given situation and is able to judge intelligently the probable consequences of each choice. Thus he will develop his analytical powers in the social sciences to supplement his scientific and engineering skills.

For those concentrating in economics, some differences in emphasis are possible, particularly in the direction of industrial relations or industrial economics. Usually, however, the choice of appropriate professional electives enables the student to complete a substantial amount of work in both these fields.

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 basic nature of political behavior and the political process at all levels; (2) to examine the role of government in relation to science and tech-

nology, both in the American and foreign political systems and in international relations; (3) to develop familiarity with the techniques of policy formulation and decision-making on issues of public policy. In the third and fourth years students concentrate upon developments in the American and comparative political systems, political theory, international politics, or political behavior.

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.

THE CURRICULUM

The curriculum for the first year in the School of Humanities and Social Studies is shown on page 131; the general curriculum and sample programs for the second, third, and fourth years are given below. Students interested in these Courses should consult with the Department of Economics and Social Science to learn of the other possible programs of study.

SECOND YEAR[1,2]

First Term

8.03	PHYSICS	
	or	5–5
8.031	PHYSICS	
14.01	ECONOMIC PRINCIPLES I	3–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	Language or basic engineering or science subject (see next page)	*8 to 12*
		43 to 47

Second Term

8.04	PHYSICS	
	or	5–5
8.041	PHYSICS	
14.02	[a]ECONOMIC PRINCIPLES II	3–5
14.91	[b]AMERICAN POLITICAL PROCESS	3–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	Language or basic engineering or science subject (see next page)	*8 to 12*
		43 to 47

THIRD YEAR[2]

First Term

14.31	[a]ELEMENTARY STATISTICS	3–5
	[b]*Political science elective subject*	3–5
	[3]*Humanities elective subject*	3–5
	Course XIV *elective subject (see next column)*	3–5
	Basic engineering or science subjects (see next page)	*24 to 26*
		48 to 50

Second Term

15.52	[a]BUSINESS AND NATIONAL INCOME ACCOUNTING	3–5
	[b]*Political science elective subject*	3–5
	[3]*Humanities elective subject*	3–5
	Course XIV *elective subject (see below)*	3–5
	Basic engineering or science subjects (see next page)	*24 to 26*
		48 to 50

FOURTH YEAR

First Term

THESIS	3
Elective subject	*8*
Course XIV *elective subjects (see below)*	*16*
Engineering or science elective subjects (see next page)	*18 to 22*
	45 to 49

Second Term

THESIS	7
Elective subject	*8*
Course XIV *elective subjects (see below)*	*24*
Engineering or science elective subjects (see next page)	*9 to 12*
	48 to 51

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] Students specializing in economics take the subjects indicated as "a"; those in political science take instead the subjects indicated as "b".

[3] Students may not use as their humanities elective 14.01 ECONOMIC PRINCIPLES I or any of the subjects indicated as electives in their own field of concentration. In addition, students concentrating in economics may not use 14.02 ECONOMIC PRINCIPLES II; those electing political science may not use 14.91 AMERICAN POLITICAL PROCESS.

COURSE XIV ELECTIVE SUBJECTS FOR SPECIALIZATION IN ECONOMICS

The elective program in economics will normally be made up of 14.03 PRICES AND PRODUCTION, one additional subject in the first group, one subject in the second group, and four other subjects chosen from any two of the following groups.

Group I

14.03 PRICES AND PRODUCTION (3–5)
14.40 MONEY AND INCOME (3–5)
14.43 PUBLIC FINANCE (3–5)
14.54 INTERNATIONAL TRADE (3–5)

Group II

14.63 LABOR RELATIONS (3–5)
14.64 LABOR ECONOMICS AND PUBLIC POLICY (3–5)
14.71 PERSONALITY AND SOCIAL STRUCTURE (3–5)
14.73 ORGANIZATION AND COMMUNICATION IN GROUPS (3–5)

Group III

14.04 INDUSTRIAL ORGANIZATION AND PUBLIC POLICY (3–5)
14.21 ECONOMICS OF INVENTION (3–5)
15.41 FINANCIAL MANAGEMENT (3–6)
15.73 MANAGEMENT LABORATORY (6–3)
21.44 CHANGING ROLE OF THE INDUSTRIAL LEADER (3–5)

Group IV

14.32 STATISTICAL QUALITY CONTROL (3–6)
14.371 STATISTICAL THEORY (3–6)
14.374 DESIGN AND ANALYSIS OF SCIENTIFIC EXPERIMENTS (3–6)
15.032 SAMPLING OF HUMAN POPULATIONS (3–6)
15.51 INDUSTRIAL ACCOUNTING (3–6)

COURSE XIV ELECTIVE SUBJECTS FOR SPECIALIZATION IN POLITICAL SCIENCE

The elective program in political science will normally include one subject in each of the following four groups, together with two additional subjects chosen from one group. 14.97 and 14.98 POLITICAL SCIENCE SEMINAR (3–5, 3–5) are required of all students in political science.

Group I

14.92 COMPARATIVE POLITICAL AND ECONOMIC SYSTEMS (3–5)
14.93 SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS (3–5)
14.94 GOVERNMENT, POLITICS, AND TECHNOLOGY (3–5)

Group II

14.55 BASIC IDEAS OF WESTERN POLITICS AND ETHICS, 500 B.C TO 1500 A.D. (3–5)
14.56 RISE OF MODERN POLITICS AND SOCIAL SCIENCE, 1500 TO 1914 (3–5)
14.57 CONTEMPORARY IDEAS ON POLITICAL AND ECONOMIC DEVELOPMENT (3–5)

Group III

14.51 INTERNATIONAL RELATIONS (3–5)
14.52 PRINCIPLES AND PROBLEMS OF AMERICAN DIPLOMACY (3–5)
14.53 SEMINAR IN INTERNATIONAL POLITICS (3–5)

Group IV

14.58 NATIONALISM AND NATIONAL DEVELOPMENT (3–5)
14.95 POLITICS, SOCIETY, AND POLICY MAKING (3–5)
14.96 INFLUENCES ON POLICY DECISIONS (3–5)

ENGINEERING OR SCIENCE SUBJECTS

Students in Course XIV-A take engineering subjects and those in Course XIV-B take science subjects, except where a language is accepted in the second year. These subjects are to be selected by each student in consultation with his Registration Officer.

A typical sequence of engineering subjects for Course XIV-A based on mechanical engineering would include:

SECOND YEAR

First Term

2.001 APPLIED MECHANICS I (3–5)

Second Term

2.002 APPLIED MECHANICS II (3–5)

THIRD YEAR

First Term

2.403 THERMODYNAMICS I (4–8)
3.11 ENGINEERING MATERIALS (6–4)

Second Term

2.003 APPLIED MECHANICS III (4–8)
2.25 FLUID MECHANICS (4–8)

FOURTH YEAR

First Term

2.37 MECHANICAL BEHAVIOR OF MATERIALS (5–4)
Engineering elective subject (9 to 12)

Second Term

2.082T MECHANICAL ENGINEERING PROBLEMS (2–4)
Engineering elective subject (6 to 9)

A typical sequence for Course XIV-B based on mathematics would include in the four-year program two terms of language (16 units), M62 LINEAR ALGEBRA (3–6), 15 units of science elective subjects, and 57 units of mathematics elective subjects, of which at least two subjects must be from the following:

M 39 METHODS OF APPLIED MATHEMATICS (3–9)
M 411 NUMERICAL ANALYSIS (5–7)
M 442 ELEMENTARY DIFFERENTIAL GEOMETRY (3–6)
M 50 FUNDAMENTALS OF MECHANICS OF CONTINUA (3–6)
M 831 ANALYSIS (3–9)
M 832 ANALYSIS (3–9)

The other mathematics electives might be M 32 ELEMENTARY STATISTICS (3–6) or any other third-, fourth-, or graduate-year mathematics subjects.

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, 14.132, 14.151, 14.191, and 14.192.
Economic history:
14.161 and 14.162.
National income and fluctuations:
14.451, 14.461, 14.472, and 14.481.
Economic development:
14.171, 14.172, and 14.174.
Industrial organization and policy:
14.271 and 14.272.
Economics of innovation:
14.281 and 14.282.
Statistics:
14.371, 14.372, and 14.382.

International economics:
14.581 and 14.582.
Labor economics and public policy:
14.671, 14.672, 14.674, 14.691, and 14.692.
Personnel administration:
14.681, 14.682, 14.693, 14.694, 14.774, and 15.312.
Human relations in industry:
14.771, 14.772, and 14.774.
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, 14.533, 14.534, 14.571, 14.951.
Political communications:
14.953, 14 954, 14.956, 14.957, 14.958.
Defense policy:
14.521, 14.523, 14.524, 14.526.
Public policy and science:
14.941, 14.942, 15.66.
Political and economic development:
4.84, 14.172.
Political theory and comparative politics:
14.57, 14.58, 14.901, 14.902
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 Master of Science Degrees

The undergraduate preparation for the Master of Science degree in Economics and Engineering or Economics and Science 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 (M22) 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, is required.
Science. One full year of college work in science is required.
Humanities. At least six semester subjects in English, history, and other humanities subjects equivalent in scope to those included in the undergraduate humanities curricula of the Institute are required.
Professional Subjects. See the separate requirements for economics and political science below.

A deficiency in mathematics may be removed by completing a special one-semester subject, MATHEMATICS FOR ECONOMISTS (14.101). 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 the appropriate subjects at the Institute to remove them.

THE DOCTORATE IN INDUSTRIAL ECONOMICS

Ordinarily, an undergraduate major in economics is required for doctoral studies in Industrial Economics. In some instances, however, qualified students who have majored in a related field may be admitted, provided that their programs have included an appreciable amount of economics.

A candidate for the doctorate must prepare himself for a General Examination covering five fields. Two or three of these fields are designated as *primary* and require more intensive preparation than the other two or three, which are designated as *secondary*. Economic theory is required as a primary field for all students, including those specializing in industrial relations. Other possible fields include national income and fluctuations, industrial organization and

policy, economics of innovation, international economics, economic development, labor economics and labor relations, human relations in industry, economic history, statistical theory and methods, and others. If statistics and economic history are not among the candidate's five fields of concentration, he must also take one graduate subject in each of these areas.

Following the Institute rules, candidates for the doctorate are required to take a Minor in a field other than economics. Possibilities include political science and international relations, industrial management, mathematics, history, other humanities or social sciences, and particular fields of science or engineering.

THE DOCTORATE IN POLITICAL SCIENCE

Ordinarily, an undergraduate major in political or social science is required for doctoral studies in political science. Qualified students who have majored in a related field of social studies (economics, history, sociology, or social psychology) or in science or engineering are also eligible for admission, provided their programs have included an emphasis upon political and public policy problems.

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 METHODS (14.901) and THEORY OF THE POLITICAL PROCESS (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 and application 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.

OTHER 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 for the doctorate.

The doctoral thesis, which must be written in residence, must make a contribution to knowledge on the subject. As a rule it represents one year's research.

Candidates are required to demonstrate their ability to read professional literature in two modern foreign languages. These languages will ordinarily be German, French, or Russian; however, other languages may be substituted when they have sufficient professional significance for the individual candidate.

Department of Humanities

HOWARD RUSSELL BARTLETT, B.S., A.M.
Professor of English and History; in charge of the Department

JOHN ELY BURCHARD, L.H.D., D.ARCH.
Professor of Humanities;
Dean of the School of Humanities and Social Studies

WILLIAM CHACE GREENE, M.A.
Professor of English

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

ERNST LEVY, B.A.
Professor of Music

CARVEL COLLINS, PH.D.
Professor of English

KLAUS LIEPMANN
Professor of Music

ROY LAMSON, PH.D.
Professor of English

HUSTON CUMMINGS SMITH, PH.D.
Professor of Philosophy

LYNWOOD SILVESTER BRYANT, A.M.
Associate Professor of English and History;
Director of Technology Press

JOHN BELL RAE, PH.D.
Associate Professor of History

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

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

EDWARD NEAL HARTLEY, A.M.
Associate Professor of History

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

ALFRED DUPONT CHANDLER, JR., PH.D.
Associate Professor of History

ROBERT SMITH WOODBURY, S.B., A.M.
Assistant Professor of English and History

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

ROBERT ELLSWORTH MACMASTER, PH.D.
Assistant Professor of History

IRVING HENRY BARTLETT, PH.D.
Assistant Professor of History

THEODORE DAVIDGE LOCKWOOD, PH.D.
Assistant Professor of History

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

WILLIAM DUANE STAHLMAN, S.B., M.A.
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MARTIN LICHTERMAN, PH.D.
Assistant Professor of History

ROWLAND LIPPINCOTT MITCHELL, JR., PH.D.
Assistant Professor of History

NORMAN NORWOOD HOLLAND, PH.D.
Assistant Professor of English

BRUCE MAZLISH, PH.D.
Assistant Professor of History

WALTER FAW CANNON, PH.D.
Assistant Professor of History

BRISON DOWLING COOCH, PH.D.
Assistant Professor of History

CHARLES FENNO HOFFMAN, JR., PH.D.
Assistant Professor of English

ROGER WARREN PROUTY, PH.D.
Assistant Professor of History

CHARLES MONTGOMERY GRAY, PH.D.
Assistant Professor of History

CHARLES ROBERT NIEHAUS, PH.D.
Assistant Professor of History

Lecturers

JOSEPH DEE EVERINGHAM, A.M.

IRVING SINGER, PH.D.

GREGORY TUCKER

Instructors

HENRY ASHTON CROSBY FORBES, A.M.

RUDOLPH BINION, PH.D.

GORDON MAURICE JENSEN, PH.D.

RICHARD LEE SCHOENWALD, PH.D.

HAROLD CLARK KIRKER, PH.D.

LEWIS GERALD BURSEY, PH.D.

THOMAS WHIPPLE PERRY, PH.D.

RICHARD CHARLES RAACK, PH.D.

JAMES BLAINE STONE, A.B.

BURLEIGH TAYLOR WILKINS, PH.D.

KENNETH FRANCIS LEWALSKI, A.M.

ARTHUR LLOYD OLSEN, A.B.

FARRE JOSEPH PEQUIGNEY, A.M.

Professor Emeritus

ARCHER TYLER ROBINSON, A.M.
Professor of English, Emeritus

THE UNDERGRADUATE PROGRAMS

Humanities and Engineering (Course XXI-A)

Humanities and Science (Course XXI-B)

Career opportunities for men who can combine technical competence with informed awareness of the human and social dimensions of today's technological world are available in increasing number in industry and government. The broad objective of the Courses in Humanities and Engineering and in Humanities and Science is to provide a four-year general education strongly rooted in science and engineering or a five-year professional education broader than is customary in most engineering colleges. These Courses are also designed to prepare students for graduate study in science, engineering, medicine, law, business, or public administration, and in fields of the humanities. Students devote about 40 per cent of their programs to humanities and about 60 per cent to either basic science or engineering.

Both Courses award a Bachelor's degree after four years; a student may study a fifth year to earn a second Bachelor's degree in the particular field of science or engineering he has been exploring; in some cases this fifth year may lead to a Master's degree.

On a base which is essentially the Institute's well-rounded program of introductory mathematics, physics, chemistry, and humanities, each of these Courses builds a "double major." One part of each program is the undergraduate curriculum of one of the professional departments, shortened through the omission of some of the more technical or specialized subjects normally taken in the fourth year. The other is a sequence of advanced work in humanities, programmed according to the student's interests and requiring concentration in a particular humanities discipline. Each student is assigned to a member of the Department who acts as his adviser. He may count on continuing guidance from his adviser in the elaboration and pursuit of his chosen program.

Suggested humanities programs include sequences in literature, history, philosophy, and the history and philosophy of science. The requirement of two subjects in HISTORY AND PHILOSOPHY OF SCIENCE (21.81, 21.82), the SENIOR SEMINAR (21.05, 21.06), and the writing of a thesis on an interdisciplinary topic are all designed to assist the student to integrate his studies and to bring into focus the insights and techniques developed in his professional and humanistic studies.

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 in the School of Humanities is shown on page 131; the curriculum for the second, third, and fourth years of both Courses is shown below.

SECOND YEAR[1]

First Term

8.03	PHYSICS	
	or	5–5
8.031	PHYSICS	
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	[2]*Humanities elective subject*	3–5
	[3]*Language or basic engineering or science subject*	*8 to 12*
		43 to 47

Second Term

8.04	PHYSICS	
	or	5–5
8.041	PHYSICS	
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	[2]*Humanities elective subject*	3–5
	[3]*Language or basic engineering or science subject*	*8 to 12*
		43 to 47

THIRD YEAR

First Term

21.81	SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS	3–5
	[2]*Humanities elective subjects*	*16*
	[3]*Basic engineering or science subjects*	*24 to 26*
		48 to 50

Second Term

21.82	SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT	3–5
	[2]*Humanities elective subjects*	*16*
	[3]*Basic engineering or science subjects*	*24 to 26*
		48 to 50

FOURTH YEAR

First Term

21.05	HUMANITIES SEMINAR	3–6
	Elective subject	*8 to 9*
	[2]*Humanities elective subjects*	*16*
	[3]*Engineering or science elective subjects*	*12 to 16*
		45 to 50

FOURTH YEAR (continued)

Second Term

21.06	HUMANITIES SEMINAR	1–4
	THESIS	12
	Elective subject	*8 to 9*
	[2]*Humanities elective subject*	3–5
	[3]*Engineering or science elective subjects*	*12 to 16*
		45 to 50

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] These elective subjects may be a language above the elementary level or any subject listed in the general third- and fourth-year humanities program, as given in Section 2 of this Catalogue; the subjects are to be selected in consultation with the Registration Officer; at least 32 units must be taken in *one* of the humanities disciplines, e.g., literature, philosophy, etc.

[3] Students in Humanities and Engineering (Course XXI-A) take engineering subjects and those in Humanities and Science (Course XXI-B) take science subjects, except where a science or engineering department accepts a language in the second year; the subjects are to be selected in consultation with each student's Registration Officer.

Science and Mathematics Teaching (Course XXI-C)

In Cooperation with the Harvard Graduate School of Education

Well-trained and broadly educated teachers of science and mathematics in secondary schools and junior colleges have an increasingly important role in our society; today they are in active demand. This degree program makes available a broad education in both science and the humanities, a considerable specialized education in one of the sciences or in mathematics, and professional training in education. The liberal education in science and humanities is provided by a sequence of basic science subjects extending over four years and a humanities program equivalent to that of Course XXI-B, Humanities and Science. (See above.) A minimum of 40 units of additional subjects in either a particular science or in mathematics, normally chosen from those which the appropriate professional department requires of or strongly recommends to its regular concentrators, will develop a solid teaching specialty. Students fulfill the requirement of professional training in education at the Harvard Graduate School of Education, under a cooperative agreement. The entire Course is arranged in close correlation with the program at the School of Education and is designed to meet the certification requirements of various state and local authorities.

The first four years are spent mainly at the Institute, though some education subjects at Harvard are introduced as early as the third year. The graduate year includes practice teaching in nearby secondary schools, as well as further studies in education at Harvard and more advanced work in mathematics and science at M.I.T. Students willing to attend the Harvard Graduate School of Education during the summer between their fourth and fifth years may qualify for the Internship Plan of practice teaching in the fifth year. The chief difference between this and the regular Apprenticeship Plan (see the Course curriculum below) is that the student is paid for practice teaching.

Continuance *beyond the third year* requires formal admission to the Harvard Graduate School of Education. Harvard reserves the right to deny admission to any applicant whom it judges unsuitable for the teaching profession; it may also disqualify any student enrolled who fails continuously to satisfy the School's standards. In general, an average of less than C in all M.I.T. subjects makes acceptance doubtful. Furthermore, it is the experience of the Graduate School of Education that a student with a record averaging only C at M.I.T. is not in a good position to fulfill the general graduate requirements at Harvard, one of which calls for an average of B or better in work done at Harvard.

This Course leads to the degrees of Bachelor of Science in Humanities and Science from the Institute and of Master of Arts in Teaching from Harvard University, awarded simultaneously at the end of the fifth (graduate) year. The curriculum for the first year in the School of Humanities is shown on page 131; the curriculum for the second, third, fourth, and fifth (graduate) years is shown below.

SECOND YEAR[1]

First Term

5.41	ORGANIC CHEMISTRY I	4–4
	and	
5.416	ORGANIC PREPARATIONS I	6–0
	or	
5.60	PHYSICAL CHEMISTRY	3–6
8.03	PHYSICS	
	or	5–5
8.031	PHYSICS	
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	[2]*Humanities elective subject*	3–5
		44 or 49

SECOND YEAR (continued)

Second Term

8.04	PHYSICS	
	or	5–5
8.041	PHYSICS	
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	[2]*Humanities elective subject*	3–5
	[3]*Science elective subject*	9
		44

THIRD YEAR[4]

First Term

8.051	ATOMIC AND NUCLEAR PHYSICS I	4–5
21.81	SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS	3–5
	[2]*Humanities elective subject*	3–5
	[3]*Science elective subject*	9
	[5]*Education subject (Harvard)*	4–7
		45

Second Term

21.82	SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT	3–5
M 32	[6]ELEMENTARY STATISTICS	3–6
	[2]*Humanities elective subject*	3–5
	[3]*Science elective subject*	9
	[5]*Education subject (Harvard)*	4–7
		45

FOURTH YEAR[4]

First Term

6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	
	or	4–6
8.08	ELECTRONICS	
21.05	HUMANITIES SEMINAR	3–6
	[2]*Humanities elective subject*	3–5
	[3]*Science elective subject*	9
	[5]*Education subject (Harvard)*	4–7
		47

Second Term

21.06	HUMANITIES SEMINAR	1–4
	THESIS	12
	[2]*Humanities elective subject*	3–5
	[3]*Science elective subject*	9
	[5]*Education subject (Harvard)*	4–7
		45

GRADUATE YEAR[4]

First Term

	[3]*Science elective subjects*	20
B-6	[7]THE AMERICAN SCHOOL (*Harvard*)	4–7
C-8	[7]CURRICULUM AND METHODS IN MATHEMATICS (*Harvard*)	
	or	4–7
C-10	[7]TEACHING OF SCIENCE (*Harvard*)	
C-16	[8]CURRICULUM AND METHODS SEMINAR (*Harvard*)	2–4
		48

Second Term

	[3]*Science elective subjects*	18
	SUPERVISED TEACHING (*Harvard*)	24
C-16	[8]CURRICULUM AND METHODS SEMINAR (*Harvard*)	2–4
		48

Students registered in the graduate year in 1958–59 who were registered in Course IX-C, Science Teaching, in 1956–57 follow the program shown above; this program will lead to the degrees of Bachelor of Science in General Science from the Institute and Master of Arts in Teaching from Harvard University.

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] These elective subjects may be a language above the elementary level or any subject listed in the general third- and fourth-year humanities program, as given in Section 2 of this Catalogue; the subjects are to be selected in consultation with the student's Registration Officer. At least 32 units must be taken in *one* of the humanities disciplines, e.g., literature, philosophy, etc.

[3] These elective subjects in science must include at least 40 units forming a related pattern in a specified science or in mathematics. These must be selected from the sequence of subjects set forth in this Catalogue in the corresponding M.I.T. Course: biology (Course VII), chemistry (Course V), geology (Course XII), mathematics (Course XVIII), or physics (Course VIII).

[4] Subjects marked *Harvard* are taken at the Harvard University Graduate School of Education.

[5] Students are required to take four subjects at Harvard in the third and fourth years. Except in cases where Harvard approval of substitution has been obtained, these must include B-1 EDUCATIONAL PSYCHOLOGY AND MEASUREMENT, A-3 PHILOSOPHY: EDUCATIONAL POLICY, and C-12 COLLEGE ALGEBRA AND GEOMETRY. Students are reminded that they should *plan their programs with a view of the problem of time scheduling*, Harvard and M.I.T. being some distance apart.

[6] 14.31 ELEMENTARY STATISTICS (3–5) and 1 unit of elective work may be substituted for M32.

[7] Substitution of another subject offered by the Harvard University Graduate School of Education may be made with the School's appro.al.

[8] Discussion and preparation seminar in the field chosen for SUPERVISED TEACHING.

Department of Modern Languages

WILLIAM NASH LOCKE, PH.D.
Professor of Modern Languages; in charge of the Department
WILLIAM FILBERT BOTTIGLIA, PH.D.
Associate Professor of Modern Languages
MORRIS HALLE, PH.D.
Associate Professor of Modern Languages
NOAM AVRAM CHOMSKY, PH.D. (*Absent*)
Associate Professor of Modern Languages
RICHARD FELIX KOCH, A.M.
Assistant Professor of Modern Languages
GEORGE ALEXANDROVICH ZNAMENSKY, B.D., ED.M.
Assistant Professor of Russian, Emeritus; Lecturer
HERMAN KLUGMAN, PH.D.
Assistant Professor of Modern Languages, Emeritus; Lecturer
JOSEPH ROY APPLEGATE, PH.D.
Assistant Professor of Modern Languages
HENRY HORNIK, PH.D.
Assistant Professor of Modern Languages
SECOR DELAHAY BROWNE, A.B.
Assistant Professor of Russian

Instructors

EDWARD STEPHEN KLIMA, M.A.
SUMNER KIRSHNER, M.A.
PRIMUS BENEDICT BON, M.A.
DAVID ALLEN DINNEEN, M.A.

Research Associate

VICTOR HUSE YNGVE, PH.D.

Professors Emeriti

GEORGE ALEXANDROVICH ZNAMENSKY, B.D., ED.M.
Assistant Professor of Russian, Emeritus; Lecturer
HERMAN KLUGMAN, PH.D.
Assistant Professor of Modern Languages, Emeritus; Lecturer

MODERN LANGUAGES

The Modern Languages Department offers subjects on several levels in German, French, and Russian. The introductory subjects aim primarily at familiarity with the spoken language, emphasizing pronunciation. The minimum essentials for a reading and speaking knowledge are stressed. The intermediate level is principally concerned with the development of a broad reading vocabulary. The texts cover some scientific matter as well as fiction, drama, and historical or descriptive works, to introduce students to the genius, institutions, and social organization of the countries in question. Advanced subjects in modern French and German include discussions of the form and content of contemporary literature in each country and are conducted entirely in the foreign language. Elective subjects in spoken French and German are also offered.

Special sections of the freshman and sophomore humanities subjects (21.01, 21.02, 21.03, and 21.04) provide reading and lectures in French, allowing students to use and improve their knowledge of the language while simultaneously satisfying the humanities requirement. These sections are open to graduates of American high and secondary schools with three or more years of unusually good achievement in French.

In addition, there are special subjects in French, German, and Russian, *open to graduate students only*. These are designed to help each student develop rapidly the ability to read technical and scientific material in his own field.

The Department also offers two seminars in linguistics. These explore the structural and semantic relationships of language, examine the problems in linguistics, and search for possible solutions to these problems.

The Department's subjects are open as electives to all qualified students throughout the Institute, but there is no undergraduate degree program in modern languages at M.I.T.

In choosing language subjects, students should assume that one year of secondary school study will be considered as roughly equivalent to one Institute term. Credit towards graduation will not be given for repeating work offered for admission.

In addition to its classroom instruction, the Modern Languages Department has an active program of research, in which the tools and concepts of science and engineering are applied to the study of spoken and written language.

SCHOOL OF INDUSTRIAL MANAGEMENT

The Dean of M.I.T.'s newest School describes its origins and present objectives.

Though the School of Industrial Management was established in 1952 under a grant of the Alfred P. Sloan Foundation, Inc., education for industrial management is no new undertaking at M.I.T. The concept of combining science and engineering education with a preparation for management was first realized in 1914, with the founding of a four-year undergraduate Course. Since then, industries based upon technology have shown spectacular growth, and the need for executives qualified in basic technology as well as in management has developed simultaneously.

The programs of the School of Industrial Management are built upon certain continuing policies. First, the School draws great strength from the fact that all its students combine the study of management with the study of science and engineering. The rigorous and systematic thought patterns essential in technology are invaluable in the development of a business executive. Similarly, subjects taught in the School of Industrial Management make an important contribution to the thinking of students who are concentrating in science or engineering, for management must be concerned with matters of judgment and with problems which have

human as well as technical aspects. The School also has a close relationship with the Department of Economics and Social Science, an association which provides continued insight into the realities of human behavior and an opportunity to relate these realities to the working of the firm.

Another important feature of all the School's teaching is a concentration on the analysis of problems. Methods of analysis are stressed, and there is less emphasis upon describing current managerial practice. Great frontiers are now opening up in the application of mathematical and statistical methods to industrial problems; the School, by environment and by purpose, contributes to this important trend.

Although the School unequivocally builds its programs as an intellectual enterprise, it recognizes without reservation its responsibility for helping each student develop a sound set of values and seeks to provide him with a strong foundation for mature judgment in both his personal and professional life.

Finally, the School is firmly committed to the objective of providing a comprehensive background for a career in general management. In no phase of its activities does it permit narrow specialization at the expense of breadth of viewpoint. Although highly advanced work in many areas of management is offered, the purpose here is not to produce specialists so much as to produce men who have a powerful understanding of the uses and limitations of these specialties in the total managerial process. This, we believe, is a fundamental and yet a practical program of education.

E. P. BROOKS

EDWARD PENNELL BROOKS, S.B.
Professor of Industrial Management; Dean
HOWARD WESLEY JOHNSON, B.S., M.A.
Associate Professor of Industrial Management; Associate Dean; Director, Executive Development Programs
ERWIN HASKELL SCHELL, S.B.
Professor of Industrial Management, Emeritus; Lecturer
DOUGLASS VINCENT BROWN, PH.D.
Alfred P. Sloan Professor of Industrial Management
DOUGLAS MURRAY McGREGOR, PH.D., LL.D.
Professor of Industrial Management
ELI SHAPIRO, PH.D.
Professor of Finance
ELTING ELMORE MORISON, A.M.
Professor of Industrial History
BILLY EARL GOETZ, PH.D.
Professor of Industrial Management
HOULDER HUDGINS, B.A.
Professor of Industrial Management
SIDNEY STUART ALEXANDER, PH.D.
Professor of Industrial Management
JAY WRIGHT FORRESTER, D.ENG.
Professor of Industrial Management
DAVID DURAND, PH.D.
Professor of Industrial Management
ROSS MacDUFFEE CUNNINGHAM, D.C.S.
Associate Professor of Marketing
GERALD BRUCE TALLMAN, PH.D.
Associate Professor of Marketing
THOMAS MASON HILL, A.B., M.B.A.
Associate Professor of Industrial Management
MYRON JULES GORDON, PH.D.
Associate Professor of Industrial Management
MARVIN EVERT SHAW, PH.D.
Associate Professor of Industrial Management
THOMSON McLINTOCK WHITIN, PH.D.
Associate Professor of Industrial Management
LEO BENJAMIN MOORE, S.M.
Associate Professor of Industrial Management
DANIEL MARK HOLLAND, PH.D.
Associate Professor of Finance
WILLIAM LOUIS LETWIN, PH.D.
Associate Professor of Industrial History
HERBERT FRANKLIN GOODWIN, S.B.
Assistant Professor of Industrial Management
ROBERT HENRY GREGORY, PH.D.
Assistant Professor of Industrial Management
EDWARD HARRY BOWMAN, PH.D.
Assistant Professor of Industrial Management

ALBERT HAROLD RUBENSTEIN, PH.D.
Assistant Professor of Industrial Management
GREGORY CHI-CHONG CHOW, PH.D.
Assistant Professor of Industrial Management
PETER SAVOIS KING, B.S., M.B.A.
Assistant Professor of Marketing
EDWIN KUH, PH.D.
Assistant Professor of Finance
RICHARD BLAISE MAFFEI, PH.D.
Assistant Professor of Industrial Management
JOHN LAWRENCE ENOS, S.B., M.A.
Assistant Professor of Industrial Management
GORDON SHILLINGLAW, PH.D.
Assistant Professor of Industrial Management
EDGAR HENRY SCHEIN, PH.D.
Assistant Professor of Industrial Management
CHADWICK JOHN HABERSTROH, PH.D.
Assistant Professor of Industrial Management
JOSEPH VINCENT YANCE, PH.D.
Assistant Professor of Industrial Management
ZENON SOTERIOU ZANNETOS, A.B., S.M.
Assistant Professor of Accounting
EDWARD LINDLEY BOWLES, D.SC.
Consulting Professor of Industrial Management
WROE ALDERSON, A.B.
Visiting Professor of Marketing
WILLIAM A. WALLACE KREBS, JR., A.B., LL.B.
Visiting Associate Professor of Law

Lecturers

SAMUEL EWER EASTMAN, LL.B., B.S.E.
STANLEY MARTIN JACKS, A.M., LL.B.
STUART MACMILLAN, PH.B., LL.B.
BERNARD J. MULLER-THYM, PH.D., LL.D.
MASON SMITH, B.S., M.B.A.
ERLIND HJALMAR THORSTEINSON

Instructors

VICTOR LEE ANDREWS, PH.D.
RICHARD LEONARD BURKE, B.A.

Assistant Director, Executive Development Programs

THOMAS MICHAEL O'FARRELL, B.S., M.B.A.

Administrative Assistants

GERTRUDE ELIZABETH BURNS
BARBARA MARIE DOYLE, A.B.
ESTHER MERRILL, B.S.
MIRIAM SHERBURNE, A.B.

Research Associates

THEODORE MARK ALFRED, A.B., M.B.A.
ROBERT WILLIAM AVERY, M.A.
RICHARD KIERSTEAD BENNETT, E.E.

Professors Emeriti

ERWIN HASKELL SCHELL, S.B.
Professor of Industrial Management, Emeritus; Lecturer
CHARLES HUNTINGTON PORTER, A.B., S.B.
Professor of Accounting, Emeritus

THE UNDERGRADUATE PROGRAM

Industrial Management (Course XV)

The undergraduate Course in Industrial Management is designed especially for students who combine an aptitude for science and engineering with the qualities necessary for effective administration. Successful management of industrial enterprises in the future will demand the ability to deal with technological problems of increasing complexity, a broad comprehension of business problems, and a deep understanding of human behavior. Fundamental training in science and engineering has proved to be an excellent base for the study of management, and the Institute is uniquely qualified to provide a curriculum which combines science and technology with administration and the humanities.

The program in Industrial Management begins in the sophomore year with an introduction to basic economics. This is followed by a subject which applies economic analysis to business problems. The junior year requires the study of six one-term subjects, each dealing with a major area of industrial management. Emphasis in these subjects is on the analysis of business problems and on understanding managerial principles. This includes the use of the many rapidly developing mathematical and statistical techniques for solving industrial problems.

The role of the social sciences as fundamental disciplines underlying successful administration is given careful attention throughout the undergraduate program. Economics, of course, is heavily stressed. The subjects in personnel administration and marketing in particular are largely based upon psychology. Students are encouraged to elect further subjects in business history and psychology.

In the senior year each student may select, with the help of his faculty adviser, two or three one-term subjects which suit his own particular interests and aptitudes. The range of elective subjects in this year is such that the student may both broaden his knowledge by the study of new areas and increase his depth of understanding by doing advanced work in familiar subjects. An important part of the fourth-year program is the thesis, which affords the dual opportunity of exploring in depth a problem of the student's own choice and of carrying out a limited research program on his own initiative.

The science and engineering programs in the Course in Industrial Management emphasize

matter of a fundamental nature rather than the details of its application. The School believes that within the limits of a four-year program, whose main objective is a sound professional education for administration, students should have a solid foundation in science and engineering subjects — first, as a preparation for effective management and second, as a preparation for further progress in professional engineering. The three suggested programs for engineering and science subjects shown below demonstrate the fundamental nature of the science and engineering sequence. Other programs based upon such fields as metallurgy and mathematics may be arranged.

The Course leads to the degree of Bachelor of Science in Industrial Management.

FIRST YEAR

First Term

5.01	GENERAL CHEMISTRY	6–5
8.01	PHYSICS	5–6
21.01	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 11	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

Second Term

5.02	GENERAL CHEMISTRY	6–5
8.02	PHYSICS	5–6
21.02	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 12	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

[1] Students accepted for the N.R.O.T.C. Program (see Section 2) omit the elective subjects and in their place take NS11 and NS12 ORIENTATION AND SEA POWER (4–5, 4–5) in the first and second terms, respectively.

ELECTIVE SUBJECTS

Students are required to earn 12 units of elective credits in their first two years. These may include Approved First-Year Elective Subjects, upperclass elective subjects, Military Science, or Air Science. Any part of this elective requirement taken in the second year will be in addition to the specified second-year curriculum of this Course. Students electing Military Science or Air Science subjects should refer to the Army and Air Force R.O.T.C. Programs in Section 2 of this Catalogue.

APPROVED FIRST-YEAR ELECTIVE SUBJECTS

The following subjects are approved as first-year electives. The number of students admitted to any one of these subjects will depend on the facilities available.

First Term

12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
20.00	MAN'S FOOD (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.005	PUBLIC SPEAKING (3–3)
AS 11	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 111	GRAPHICS LABORATORY I (3–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 21	[1]SPOKEN GERMAN (3–3)
L 31	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 61	[1]INTRODUCTION TO SPOKEN FRENCH (3–3)
M 100	ELEMENTARY NUMBER THEORY (2–4)
MS 11	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

Second Term

1.002	TECHNOLOGY IN OUR CIVILIZATION (2–4)
4.00	STRUCTURE OF THE CITY (3–3)
7.00	PERSPECTIVES IN LIFE SCIENCE (3–3)
12.00	EARTH SCIENCES (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) (2–4)
12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.006	PUBLIC SPEAKING (3–3)
AS 12	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 121	GRAPHICS LABORATORY II(3–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 14	ELEMENTARY NOMOGRAPHY (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 22	[1]SPOKEN GERMAN (3–3)
L 32	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 62	[1]CONVERSATIONAL FRENCH (3–3)
M 101	TOPICS IN DISCRETE MATHEMATICS (2–4)
MS 12	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

[1] The prerequisite is 3 years of high school German or French, as the case may be, or the equivalent.

SECOND YEAR[1]

First Term

8.03	PHYSICS	5–5
14.01	ECONOMIC PRINCIPLES I — *Humanities*	3–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	Engineering or science elective subjects (see below)	*10*
		45

Second Term

8.04	PHYSICS	5–5
15.01	INDUSTRIAL MANAGEMENT I	3–6
21.04	HUMANITIES	3–5
M 221	PROBABILITY AND OPERATIONS ANALYSIS	3–6
	Engineering or science elective subjects (see below)	*10*
		46

SECOND YEAR (continued)
Summer
Industrial practice is recommended.

THIRD YEAR
First Term

15.02	INDUSTRIAL MANAGEMENT II	3–6
15.50	ACCOUNTING	5–4
15.81	MARKETING	3–6
	Elective subjects (see below)	*19*
		46

Second Term

15.30	PERSONNEL ADMINISTRATION	3–6
15.41	FINANCIAL MANAGEMENT	3–6
15.71	PRODUCTION MANAGEMENT	3–6
	Elective subjects (see below)	*26*
		53

FOURTH YEAR
First Term

	THESIS	2
	Elective subjects (see below)	*44*
		46

Second Term

	THESIS	10
	Elective subjects (see below)	*35*
		45

ELECTIVE SUBJECTS

Each student is expected to plan a schedule of at least 144 elective units, excluding all freshman electives. This must be approved by his Registration Officer and must fulfill the following requirements:

1. At least 72 units in an approved engineering and / or science program. This sequence must be started in the second year. Suggested sequences in three major fields are shown below.
2. Completion of the general M.I.T. humanities requirement as described in Section 2 of this Catalogue. Concentration in Economics (Field Six) and Labor Relations (Field Eight) is not permitted in satisfaction of the humanities requirement. 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken, as specified.
3. The remaining elective units may be in any department of the Institute. They must comprise a program which satisfies the student's Registration Officer. Ordinarily no more than 27 units may be in further industrial management subjects.

SUGGESTED PROGRAMS OF ENGINEERING OR SCIENCE SUBJECTS
First Program
SECOND YEAR

2.001	APPLIED MECHANICS I	3–5
2.002	APPLIED MECHANICS II	3–5

THIRD YEAR

1.611	FLUID MECHANICS	3–6
2.40	HEAT ENGINEERING	4–5
2.42	HEAT ENGINEERING	3–6
3.11	ENGINEERING MATERIALS	6–4

FOURTH YEAR

6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	4–6
6.19	FUNDAMENTALS OF ELECTRONICS	4–6
		73

Second Program
SECOND YEAR

6.00	INTRODUCTORY CIRCUIT THEORY	7–5
6.01	INTRODUCTORY CIRCUIT THEORY	7–5

THIRD YEAR

6.02	ELECTRONIC DEVICES AND CIRCUITS	7–5
6.05	ELECTRONIC CIRCUITS AND SIGNALS	7–5
M 351	ADVANCED CALCULUS FOR ENGINEERS	3–6
M 352	ADVANCED CALCULUS FOR ENGINEERS	3–6

FOURTH YEAR

6.25	INTRODUCTION TO DIGITAL COMPUTERS	3–6
		75

Third Program
SECOND YEAR

5.41	ORGANIC CHEMISTRY I	4–4
10.11	CHEMICAL ENGINEERING	2–3
10.17	INDUSTRIAL CHEMISTRY	3–4

THIRD YEAR

5.61	PHYSICAL CHEMISTRY I	4–4
5.62	PHYSICAL CHEMISTRY II	4–4
10.28	CHEMICAL ENGINEERING THERMODYNAMICS	4–6
10.29	CHEMICAL ENGINEERING	4–6

FOURTH YEAR

10.31	CHEMICAL ENGINEERING	4–6
10.32	CHEMICAL ENGINEERING	4–6
		76

Other sequences may be arranged with the approval of the Registration Officer.

GRADUATE STUDY IN INDUSTRIAL MANAGEMENT

The School of Industrial Management offers graduate study leading to the degree of Master of Science in Industrial Management. The 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 curriculum is closely correlated with the graduate subjects in the Department of Economics and Social Science. While a doctorate in industrial management is not offered, the faculty of the School joins that in the Department of Economics and Social Science in programs leading to the Doctor of Philosophy in Industrial Economics. The various and extensive resources of other departments are likewise available. Joint programs in industrial management and fields of engineering may be arranged. Depending on their depth and coverage, such programs may lead to one Master's degree without specification, two Master's degrees, or a doctorate.

The typical Master's degree program in industrial management requires two years of study at M.I.T. Credit for subjects completed elsewhere may permit some students to meet the requirements for the degree in three semesters or in one year. The first-year curriculum for those who have done no previous work in this field normally includes the following subjects:

STATISTICAL METHOD (14.381)
PROBLEMS IN AMERICAN POLITICAL ECONOMY (15.201)
SOCIAL PSYCHOLOGY (15.371)
MANAGERIAL ACCOUNTING (15.501)
ECONOMICS OF THE FIRM (15.511)
ECONOMICS AND INDUSTRIAL MANAGEMENT (14.117)
LABOR-MANAGEMENT RELATIONS (15.312)
FINANCIAL MANAGEMENT (15.412)
PRODUCTION MANAGEMENT (15.712)
MARKETING (15.812T)

The second year is given wholly to advanced work, in accordance with the general requirements for the Master's degree. The typical program includes eight elective subjects and a thesis, the latter representing an individual research project conducted under the supervision of a separate staff committee for each student. Subject offerings are described elsewhere in this Catalogue. Selection is not limited to offerings in the School of Industrial Management.

Features of the graduate program include special seminars with visiting lecturers from industry, group field work, participation in faculty research, and individual field and laboratory investigation. The facilities of the M.I.T. Computation Center are available for use in testing models designed to aid in management decision-making. The Master's thesis usually involves intensive study of some industrial problem of significance to a participating company or to industry in general. Part-time research assistantships carrying substantial stipends and affording opportunity for direct participation in faculty research are available.

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:

Admission Test for Graduate Study in Business. All candidates for admission for the degree of Master of Science in Industrial Management, other than applicants for the Executive Development Program (see below), are required to take the Admission Test for Graduate Study in Business. This test is administered by the Educational Testing Service, Princeton, New Jersey; information about dates and locations at which the test will be administered may be obtained from that agency.

Prerequisite Subjects. Applicants for graduate study in Industrial Management usually have a college degree in some recognized field of science or engineering. The undergraduate program must have included regular college courses of not less than one year each in physics and calculus, and a course in elementary economics.

POSTGRADUATE STUDY IN INDUSTRIAL MANAGEMENT

Two programs are provided in the School of Industrial Management for business administrators who wish to extend their knowledge of the fundamentals behind effective management. The *Executive Development Program*, for which Sloan Fellowships are available under special grants of the Alfred P. Sloan Foundation, Inc., is a twelve-month study of the fundamentals of business management, intended for young executives about to reach major managerial responsibilities. A part of this program is taken in conjunction with the regular graduate program, and it leads to the degree of Master of Science in Industrial Management. The *Program for Senior Executives* makes the facilities of the School of Industrial Management available to mature business executives during two ten-week study periods each year.

A statement of the role of science at M.I.T., by the Dean of the School.

Science is an effort to see as deeply as possible into the nature of the physical world, to understand the relationships among the phenomena of nature. Today science is one of the most exciting of human activities because of the rapidity with which it is providing new insights and affecting human culture.

The scientist, in carrying on his work, has a great variety of opportunities open to him. He is needed as a teacher at all levels of education. He is encouraged as an individual to seek and pursue new directions for the extension of knowledge. Great projects involving the teamwork of hundreds or even thousands of trained people need scientists at all levels of their organization. The scientist is wanted as an administrator in enterprises involving the work of other scientists and engineers.

The School of Science at M.I.T. offers a broad training which fits students for work in any of these activities. Participation in the research programs being carried out by the staff provides additional training in many highly specialized fields and gives the prospective scientist an insight into the details of how scientific knowledge grows.

The fields of teaching and research in the School of Science may be classified, broadly speaking, into four fields —

physical sciences, life sciences, earth sciences, and mathematics — the latter a language common to all science.

The physical sciences are concerned with the structure and interaction of matter and energy. Particularly active in this category at present are studies of atomic nuclei, of elementary particles, and of the great concentrations of energy which can be released in nuclear reactions; of electron physics and the incredibly varied ways in which the motion of this lightest of the particles can be used; the structures of atoms and molecules and of the electric and magnetic interaction of their various parts; the structures of liquids and solids, of metals, of insulators, of semiconductors, and the analysis and building up of molecular assemblages of increasing complexity.

The life sciences cover a very broad field. The most fundamental division is concerned with molecular biology and the chemistry of the molecules found in living cells. These molecules occur in a wide variety of forms, from the simplest inorganic and organic types up to the most complex known, the protein molecules. The properties of these molecules, when gathered together, govern the structure and the energy-converting properties of living systems. In cellular biology the scientist studies the structure, function, and origin of whole cells. In systems biology he examines the combined effects of aggregates of similar cells whose coordinated action determines particular activities of an entire plant or animal. Finally, psychologists, sociologists, and ecologists study the input-output relationships of the whole organism. Teaching and research in all these fields and in the relations between them are carried out at M.I.T. in biology and related departments.

In the earth sciences a great variety of physical and chemical phenomena present themselves in complex systems that call for a penetrating application of the basic concepts of the physical sciences. Much of the field of classical physics, not related to the atom or its nucleus, was historically developed in the study of these earth science problems, and recent advances in our understanding of the earth's atmosphere, of weather prediction and control, and of the seas and oceans are continuations of this effect. The history and development of the earth in its present form, the dynamics of its interior and surface, its magnetic field, its electrical and chemical constitution — these are all studies in geophysics, geology, oceanography, and meteorology.

Mathematics plays an increasingly important role in all of science, and mathematicians are continuing their tradition of fruitful cooperation and progress in both pure and applied mathematical fields.

The School of Science at M.I.T. has close and important relationships with the other schools, with the surrounding community, and with the nation. The continuing close contact of our staff with a wide variety of problems of industry and of state and national governments provides a most stimulating atmosphere for study.

GEORGE R. HARRISON

THE FIRST YEAR IN THE SCHOOL OF SCIENCE

The science subjects required in the first two undergraduate years in all the schools at M.I.T. are intended to acquaint the future citizen, whatever his profession, with an important part of our heritage from the past. They are, in this sense, a part of the general education of every M.I.T. student.

In addition, the value of a broad and thorough knowledge of the sciences for engineering innovation and evolution has been dramatically demonstrated during recent decades, and the curricula throughout the Schools of Science and Engineering reflect an appreciation of this fact.

There is no essential difference in the first-year curricula for these two Schools. Both emphasize the fundamentals of science, as preparation for the more detailed studies in either science or engineering which follow. First-year electives give students in the School of Science opportunities to explore fields in which they may later undertake major studies — or to follow other important interests.

The curriculum below shows the minimum requirements for the first year in all Courses in the School of Science.

First Term

5.01	GENERAL CHEMISTRY	6–5
8.01	PHYSICS	5–6
21.01	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 11	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

Second Term

5.02	GENERAL CHEMISTRY	6–5
8.02	PHYSICS	5–6
21.02	FOUNDATIONS OF WESTERN CIVILIZATION	3–5
M 12	CALCULUS	3–6
	[1]*Elective subject (see below)*	*6*
		45

[1] Students accepted for the N.R.O.T.C. Program (see Section 2 of this Catalogue) omit the elective subjects and take in their place NS11 and NS12 ORIENTATION AND SEA POWER (4–5, 4–5) in the first and second terms, respectively.

ELECTIVE SUBJECTS

Students are required to earn 12 units of elective credits in their first two years. These may include Approved First-Year Elective Subjects, upper-class elective subjects, Military Science, or Air Science. Any part of this elective requirement taken in the second year will be in addition to the specified second-year curriculum of the Course elected. Students electing Military Science or Air Science subjects should refer to the Army and Air Force R.O.T.C. Programs in Section 2 of this Catalogue.

APPROVED FIRST-YEAR ELECTIVE SUBJECTS

The following subjects are approved as first-year electives. The number of students admitted to any one of these subjects will depend upon the facilities available.

First Term

12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
20.00	MAN'S FOOD (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.005	PUBLIC SPEAKING (3–3)
AS 11	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 111	GRAPHICS LABORATORY I (3–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 21	[1]SPOKEN GERMAN (3–3)
L 31	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 61	[1]INTRODUCTION TO SPOKEN FRENCH (3–3)
M 100	ELEMENTARY NUMBER THEORY (2–4)
MS 11	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

Second Term

1.002	TECHNOLOGY IN OUR CIVILIZATION (2–4)
4.00	STRUCTURE OF THE CITY (3–3)
7.00	PERSPECTIVES IN LIFE SCIENCE (3–3)
12.00	EARTH SCIENCE (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) (2–4)
12.001	ASTRONOMY (3–3)
19.003	ELEMENTARY METEOROLOGY I (3–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–4)
21.002	ENGLISH COMPOSITION (2–4)
21.006	PUBLIC SPEAKING (3–3)
AS 12	AIR SCIENCE (3–0)
D 11	ENGINEERING DRAWING (4–2)
D 12	DESCRIPTIVE GEOMETRY (4–2)
D 121	GRAPHICS LABORATORY II (3–2)
D 13	GRAPHICAL PROCESSES (2–4)
D 14	ELEMENTARY NOMOGRAPHY (2–4)
D 15	BASIC MACHINE DRAWING (4–2)
L 22	[1]SPOKEN GERMAN (3–3)
L 32	ENGLISH FOR FOREIGN STUDENTS (3–3)
L 62	[1]CONVERSATIONAL FRENCH (3–3)
M 101	TOPICS IN DISCRETE MATHEMATICS (2–4)
MS 12	MILITARY SCIENCE (3–0)

Any language subject for which the student is prepared.

[1] The prerequisite is 3 years of high school German or French, as the case may be, or the equivalent.

Department of Biology

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Associate Professor of Physiology; Executive Officer
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CYRUS LEVINTHAL, PH.D.
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MELVIN JACOB GLIMCHER, M.D.
MARCUS CAMPBELL GOODALL
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ROBERT LAWRENCE HERRMANN, PH.D.
ALAN JOHN HODGE, PH.D.
JAMES FREDERICK KOERNER, PH.D.
GEORG KARL MANNER, PH.D.
MARIO LUXORO MARIANI, PH.D.
MURRAY DAVID ROSENBERG, PH.D.
FRANK GEORGE ROTHMAN, PH.D.
MIRIAM FIELDS SCHURIN, PH.D.
NEVILLE DAVID SYMONDS, PH.D.
EDWIN WILLIAM TAYLOR, PH.D.
ETHEL SOLZENBERG TESSMAN, PH.D.
IRWIN TESSMAN, PH.D.
BERT LESTER VALLEE, M.D.

Professors Emeriti

SAMUEL CATE PRESCOTT, SC.D.
Professor of Industrial Biology, Emeritus
CLAIR ELSMERE TURNER, DR.P.H., SC.D.
Professor of Public Health, Emeritus

BIOLOGY

The field of biology has undergone an impressive development during the last twenty-five years. From the conventional fields of classical botany and zoology has evolved a new field of scientific endeavor. Today biology is an exact science, utilizing physics and chemistry and surpassing both these fields in its scope and its immediate importance to man's life and health. New scientific concepts have emerged from this development; the experimental means of the classical biologist are supplemented by modern research methods. The research laboratory of today's biologist comprises electronic and optical systems of all kinds, electron microscopes, and mass spectrographs, as well as many of the methods of electrical and nuclear instrumentation.

This new approach to the biological sciences is especially at home in the M.I.T. environment, where there are important activities and facilities in all the physical sciences. The Department of Biology thus offers unusual opportunities to undergraduate, graduate, and postdoctoral students.

THE UNDERGRADUATE PROGRAM

Quantitative Biology (Course VII)

The undergraduate curriculum in the biological sciences is designed to prepare students for teaching and research careers in biology and for work in industries which are concerned with biological materials and fermentation processes. In addition, the Department places great emphasis on its premedical training program. Aiding in this program are a dozen or more medical doctors who have come to the Department for special postdoctoral studies and research. Students who graduate from the program find that it is an excellent preparation for future study in medical school.

The Course stresses the application of quantitative, analytical methods in the subjects of pure biology; hence particular emphasis is given to those fields which, in the present stage of development, are susceptible of such treatment. Since modern medicine is rapidly becoming less empirical and more scientific, it is especially important that those who wish to prepare for medical research become acquainted with the quantitative approach to biological phenomena.

The first two years of the Course are devoted to fundamental subjects in mathematics, physics, and chemistry plus introductory biology and studies in the humanities; specialization begins in the third year. While the student is assured of a sound background in mathematics, physics, chemistry, and the fundamentals of modern biology, provision is made in the third and fourth years for a wide choice of electives, both in the biological and other sciences and in the humanities.

The Course leads to the degree of Bachelor of Science in Quantitative Biology. The curriculum for the first year is shown on page 151; the curriculum for the second, third, and fourth years is as follows:

SECOND YEAR[1]

First Term

7.01	GENERAL BIOLOGY I	3–4
7.011	GENERAL BIOLOGY LABORATORY I	3–0
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	Elective subject	*8*
		45

Second Term

7.02	GENERAL BIOLOGY II	3–4
7.021	GENERAL BIOLOGY LABORATORY II	3–1
8.04	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	Elective subject	*8*
		46

THIRD YEAR

First Term

5.41	ORGANIC CHEMISTRY I	4–4
5.416	ORGANIC PREPARATIONS I	6–0
5.61	PHYSICAL CHEMISTRY I	4–4
5.611	PHYSICAL CHEMISTRY LABORATORY I	4–2
7.03	GENETICS AND CYTOLOGY	6–4
	Humanities (see Section 2)	3–5
		46

Second Term

5.14	ANALYTICAL CHEMISTRY I	3–3
5.142	ANALYTICAL CHEMISTRY LABORATORY I	5–0
5.62	PHYSICAL CHEMISTRY II	4–4
5.621	PHYSICAL CHEMISTRY LABORATORY II	4–2
7.04	DEVELOPMENTAL BIOLOGY	8–4
	Humanities (see Section 2)	3–5
	Elective subject	*8*
		53

Students registered in the third year, second term, 1958–59: omit 5.14 and 5.142. Change *elective subjects* to *12.*

FOURTH YEAR

First Term

7.05	GENERAL BIOCHEMISTRY AND PHYSIOLOGY I	3–6
7.051	GENERAL BIOCHEMISTRY AND PHYSIOLOGY LABORATORY I	8–0
	THESIS	10
	Humanities (see Section 2)	3–5
	Elective subjects	*12*
		47

Second Term

7.06	GENERAL BIOCHEMISTRY AND PHYSIOLOGY II	3–6
7.061	GENERAL BIOCHEMISTRY AND PHYSIOLOGY LABORATORY II	6–0
	THESIS	10
	Humanities (see Section 2)	3–5
	Elective subjects	*16*
		49

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

GRADUATE STUDY IN BIOLOGY

The Department of Biology offers graduate work leading to the degrees of Master of Science in Biology, Biochemistry, or Biophysics, and Doctor of Philosophy in Biology in any one of the following fields of specialization: analytical biology, general 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, pure and applied biological research, medical research, and in many fields of industry and industrial research, such as biophysical, biochemical, pharmaceutical, leather, oil, fermentation, and other industries. The educational program is based upon a number of general and specialized subjects and assignments and upon the student's active participation in the Department's research projects or his own research work.

Research facilities are available for a wide variety of fields in analytical biology, biochemistry, and biophysics.

ANALYTICAL BIOLOGY

The laboratories of biology apply chemical and physical methods to modern problems of biology. Major areas of research include molecular biology, analytical cytology, physiological genetics, cellular physiology, growth, and differentiation. Specific current research projects include the chemistry and structure of nerve tissue, connective tissue and chromosomes, electrical properties of nerve and muscle, and the study of tissues in culture.

BIOCHEMISTRY

The laboratories of the Division of Biochemistry are equipped with the most modern tools for teaching and research. Special equipment for the isolation and characterization of enzymes, a radioactivity center, and a mass spectrograph are some of the devices in current use in these laboratories for the solution of problems in enzymology, biosynthesis of proteins, nucleic acids and co-enzymes, intermediary metabolism, and microbiology.

BIOPHYSICS

The physical aspects of biological problems are approached in the biophysical laboratories through the use of techniques such as X-ray diffractions, electron microscopy, ultracentrifugation, electrophoresis, and spectroscopy as well as through the development of new instruments. Current research problems lie in the area of the structures of proteins, polysaccharides, and nucleic acids; the physical chemistry of proteins and their interactions; communications biophysics; and instrumentation for use in biology and medicine.

Attention is directed to the cooperative arrangement with Harvard University described in Section 3 of this Catalogue.

Entrance Requirements for Graduate Study

The Department modifies the general Institute requirements for graduate study (see Section 3) as follows:

Mathematics
CALCULUS (M11, M12)

Physics
One year of college physics

Chemistry
ORGANIC CHEMISTRY I (5.41)

Professional subjects
GENERAL BIOCHEMISTRY AND PHYSIOLOGY I and II (7.05, 7.06) *or* their equivalent

Deficiencies in the subjects listed above may be removed, if not too extensive, while pursuing a graduate program.

Requirements for Advanced Degrees

There are no specified programs for degree work, since the subjects required vary with the field of specialization. Each student selects his own program, according to certain broad principles, after consultation with the Graduate Committee of the Department.

In addition to the general requirements for advanced degrees (see Section 3), the Department requires all students to take BIOLOGY SEMINAR (7.31, 7.32). A reading knowledge of French and German is required for a Doctor's degree.

Assistantships and Fellowships

A number of qualified students are appointed each year as teaching or research assistants. A research assistant may be permitted to use the results of his assigned research work in a graduate thesis, with possible acceleration of his program. In addition, a number of predoctoral and postdoctoral fellowships are available in analytical biology, physiology, biochemistry, and biophysics. Information about assistantships and fellowships is available from the Head of the Department; applications for the fall term must be made before the March 31 preceding.

Department of Chemistry

ARTHUR CLAY COPE, PH.D., SC.D.
Professor of Organic Chemistry; in charge of the Department
LEICESTER FORSYTH HAMILTON, S.B.
Professor of Analytical Chemistry, Emeritus; Lecturer; Executive Officer
WALTER CECIL SCHUMB, PH.D.
Professor of Inorganic Chemistry, Emeritus, Lecturer
GEORGE SCATCHARD, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus; Lecturer
JAMES ALEXANDER BEATTIE, PH.D.
Professor of Physical Chemistry
CHARLES DUBOIS CORYELL, PH.D.
Professor of Chemistry
ISADORE AMDUR, PH.D.
Professor of Physical Chemistry
JOHN CLARK SHEEHAN, PH.D.
Professor of Organic Chemistry
WALTER HUGO STOCKMAYER, PH.D.
Professor of Physical Chemistry
RICHARD COLLINS LORD, PH.D.
Professor of Chemistry; Director of Spectroscopy Laboratory
GEORGE ELBERT KIMBALL, PH.D.
Professor of Chemistry (Visiting)
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
FREDERICK SYDNEY DAINTON, PH.D., SC.D.
Arthur D. Little Professor of Chemistry (Visiting)
LOUIS HARRIS, PH.D.
Associate Professor of Physical Chemistry
AVERY ALLEN ASHDOWN, PH.D.
Associate Professor of Organic Chemistry, Emeritus; Lecturer
Secretary of the Society of Arts
STEPHEN GERSHOM SIMPSON, PH.D.
Associate Professor of Analytical Chemistry
RALPH CHILLINGWORTH YOUNG, PH.D.
Associate Professor of Inorganic Chemistry, Emeritus; Lecturer
ARTHUR RANDALL DAVIS, PH.D.
Associate Professor of Inorganic Chemistry, Emeritus; Lecturer
NICHOLAS ATHANASIUS MILAS, PH.D.
Associate Professor of Organic Chemistry
EDMUND LEE GAMBLE, PH.D.
Associate Professor of Inorganic Chemistry
LAWRENCE JOSEPH HEIDT, PH.D.
Associate Professor of Physical Chemistry
DAVID NEWTON HUME, PH.D.
Associate Professor of Chemistry
LOCKHART BURGESS ROGERS, PH.D.
Associate Professor of Chemistry
DAVID POWELL SHOEMAKER, PH.D.
Associate Professor of Chemistry
FREDERICK DAVIS GREENE, II, PH.D.
Associate Professor of Chemistry
JOHN STEWART WAUGH, PH.D.
Associate Professor of Chemistry
CARL WESLEY GARLAND, PH.D.
Assistant Professor of Chemistry
HERBERT OTIS HOUSE, PH.D.
Assistant Professor of Chemistry
NORMAN ALLAN NELSON, PH.D.
Assistant Professor of Chemistry
FRANK ALBERT COTTON, PH.D.
Assistant Professor of Chemistry
WILLIAM ROBERT MOORE, PH.D.
Assistant Professor of Chemistry
WALTER ROLLIER THORSON, PH.D.
Assistant Professor of Chemistry

Instructors

KLAUS BIEMANN, PH.D.
DIETMAR SEYFERTH, PH.D.
JAMES WILLIAM ROSS, JR., PH.D.

Research Associate

STEPHEN MEARS NAGY, SC.D.

Professors Emeriti

FREDERICK GEORGE KEYES, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus
MILES STANDISH SHERRILL, PH.D.
Professor of Physical Chemistry, Emeritus
EARLE BOWMAN MILLARD, PH.D.
Professor of Physical Chemistry, Emeritus
WALTER CECIL SCHUMB, PH.D.
Professor of Inorganic Chemistry, Emeritus; Lecturer
LEICESTER FORSYTH HAMILTON, S.B.
Professor of Analytical Chemistry, Emeritus; Lecturer
GEORGE SCATCHARD, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus; Lecturer
AVERY ADRIAN MORTON, PH.D.
Professor of Organic Chemistry, Emeritus
ALPHEUS GRANT WOODMAN, S.B.
Associate Professor of Analytical Chemistry, Emeritus
AVERY ALLEN ASHDOWN, PH.D.
Associate Professor of Organic Chemistry, Emeritus; Lecturer
RALPH CHILLINGWORTH YOUNG, PH.D.
Associate Professor of Inorganic Chemistry, Emeritus; Lecturer
ARTHUR RANDALL DAVIS, PH.D.
Associate Professor of Inorganic Chemistry, Emeritus; Lecturer
GERHARD DIETRICHSON, PH.D.
Associate Professor of Physical 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 programs for three graduate 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 PROGRAM

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, analytical, organic, and physical chemistry, supplemented by instruction in mathematics and physics and in the humanities and languages, including English, history, German, French, and other nonprofessional subjects.

In the third and fourth years, elective time allows each student to extend his knowledge in fields of special interest. Students intending to take graduate work, for example, may elect a series of 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.

Elective series are available in advanced analytical, inorganic, nuclear, organic, and physical chemistry; in chemical engineering, ceramics, textiles, economics, physics, mathematics, geology, biology and biochemistry, food technology, and metallurgy.

The Course aims to stimulate and develop the research attitude, and the schedule includes a thesis in the fourth year, to give the student an opportunity to demonstrate his aptitude for creative effort.

The Course leads to the degree of Bachelor of Science in Chemistry. The curriculum for the first year is described on page 151; the curriculum for the second, third, and fourth years is shown below.

SECOND YEAR[1]

First Term

5.41	ORGANIC CHEMISTRY I	4–4
5.412	ORGANIC PREPARATIONS I	5–0
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	[2]LANGUAGE	3–5
		48

Second Term

5.42	ORGANIC CHEMISTRY II	4–4
5.422	ORGANIC PREPARATIONS II	5–2
8.04	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
		42

THIRD YEAR

First Term

5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	2–4
5.428	QUALITATIVE ORGANIC ANALYSIS	9–1
5.61	PHYSICAL CHEMISTRY I	4–4
5.613T	PHYSICAL CHEMISTRY LABORATORY I	6–3
	Humanities (see Section 2)	3–5
	[3]*Elective subject*	*9*
		50

Second Term

5.14	ANALYTICAL CHEMISTRY I	3–3
5.141	ANALYTICAL CHEMISTRY LABORATORY I	9–0
5.62	PHYSICAL CHEMISTRY II	4–4
5.623T	PHYSICAL CHEMISTRY LABORATORY II	6–3
	Humanities (see Section 2)	3–5
	[3]*Elective subject*	*9*
		49

FOURTH YEAR ***Beginning in 1959–60***

First Term

5.16	ANALYTICAL CHEMISTRY II	3–3
5.161	ANALYTICAL CHEMISTRY LABORATORY II	5–2
	THESIS	10
	Humanities (see Section 2)	3–5
	[3]*Elective subjects*	*15*
		46

Second Term

	THESIS	20
	Humanities (see Section 2)	3–5
	[3]*Elective subjects*	*18*
		46

FOURTH YEAR ***1958–59 only***

First Term

5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	2–4
5.43	ORGANIC CHEMISTRY III	2–4
	THESIS	15
	Humanities (see Section 2)	3–5
	[4]*Elective subjects*	*21*
		45

FOURTH YEAR (*1958–59 only*) (continued)
Second Term

5.44	ORGANIC CHEMISTRY IV	2–4
	THESIS	15
	Humanities (see Section 2)	3–5
	[4]*Elective subjects*	*16*
		45

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.
[2] The second-year language should be L11 or L12 ELEMENTARY GERMAN, or L13 or L14 INTERMEDIATE GERMAN. 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 time.
[3] Students are required to take at least 6 units from each of the following groups as part of their elective programs: advanced inorganic chemistry (subjects 5.09 and 5.091), organic chemistry (subjects 5.43, 5.44, 5.51, 5.54, and 5.55), and physical chemistry (subjects 5.67, 5.68, 5.70, 5.71, and 5.75).
[4] Students are expected to take 5.68 KINETICS OF CHEMICAL REACTIONS (2–4) and 5.67 INTRODUCTION TO ATOMIC AND MOLECULAR STRUCTURE (2–4) or 5.75 INTRODUCTION TO QUANTUM THEORY (2–4).

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 realise the desirability and even necessity of supporting fundamental scientific investigations relative to their processes, as a basis for their future development.

The Department of Chemistry offers graduate programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science in Chemistry. Details of these programs, which differ according to whether the candidate chooses to specialize in analytical, inorganic and nuclear, organic, or physical chemistry, are recorded below. Students working toward the doctorate are expected to choose one of these four fields of specialization; students working toward the Master's degree may make a similar selection or may take a program which includes an approved combination of these fields.

Attainment of the Master's degree is not prerequisite to a program of study leading to a doctorate. Master's candidates may, by permission, change to the corresponding doctoral program without loss of credit.

PHYSICAL CHEMISTRY

Graduate subjects in physical chemistry cover the fundamentals of thermodynamics, statistical mechanics, kinetic theory and molecular structure. The Minor in mathematics and physics broadens this basis. The research gives intensive specialization in a narrower field and develops experimental technique and ability to carry on independent investigations.

Research in physical chemistry is being carried out in the following fields, and the laboratory is especially well, often uniquely, equipped for such research:

Pressure-volume-temperature relations of gases and liquids.
The absolute temperature scale.
Heat capacities and latent heats at low temperatures.
Properties of gases at low pressures.
Diffusion of gases.
Scattering and other properties of molecular beams.
Electromotive force in concentration cells, and oxidation-reduction potentials.
Vapor pressures of liquid solutions.
Infra-red, ultra-violet and Raman spectroscopy.
Precision photometry.
Kinetics of thermal and photochemical reactions.
Spectrophotometric studies in visible and ultraviolet light of the nature of metallic ions in water.
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 diffraction.
Nuclear resonance studies of the constitution of molecules and crystals.
Lattice dynamics and low-temperature elastic constants
Absorption spectra of adsorbed molecules.

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 vita-

mins), elucidation of the mechanisms of reactions and the relation of structure to reactivity, investigations directed toward the discovery and application of new synthetic methods, and investigations of organometallic compounds, peroxides and photochemical transformation.

Much use is made of such methods as infrared and ultraviolet spectroscopy, nuclear magnetic resonance, radioactive tracers, mass spectrophotometry, and gas chromatography.

INORGANIC AND NUCLEAR CHEMISTRY

Inorganic Chemistry

Opportunities for research in inorganic chemistry, nuclear chemistry, and allied fields of interest have never been more abundant than they are today. In recent years, remarkable advances have been reported in many areas, including the utilization of the less familiar elements, such as titanium, niobium, tantalum, the rare earth metals, uranium and the synthetic heavier elements; the isolation of small quantities of the compounds of other hitherto unknown elements, such as technetium (element No. 43) and promethium (element No. 61); and the utilization of certain non-metallic elements, such as selenium and fluorine.

Inorganic chemistry is not to be considered as primarily concerned with a method or limited body of methods. It is rather an area of interest in which all useful methods are to be utilized as fully and ingeniously as possible. It has two aspects, the preparative and the physico-chemical, which are by no means separate in practice. It is, of course, necessary for the inorganic chemist to be skilled in the preparation of substances which are in a reasonably high state of purity, and ample opportunity is provided for training of this type.

In addition to the impetus which has resulted from the increased accessibility to study of new areas of the periodic table, the theoretical or physico-chemical side of inorganic chemistry has been offered challenging new means of attack on basic problems by recent developments of techniques and advances in theory. Infrared and Raman spectroscopy, visible and ultraviolet spectrometry, magnetic studies of various types including nuclear and electron resonance, as well as new methods for dealing with such problems as the kinetics of the many very fast inorganic reactions are becoming a part of the inorganic chemist's body of essential techniques.

The contributions of the laboratory, therefore, will be found to include the isolation and study of numerous inorganic compounds, and physical-chemical investigations of the structures, bonding and reactivities of inorganic compounds. Particular attention is being given to the chemistry of organometallic compounds, to the elaboration of the chemistry of some of the non-transition elements and to physical-chemical and preparative studies of the complexes of transition metals. The initiative of the student in suggesting problems in other areas is encouraged.

Nuclear Chemistry

The Institute's Laboratory for Nuclear Science provides access to outstanding facilities for research in nuclear chemistry; a large cyclotron, synchrotron, linear accelerator, and Van de Graaff accelerator are available for the study of nuclear reactions and the preparation of radionuclides. The M.I.T. reactor also offers excellent opportunities for activation with neutrons, the properties of radionuclides, and the effects of radiation on matter.

The research worker may undertake detailed studies of nuclear reactions in the low- or high-energy regions, including fission and spallation; or studies of nuclear properties as a function of nuclear structure, including search for and identification of new species. The radiochemical resources are favorable for a variety of studies of chemical properties by tracer methods, including the properties of elements at very low concentration and the factors to be controlled in the development of new separation methods for constituents of radioactive mixtures. Other studies involve the physical-inorganic principles underlying the chemical problems of nuclear science and the applications of radiotracer techniques to general chemical problems. Modern counting equipment is available in the Department.

ANALYTICAL CHEMISTRY

The graduate curriculum in analytical chemistry is designed to prepare men for leadership both in industrial and in academic laboratories. The program provides a broad background in inorganic, physical, and organic chemistry and places emphasis upon both organic and inorganic aspects of analytical chemistry. The subjects stress principles and methods; the thesis aims at providing a varied research experience, and specialization in a field of limited scope.

The laboratory is unusually well equipped for studies involving modern instrumental methods. The student is able to employ a wide variety of

methods, as well as to use a number of different instruments designed to carry out the same general technique and compare their performances. Research is being carried on in polarography; electrochemical theory; electrodeposition of trace elements; fluorescence; spectrophotometry; flame photometry; ion exchange; gas chromatography; fused salt systems; complex formation; separation chemistry; non-aqueous titrations; thermometric titrations; photometric titrations; the analytical chemistry of fission elements; development of chemical and instrumental methods for the elucidation of the structure of organic compounds and their application to natural products, such as alkaloids and peptides; and mass spectroscopy of organic molecules.

Entrance Requirements for Graduate Study

The general admission requirements are those set forth in Section 3 of this Catalogue, with the following exceptions and additions:

MATHEMATICS

Doctoral candidates with their Major in analytical, inorganic or organic chemistry need not present M22 DIFFERENTIAL EQUATIONS.

PROFESSIONAL SUBJECTS

All candidates for admission to graduate work in this Department must present equivalents of the following subjects:

GENERAL CHEMISTRY (5.01, 5.02)
QUALITATIVE INORGANIC ANALYSIS
QUANTITATIVE ANALYSIS
ORGANIC CHEMISTRY I and II (5.41, 5.42)
ORGANIC PREPARATIONS I (5.412)
ORGANIC PREPARATIONS II (5.422)
QUALITATIVE ORGANIC ANALYSIS (5.428)
PHYSICAL CHEMISTRY I and II (5.61, 5.62)
PHYSICAL CHEMISTRY LABORATORY I and II (5.613T, 5.623T)

The Master of Science Degree

In addition to the general requirements set forth in Section 3, a reading knowledge of German is required.

The Doctorates

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, at the end of the week preceding the opening of the fall term and in the week following the spring vacation. 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 spring.

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

5.15, 5.151, 5.192, 5.193, 5.194, 5.196, 5.426, 5.67, 5.71, and during each year of residence 5.915, 5.916, 5.951, and 5.952.

INORGANIC AND NUCLEAR CHEMISTRY

5.68, 5.71, together with at least 14 units in approved subjects, such as X-RAYS AND CRYSTAL PHYSICS, NUCLEAR PHYSICS, RADIO-CHEMISTRY, X-RAY METALLOGRAPHY, or CRYSTALLOGRAPHY, and during each year of residence 5.071T, 5.912, 5.941, and 5.942.

ORGANIC CHEMISTRY

5.43, 5.44, 5.51, 5.54, 5.55, and during each year of residence 5.913 and 5.914.

PHYSICAL CHEMISTRY

5.70, 5.71, 5.75, and any four of the following subjects: 5.72, 5.73T, 5.74, 5.76, 5.77, 5.78 and 5.79; and during each year of residence 5.931 and 5.932.

After completing the program of Major subjects, the candidate must pass a comprehensive examination, including both written and oral parts, in his Major field.

In the interpretation of these requirements, the Department will consider the candidate's previous academic record and professional experience, together with his particular aims and objectives, and will take a liberal attitude toward substitution of other subjects of equivalent educational and scientific value. Graduate students are urged to select a research supervisor during the first or second academic term of residence and to plan their program of study in consultation with him and with the chairman of the Department's graduate committee.

Inquiries should be addressed to the Chairman of the Department Committee on Graduate Students.

Teaching Assistants

The Department appoints a number of teaching assistants who are candidates for the degree of Doctor of Philosophy in Chemistry. Teaching assistants serve in the laboratories of the Department and may be asked to conduct recitation sections on a regular part-time schedule throughout the academic year. Inquiries about appointments should be addressed to the Head of the Department.

Department of Food Technology

BERNARD EMERSON PROCTOR, PH.D.
Professor of Food Technology; in charge of the Department; Director of the Samuel Cate Prescott Laboratories of Food Technology
SAMUEL ABRAHAM GOLDBLITH, PH.D.
Associate Professor of Food Technology; Executive Officer
ROBERT SAMUEL HARRIS, PH.D.
Professor of Biochemistry of Nutrition
CECIL GORDON DUNN, PH.D.
Associate Professor of Industrial Microbiology
JOHN THEODORE ROOSEVELT NICKERSON, PH.D.
Associate Professor of Food Processing
STANLEY ELY CHARM, SC.D.
Assistant Professor of Food Processing
GEORGE JOSEPH FULD, SC.D.
Assistant Professor of Food Engineering

Lecturers

CHARLES N. FREY, PH.D., D.SC.
WILLIAM GEISLER
ARNOLD JOHN LEHMAN, PH.D., M.D.
JAMES ROBERT WILSON, M.D.

Research Associates

CHARLES WOODBURY FIFIELD, PH.D.
MAHENDRA NARAYAN DEB GOSWAMI, PH.D.
JOHAN EDUARD HOFF, M.S.
MARCUS KAREL, A.B.
JOSEPH JOHN LICCIARDELLO, M.S.
MABEL CRAWFORD MERRITT, B.S.
SANFORD ARTHUR MILLER, PH.D.
ABRAHAM EDWARD NIZEL, D.M.D., M.S.D.
ERNST REINHARD PARISER, M.A.
PHILIP MORRISON RICHARDSON, PH.D.
EMILY LIPPINCOTT WICK, PH.D.

FOOD TECHNOLOGY

Food Technology offers a new and exciting career to the young man with a scientific bent and an interest in human needs. It is a pioneering field, with countless and rewarding opportunities for the imaginative and inquisitive mind. Developing new products and adjusting them to successful manufacture, quality maintenance, finding improved methods for cost reduction, solving problems relating to the constituents of food, and designing machinery and equipment to prepare foods for human consumption are among the many areas of opportunity. The great need is for trained personnel, and the Department of Food Technology is uniquely suited to train men for all phases of today's extensive food industry.

The Department was established in 1945 and is today recognized as a leader in the "forward look" for the food industry. The Samuel Cate Prescott Laboratories of Food Technology, housed in the new (1953) John Thompson Dorrance Building, provide space and equipment for research in food processing, food packaging, food engineering, development of new food products, fishery technology, nutritional biochemistry, industrial microbiology, flavor evaluation, and the radiation sterilization of foods — a field in which this Department has pioneered.

Modern instruments utilizing the latest developments in electronics, physics, and electrical engineering are available for the objective evaluation of new processing technology. Facilities for research in "cold" sterilization of foods, drugs, and pharmaceuticals, for example, include an electron accelerator, a kilo-curie cobalt-60 source, an X-ray source, and a fission-product source.

The Department also has an excellently equipped pilot plant for research in food engineering, including various types of heat transfer equipment and refrigeration equipment and facilities for investigations in biochemical engineering dealing with many unit operations, such as evaporation dehydration, filtration, extraction, distillation, concentration, thermal processing, ion exchange, and the production of important metabolic products of microorganisms and other engineering operations. Among these facilities is a 50-gallon pilot plant fermentor with automatic controls.

M.I.T. considers its primary and most important product to be trained men; such men will not only become leaders in the food industry

but will also be the moral and financial support of any area or community. The objectives of the Department of Food Technology — thorough training; accent on the basic sciences and on fundamental research, as well as on immediately practical results; and coordination of instruction in science, engineering, and business management — are all prerequisites to a career in the present-day food industry.

Such a career appears to have an unlimited future. Estimates indicate that there are now 100,000 new mouths to feed each day, and that the world population will increase from 2.5 billion to 3.5 or 4 billion in the next twenty-five years. Food must be available and, more important, it must be nutritionally adequate. These problems must be solved on a world-wide basis, and trained workers are needed to find the solutions.

THE UNDERGRADUATE PROGRAMS

Food Technology (Course XX)

The undergraduate curriculum in food technology is under constant review by the staff of the Department, in an effort to meet the needs of changing times and the challenge of new perspectives. The curriculum is planned to provide students with a broad base in all the contributory sciences, supplemented by the more specific technological aspects that especially concern the food industries.

The Department insists that undergraduates first secure a broad basic training in physics, chemistry, bacteriology, and mathematics, and in economic principles, as a foundation for the more advanced subjects. In their advanced work, students are encouraged to seek electives outside the Department as well as within it, in accordance with their own aptitudes, skills, and needs. This is particularly true in the senior year, when considerable latitude is allowed in the election of subjects. (Note the revised programs, beginning with the Class of 1961.) Superior students are encouraged to obtain further education leading to advanced degrees in food technology.

The Department helps students to obtain temporary employment in food manufacturing firms throughout the United States during summers between the second, third, and fourth years. This summer employment gives students excellent experience for planning educational programs, as well as providing financial assistance.

The Course leads to the degree of Bachelor of Science in Food Technology. The curriculum for the first year is given on page 151; the curriculum for the second, third, and fourth years is shown below.

SECOND YEAR[1]

First Term

5.41	ORGANIC CHEMISTRY I	4–4
5.416	ORGANIC PREPARATIONS I	6–0
7.01	GENERAL BIOLOGY I	3–4
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		48

Second Term

8.04	PHYSICS	5–5
20.01T	CHEMISTRY AND TECHNOLOGY OF FOOD SUPPLIES I	7–2
20.41	BACTERIOLOGY I	7–3
21.04	HUMANITIES	3–5
M 221	PROBABILITY AND OPERATIONS ANALYSIS	3–6
		46

THIRD YEAR (*Beginning in 1959–60*)

First Term

2.601	FOOD ENGINEERING	4–2
5.61	PHYSICAL CHEMISTRY I	4–4
20.02	CHEMISTRY AND TECHNOLOGY OF FOOD SUPPLIES II	7–3
20.13T	CHEMICAL ENGINEERING FOOD APPLICATIONS	7–6
	[2]*Humanities*	3–5
		45

Second Term

2.602	FOOD ENGINEERING	4–2
5.14	ANALYTICAL CHEMISTRY I	3–3
5.142	ANALYTICAL CHEMISTRY LABORATORY I	5–0
5.62	PHYSICAL CHEMISTRY II	4–4
20.11	TECHNOLOGY OF FOOD PRODUCTS	6–4
20.14	CHEMICAL ENGINEERING FOOD APPLICATIONS	6–4
	[2]*Humanities*	3–5
		53

FOURTH YEAR (*Beginning in 1960–61*)

First Term

7.05	GENERAL BIOCHEMISTRY AND PHYSIOLOGY I	3–6
20.12	TECHNOLOGY OF FOOD PRODUCTS	6–4
20.32T	CHEMISTRY OF NUTRITION	7–3
	THESIS	3
	[2]*Humanities*	3–5
	Elective subjects	*10*
		50

Second Term

20.45	BACTERIOLOGY II	6–2
	THESIS	9
	[2]*Humanities*	3–5
	Elective subjects	*25*
		50

THIRD YEAR (*1958–59 only*)

First Term

5.41	ORGANIC CHEMISTRY I	4–4
5.61	PHYSICAL CHEMISTRY I	4–4
20.01	CHEMISTRY AND TECHNOLOGY OF FOOD SUPPLIES I	7–3
20.42	INDUSTRIAL MICROBIOLOGY	6–4
	[2]*Humanities*	3–5
	Elective subject	*8*
		52

Second Term

5.15	INSTRUMENTAL ANALYSIS	2–2
5.151	INSTRUMENTAL ANALYSIS LABORATORY	4–2
5.62	PHYSICAL CHEMISTRY II	4–4
20.02	CHEMISTRY AND TECHNOLOGY OF FOOD SUPPLIES II	7–3
	[2]*Humanities*	3–5
	Elective subject	*9*
		45

FOURTH YEAR (*1958–59 and 1959–60 only*)

First Term

2.601	FOOD ENGINEERING	4–2
7.05	GENERAL BIOCHEMISTRY AND PHYSIOLOGY I	3–6
20.11	TECHNOLOGY OF FOOD PRODUCTS	6–4
20.13	CHEMICAL ENGINEERING FOOD APPLICATIONS	4–6
20.32	CHEMISTRY OF NUTRITION	4–2
	THESIS	3
	[2]*Humanities*	3–5
		52

Second Term

2.602	FOOD ENGINEERING	4–2
20.12	TECHNOLOGY OF FOOD PRODUCTS	6–4
20.14	CHEMICAL ENGINEERING FOOD APPLICATIONS	6–4
	THESIS	9
	[2]*Humanities*	3–5
	Elective subject	*5*
		48

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2]14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2 of this Catalogue.

Biochemical Engineering (Course XX-B)

Recent developments in the production of pharmaceuticals and antibiotics and in the food and fermentation industries indicate a great need for technical personnel with training in the basic biological sciences and in engineering, especially in chemical engineering. To meet this need, the Department offers a coordinated program in biochemical engineering, including instruction in microbiology, biochemistry, bacteriology, and biology, all expressed through an engineering operation. The chemical engineering subjects included in the Course emphasize biological reactions, and the applications of biology, bacteriology, and biochemistry are stressed. The Course leads to the degree of Bachelor of Science in Biochemical Engineering. The curriculum for the first year is given on page 151; the curriculum for the second, third, and fourth years is shown below.

SECOND YEAR[1]

First Term

5.41	ORGANIC CHEMISTRY I	4–4
5.416	ORGANIC PREPARATIONS I	6–0
7.01	GENERAL BIOLOGY I	3–4
8.03	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		48

Second Term

5.42	ORGANIC CHEMISTRY II	4–4
8.04	PHYSICS	5–5
20.41	BACTERIOLOGY I	7–3
21.04	HUMANITIES	3–5
M 221	PROBABILITY AND OPERATIONS ANALYSIS	3–6
		45

THIRD YEAR (*Beginning in 1959–60*)

First Term

2.601	FOOD ENGINEERING	4–2
5.61	PHYSICAL CHEMISTRY I	4–4
20.13T	CHEMICAL ENGINEERING FOOD APPLICATIONS	7–6
20.42	INDUSTRIAL MICROBIOLOGY	6–4
	[2]*Humanities*	3–5
	Elective subject	*7*
		52

Second Term

5.14	ANALYTICAL CHEMISTRY I	3–3
5.142	ANALYTICAL CHEMISTRY LABORATORY I	5–0
5.62	PHYSICAL CHEMISTRY II	4–4
10.29	CHEMICAL ENGINEERING	4–6
20.14	CHEMICAL ENGINEERING FOOD APPLICATIONS	6–4
	[2]*Humanities*	3–5
		47

FOURTH YEAR (*Beginning in 1960–61*)

First Term

5.16	ANALYTICAL CHEMISTRY II	3–3
5.161	ANALYTICAL CHEMISTRY LABORATORY II	5–2
7.05	GENERAL BIOCHEMISTRY AND PHYSIOLOGY I	3–6
20.32T	CHEMISTRY OF NUTRITION	7–3
20.47	BIOCHEMICAL ENGINEERING	8–2
	[2]*Humanities*	3–5
		50

Second Term

20.45	BACTERIOLOGY II	6–2
20.48	BIOCHEMICAL ENGINEERING	8–2
	THESIS	12
	[2]*Humanities*	3–5
	Elective subjects	*12*
		50

THIRD YEAR (*1958–59 only*)

First Term

5.41	ORGANIC CHEMISTRY I	4–4
5.416	ORGANIC PREPARATIONS I	6–0
5.61	PHYSICAL CHEMISTRY I	6–4
10.17	INDUSTRIAL CHEMISTRY	3–4
20.42	INDUSTRIAL MICROBIOLOGY	6–4
	[2]*Humanities*	3–5
		47

Second Term

5.15	INSTRUMENTAL ANALYSIS	2–2
5.151	INSTRUMENTAL ANALYSIS LABORATORY	4–2
5.42	ORGANIC CHEMISTRY II	4–4
5.426	QUALITATIVE ORGANIC ANALYSIS	6–0
5.62	PHYSICAL CHEMISTRY II	4–4
	[2]*Humanities*	3–5
	Elective subjects	10
		50

FOURTH YEAR (*1958–59 and 1959–60 only*)

First Term

7.05	GENERAL BIOCHEMISTRY AND PHYSIOLOGY I	3–6
20.13	CHEMICAL ENGINEERING FOOD APPLICATIONS	4–6
20.32	CHEMISTRY OF NUTRITION	4–2
20.47	BIOCHEMICAL ENGINEERING	8–2
	THESIS	7
	[2]*Humanities*	3–5
		50

Second Term

20.14	CHEMICAL ENGINEERING FOOD APPLICATIONS	6–4
20.48	BIOCHEMICAL ENGINEERING	8–2
	THESIS	8
	[2]*Humanities*	3–5
	Elective subjects	*12*
		48

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] 14.01 ECONOMIC PRINCIPLES I (3–5) is a requirement for graduation and must be one of the humanities subjects taken. The humanities requirement is described in Section 2 of this Catalogue.

GRADUATE STUDY IN FOOD TECHNOLOGY AND BIOCHEMICAL ENGINEERING

The Department of Food Technology offers advanced programs leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Food Technology. It also offers graduate programs in biochemical engineering leading to the degrees of Master of Science and Doctor of Science in Biochemical Engineering.

The fields of research open to the graduate student in food technology are many. They relate to such varied problems as food processing (thermal and chemical), plant design, product control, instrumentation, packaging, utilization of by-products, sanitation and bacteriology of foods, fisheries technology, and nutritional biochemistry. The objective evaluation of food quality, the application of electronic techniques in this evaluation, the chemical evaluation of the components of foods that contribute to their flavor and odor characteristics, and the relation of processing methods to flavor development and conservation are also fields of research of primary interest in food technology.

Entrance Requirements for Graduate Study

The general requirements for admission to the Graduate School are given in Section 3 of this Catalogue. Applicants for advanced study in the Department of Food Technology are required to meet, as prerequisites, the general equivalent of the undergraduate program in food technology. Graduates from accredited institutions who present evidence of a high order of scholarship in related professional fields may be permitted either equivalent substitutions for these prerequisites or the privilege of taking examinations for advanced standing in the case of deficiencies.

The Master of Science Degrees

The general requirements for all Master's degrees are set forth in Section 3.

MASTER OF SCIENCE IN FOOD TECHNOLOGY

Students who have a Bachelor's degree in food technology from M.I.T. or who have an equivalent educational background may attain a Master of Science in Food Technology in one year. While the program for the degree is extremely flexible, the following graduate subjects are strongly recommended:

ADVANCED FOOD TECHNOLOGY (20.51, 20.52)
FOOD TECHNOLOGY SEMINAR (20.61, 20.62)
FOOD INDUSTRY SEMINAR (20.91, 20.92)

Subjects in industrial management, 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, chemistry of microorganisms, chemical engineering, or industrial management, again depending on the individual student. The following subjects are normally taken by all students:

ADVANCED INDUSTRIAL MICROBIOLOGY (20.43, 20.44)
FOOD TECHNOLOGY SEMINAR (20.61, 20.62)
FOOD INDUSTRY SEMINAR (20.91, 20.92)

The Doctorates

The curriculum for the doctorate in food technology offers opportunity for advanced study and research on the chemical, biological, engineering, or economic aspects of food production and on the development and control of new processes for improving food products and conserving their nutritive qualities. This curriculum may be combined with studies in chemical engineering, chemistry, mechanical engineering, physics, industrial management, and other subjects.

Candidates for doctorates are required to demonstrate proficiency in two foreign languages; these are chosen upon consultation between each student and his Graduate Registration Officer.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN FOOD TECHNOLOGY

The choice of subjects in programs for the degrees of Doctor of Philosophy and Doctor of Science in Food Technology depends on each student's background, his aptitudes, and his future plans. The Department Committee on Graduate Students assists with the planning of programs.

Students are expected to prepare themselves early in their graduate program for qualifying examinations for the doctorate. Following successful completion of these examinations, comprehensive written and oral general doctoral examinations are taken by each student. These test his understanding of the fundamentals of modern food science, food technology, and food engineering, as well as of the basic related scientific disciplines. They also test his ability to utilize these basic sciences in the many problems of modern food technology.

DOCTOR OF SCIENCE IN BIOCHEMICAL ENGINEERING

No particular sequence of graduate subjects is specified for the degree of Doctor of Science in Biochemical Engineering. Advanced studies are recommended in the fields of biochemistry, microbiology, enzymology, and chemical engineering; studies in these basic sciences are coordinated with problems in the modern fermentation industry. Programs must be approved by an interdepartmental committee, which includes representatives from the Departments of Food Technology, Biology, and Chemical Engineering. Doctoral examinations, which are prepared and conducted by this committee, follow the same pattern described above for food technology and include qualifying and general examinations.

Assistantships

The Department offers a limited number of graduate research assistantships for work in the areas of food processing, radiation preservation, rheology, nutritional biochemistry, bacteriology, chemistry of flavor, and packaging. Applications — accepted only from admitted graduate students — should be made to the Head of the Department.

Department of Geology and Geophysics

ROBERT RAKES SHROCK, PH.D.
Professor of Geology; in charge of the Department

PATRICK MASON HURLEY, PH.D.
Professor of Geology; Executive Officer

MARTIN JULIAN BUERGER, PH.D.
Institute Professor; Professor of Mineralogy and Crystallography; Director of School for Advanced Study

HAROLD WILLIAMS FAIRBAIRN, PH.D.
Professor of Geology

ROLAND DANE PARKS, E.M., M.S.
Associate Professor of Mineral Industry

WALTER LUCIUS WHITEHEAD, PH.D.
Associate Professor of Geology, Emeritus; Lecturer

ELY MENCHER, PH.D.
Associate Professor of Geology

WILLIAM HENRY DENNEN, PH.D.
Associate Professor of Geology

JOHN BRACKETT HERSEY, PH.D.
Associate Professor of Oceanography

WILLIAM STELLING VON ARX, PH.D.
Associate Professor of Oceanography

STEPHEN MILTON SIMPSON, JR., PH.D.
Assistant Professor of Geophysics

WILLIAM FRANCIS BRACE, PH.D.
Assistant Professor of Geology

RICHARD RAYMAN DOELL, PH.D.
Assistant Professor of Geophysics

WILLIAM HAMET PINSON, JR., PH.D.
Assistant Professor of Geology

JOHN WIDMER WINCHESTER, PH.D.
Assistant Professor of Geochemistry

ARTHUR JAMES BOUCOT, PH.D.
Assistant Professor of Geology

HARRY HUGHES, PH.D.
Assistant Professor of Geophysics

THEODORE RICHARD MADDEN, S.B.
Assistant Professor of Geophysics

Lecturers

NORMAN ABRAHAM HASKELL, PH.D.

DONALD JONATHAN MACNEIL, PH.D.

Professors Emeriti

HERVEY WOODBURN SHIMER, PH.D., SC.D.
Professor of Paleontology, Emeritus

FREDERICK KUHNE MORRIS, PH.D.
Professor of Geology, Emeritus

WARREN JUDSON MEAD, PH.D.
Professor of Geology, Emeritus

WALTER LUCIUS WHITEHEAD, PH.D.
Associate Professor of Geology, Emeritus; Lecturer

GEOLOGY AND GEOPHYSICS

The origin, age, and composition of the earth, the physical state of the earth's interior, and the origin of the oceans and atmosphere are among the most challenging and perplexing problems of science. They all lie within the domain of the earth scientists — geologists, geochemists, geophysicists, meteorologists, and oceanographers — but they can be successfully attacked only by using the latest contributions from the physical and engineering sciences.

Our expanding industrial economy is making heavy demands on the petroleum and mineral industries, and on the companies that find and develop the raw materials for these industries. Reserves of petroleum and natural gas, of metallic ores, and of many non-metallic substances such as domestic water are increasingly difficult to maintain; likewise, reserves of nuclear fuels are now being sought everywhere. The easy discoveries have been made, the low-cost deposits have been exhausted, and industries must rely in the future on improvements and new developments in geological, geochemical, and geophysical methods in their exploration programs. Industry's needs for men trained in these fields of earth science are shared by research, government, military, and atomic energy organizations engaged in a wide variety of projects related to raw materials, defense, global strategy, and pure scientific discovery.

Thus, careers in geology, geochemistry, and geophysics 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.

THE UNDERGRADUATE PROGRAMS

The Department of Geology and Geophysics offers a four-year program which includes fundamental sciences, professional electives, and unusual opportunity for field work.

For those who wish especially thorough training for more diversified activities, the Department recommends the five-year program which leads to both Bachelor's and Master's degrees.

Geology and Geophysics (Course XII)

The undergraduate Course in Geology and Geophysics emphasizes diversification of subject matter and flexibility in the choice of subjects. It requires a well-rounded program of mathematics, physics, chemistry, and certain engineering subjects, and permits a broad choice in professional subjects in geology, geochemistry, and geophysics. There is also a generous allotment of time for unrestricted electives, which students may choose from any department in the Institute.

Laboratory and field work are emphasized at every level of the program, in the belief that students learn best by doing. The summer following the sophomore year is spent at the Nova Scotia Centre for the Geological Sciences, where students learn surveying, mapping, and geological and geophysical field methods during a ten-week period, five weeks of which are spent in tent camps.

An optional cooperative program of geophysical field training has been arranged with Geophysical Service, Inc., of Dallas, Texas, for the summer following the third year. During this summer, students who participate in the program serve with the company as regular employees; after a week of orientation lectures in Dallas, they join field parties engaged in seismic exploration in a part of the continent where active petroleum search is going on. Other juniors, employed by petroleum and mining companies, may spend the summer in areas as distant as Mexico, California, British Columbia, New Brunswick, or Newfoundland. This professional field experience is considered to be an essential part of each student's undergraduate program; it gives him an opportunity to test and apply what he has learned and also shows him why he will need subjects that remain to be taken later in his curriculum.

There are many excellent opportunities for advanced undergraduates in research at M.I.T., where theoretical work on the methods and instruments of geochemistry and geophysics is going on constantly. Some positions offer a combination of theoretical and instrumental work in a laboratory and applied work in the field. For such positions graduates of this Department have always been much in demand.

Each student entering the Course is assigned to a staff member of the Department, who acts as his adviser. The student has the responsibility of working out his own program of subjects each term, but he will always have the guidance of his adviser in doing so. By choosing the proper electives he may concentrate his work in one or a combination of the following fields: basic geology; crystallography; engineering geology; geochemistry; geophysics; mineralogy; mineral industry; mineral deposits; mineral

fuels (petroleum and natural gas); petrology; sedimentation, stratigraphy, and paleontology; structural geology; and theoretical geology.

This four-year Course leads to the degree of Bachelor of Science in Geology and Geophysics. It is strongly recommended, however, that all qualified seniors continue into the five-year program described below, since the fifth year offers an excellent opportunity for students to extend and deepen their training and to prepare themselves better for professional or further academic work.

The curriculum for the four-year program in Geology and Geophysics (Course XII) is shown below; the first year is described on page 151.

SECOND YEAR[1]

First Term		
8.031	PHYSICS	5–5
12.011	MINERALOGY I	7–3
12.301	PHYSICAL GEOLOGY	7–4
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
		48
Second Term		
8.041	PHYSICS	5–5
12.302	HISTORICAL GEOLOGY	7–4
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	Elective subject (see next column)	*8*
		46
Summer		
	At the Nova Scotia Centre for the Geological Sciences:	
12.303	GEOLOGICAL SURVEYING	7–0
12.304	FIELD INVESTIGATIONS AND REPORTS	17–0
		24

THIRD YEAR

First Term		
	[2]*Humanities*	3–5
	Elective subjects (see next column)	*40*
		48
Second Term		
	[2]*Humanities*	3–5
	Elective subjects (see next column)	*40*
		48

FOURTH YEAR

First Term		
	[2]*Humanities*	3–5
	Elective subjects (see next column)	*40*
		48
Second Term		
	[3]THESIS	15
	[2]*Humanities*	3–5
	Elective subjects (see below)	*25*
		48

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] The required humanities may be taken at any time after the first term of the second year, provided that existing subject sequences in humanities are followed. These sequences and the humanities requirement are described in Section 2 of this Catalogue.

[3] THESIS may be started in the first term of the fourth year, but not more than a total of 15 units will be accepted for graduation.

ELECTIVE SUBJECTS (COURSE XII)

Each student is expected to plan his own schedule of elective subjects in cooperation with a faculty adviser, whose approval is required. These subjects must be chosen so that they fulfill the following requirements:

1. At least 54 units must be in some combination of subjects in mathematics, physics, and chemistry (in addition to subjects in these fields scheduled in the first two years), and electrical engineering.
2. At least 64 units must be in professional subjects in geology and geophysics (in addition to the subjects scheduled in the second year and the summer following the second year, and excluding THESIS).
3. At least 35 additional units may be in unrestricted electives, excluding all freshman electives. These unrestricted electives may be taken in any department in the Institute, provided only that they be approved by the student's adviser.

Geology and Geophysics (Five-Year Course) (Course XII-A)

The problems that geologists, geochemists, geophysicists, and other earth scientists now have to consider require more basic science and more geological training than ever before, and this situation will certainly be intensified in the future. For this reason, students no longer receive training adequate for certain kinds of professional careers in the earth sciences in the normal four-year program. The primary educational objective of Course XII-A is to train geologists, geochemists, and geophysicists for the

future; the five-year plan tabulated below 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 and Master of Science in Geology and Geophysics, awarded simultaneously at the end of the graduate year. The curriculum is as follows:

FIRST, SECOND, AND THIRD YEARS

Same as Geology and Geophysics (Course XII)

FOURTH YEAR

First Term	
[1]*Humanities*	3–5
Elective subjects	*40*
	48
Second Term	
[1]*Humanities*	3–5
Elective subjects	*40*
	48

GRADUATE YEAR[2]

First Term	
Elective subjects	*48*
Second Term	
[3]THESIS	30
Elective subjects	*18*
	48

[1] The required humanities may be taken at any time after the first term of the second year, provided that existing subject sequences in humanities are followed. These sequences and the humanities requirement are described in Section 2 of this Catalogue.

[2] Students must comply with all regulations of the Graduate School for the Master of Science degree with specification.

[3] THESIS may be started in the first term of the graduate year, and up to 10 units of additional thesis may be substituted for elective subjects in the graduate year.

ELECTIVE SUBJECTS (COURSE XII-A)

Each student is expected to plan his own schedule of elective subjects in the second, third, fourth, and graduate years in cooperation with a faculty adviser, whose approval is required. These subjects must be chosen so that they fulfill the following requirements:

1. At least 54 units must be in some combination of subjects in mathematics, physics, and chemistry (in addition to subjects in these fields scheduled in the first two years), and electrical engineering.
2. At least 98 units must be in professional subjects in Course XII (in addition to the subjects scheduled in the second year and the summer following the second year, and excluding 30 units of thesis), of which at least 34 units must be in graduate ("A") subjects.
3. At least 82 additional units may be in unrestricted electives, excluding all freshman electives. These unrestricted electives may be taken in any department in the Institute, provided only that they be approved by the student's adviser.

GRADUATE STUDY IN GEOLOGY AND GEOPHYSICS

The Department of Geology and Geophysics offers a wide choice of graduate study and research for specialization in the following fields: basic geology; crystallography; engineering geology; geochemistry; geophysics; mineralogy; mineral industry; mineral deposits; mineral fuels; petroleum geology; petrology; sedimentation, stratigraphy, and paleontology; structural geology; and theoretical geology. In the borderland between geology, geophysics, geochemistry, and another science, the student may arrange a program of study and research under 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 governmental agencies.

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 Geology and Geophysics at the Institute. If the student is not fully prepared in certain of the required subjects, he usually will be asked to extend his preparation in these while he pursues his advanced work. The subjects to be taken for this purpose will be designated by the Department Committee on Graduate Students after the student's preparation and proposed program of study have been considered. The actual program of advanced subjects and research leading to a graduate degree is arranged by the student and his faculty advisers, to whom he is assigned at the time he first registers and who will generally direct the major part of his program.

The Master of Science Degree

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 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. Departmental requirements for graduate work leading to these degrees are given above. In addition, candidates for doctorates may be asked to meet certain other requirements in study or research. Possible fields of specialization are also indicated above.

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, to survey his training and attainments and to serve as a basis for certifying him for a Doctor's program.

The program of graduate work may, with the approval of the Department Committee on Graduate Students, include subjects in other departments for which the student has adequate preparation.

Each candidate for the doctorate must demonstrate that he can read scientific literature in his field of specialization in English and in two other languages; French, German, and Russian are among the appropriate languages. Ordinarily this requirement should be satisfied by the time the General Examination is taken and before undertaking thesis research.

The Minor requirement is generally satisfied by taking at least 24 units of approved study in another department.

Teaching and Research Assistants

The Department regularly appoints 15–20 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 Chairman of the Department.

Department of Mathematics

WILLIAM TED MARTIN, PH.D.
Professor of Mathematics; in charge of the Department

GEORGE BRINTON THOMAS, JR., PH.D.
Associate Professor of Mathematics; Executive Officer

NORBERT WIENER, PH.D., SC.D.
Professor of Mathematics

PHILIP FRANKLIN, PH.D.
Professor of Mathematics;
Assistant Secretary of the Faculty

RAYMOND DONALD DOUGLASS, PH.D., SC.D.
Professor of Mathematics

DIRK JAN STRUIK, PH.D.
Professor of Mathematics

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.
Professor of Mathematics

WARREN AMBROSE, PH.D.
Professor of Mathematics

GEORGE WILLIAM WHITEHEAD, PH.D. (*Absent*)
Professor of Mathematics

PRESCOTT DURAND CROUT, PH.D.
Associate Professor of Mathematics

GEORGE PROCTOR WADSWORTH, PH.D.
Associate Professor of Mathematics

SAMUEL DEMITRY ZELDIN, PH.D.
Associate Professor of Mathematics

FRANCIS BEGNAUD HILDEBRAND, PH.D.
Associate Professor of Mathematics

ALBERTO PEDRO CALDERON, PH.D.
Associate Professor of Mathematics

KENKICHI IWASAWA, DR.SCI.
Associate Professor of Mathematics

NESMITH CORNETT ANKENY, PH.D. (*Absent*)
Associate Professor of Mathematics

JOHN NASH, PH.D.
Associate Professor of Mathematics

JURGEN KURT MOSER, DR.RER.NAT.
Associate Professor of Mathematics

ISADORE MANUAL SINGER, PH.D.
Associate Professor of Mathematics

LOUIS NORBERG HOWARD, PH.D.
Assistant Professor of Mathematics

HARTLEY ROGERS, JR., PH.D.
Assistant Professor of Mathematics

HENRY PRATT McKEAN, JR., [illegible].D.
Assistant Professor of Mathematics

DANIEL BURRILL RAY, PH.D.
Assistant Professor of Mathematics

MARVIN LEE MINSKY, PH.D.
Assistant Professor of Mathematics

GEORGE EDWARD BACKUS, PH.D.
Assistant Professor of Mathematics

ARTHUR PAUL MATTUCK, PH.D.
Assistant Professor of Mathematics

FRANKLIN PAUL PETERSON, PH.D.
Assistant Professor of Mathematics

Lecturers

ALFRED WILLIAM ADLER, PH.D.
RICHARD HENRY CROWELL, PH.D.
DONALD JOSEPH NEWMAN, PH.D.

C. L. E. Moore Instructors

KENNETH MYRON HOFFMAN, PH.D.
RALPH THEODORE DAMES, PH.D.
ADRIANO MARIO GARSIA, PH.D.
RAY ALDEN KUNZE, PH.D.
ROGER NOEL PEDERSON, PH.D.
EUGENE RICHARD RODEMICH, PH.D.
JOHN WOLFGANG SMITH, PH.D.

Instructors

DONALD LESTER KREIDER, B.S.
JAN LIST BOAL, M.S.
SAMSON MORDECAI ROSENZWEIG, B.S.
JOHN RICHARD SCHUE, B.A.
DAVID JOHN BENNEY, M.SC.
RICHARD LAWRENCE BISHOP, B.S.
ANDREW BROWDER, S.B.
GEORGE CLARK BUSH, S.M.
PAUL JOSEPH COHEN, PH.D.
RICHARD JAMES CRITTENDEN, B.A.
MICHAEL GINSBURG, S.B.
JOLYON RICHARD TESSMER, B.S.
LAWRENCE JULIAN WALLEN, B.A.
JAMES YEH, PH.D.

Administrative Assistant

RUTH SELMA GOODWIN, A.B.

Research Associate

SHOSHICHI KOBAYASHI, PH.D.

Professor Emeritus

HENRY BAYARD PHILLIPS, PH.D., LL.D.
Professor of Mathematics, Emeritus

MATHEMATICS

This Department offers a variety of programs to those interested in mathematics primarily as a pure science or for the additional purpose of applying it to other sciences, to fields of engineering, or to business.

THE UNDERGRADUATE PROGRAM

Mathematics (Course XVIII)

Each undergraduate's program is arranged through continuous collaboration between the individual student and his Registration Officer, 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.

The undergraduate Course leads to the degree of Bachelor of Science in Mathematics. The curriculum for the first year is shown on page 151; the curriculum for the second, third, and fourth years is as follows:

SECOND YEAR[1]

First Term

8.031	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	LANGUAGE	3–5
	Engineering or science elective subject (not mathematics)	*8*
		43

Second Term

8.041	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	LANGUAGE	3–5
	Engineering or science elective subject	*9*
		44

THIRD YEAR

First Term

M 62	LINEAR ALGEBRA	3–6
M 831	ANALYSIS	3–9
	Humanities (see Section 2)	3–5
	[2]*Professional elective subject*	*9*
	Elective subject	*9*
		47

Second Term

M 832	ANALYSIS	3–9
	Humanities (see Section 2)	3–5
	[2]*Professional elective subject*	*9*
	Elective subjects	*18*
		47

FOURTH YEAR

First Term

	THESIS	5
	Humanities (see Section 2)	3–5
	[2]*Professional elective subjects*	*24*
	Elective subject	*8*
		45

Second Term

M 442	ELEMENTARY DIFFERENTIAL GEOMETRY	3–6
	THESIS	7
	Humanities (see Section 2)	3–5
	[2]*Professional elective subject*	*12*
	Elective subject	*12*
		48

[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] At least 30 of the 54 units of professional elective subjects must be chosen from mathematics subjects; the remaining 24 units are to be chosen from mathematics and/or engineering or science subjects which, together with the 30 units of mathematics subjects, make up an integrated program. All of these 54 units must be in subjects at the third year, fourth year, or graduate level.

GRADUATE STUDY IN MATHEMATICS

On the graduate level, the Department offers programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science in Mathematics.

Students may select their programs from a broad range of subjects, descriptions of which appear elsewhere in this Catalogue. Numerous informal seminars supplement the basic program, and there is also a weekly Mathematics Colloquium. administered jointly by the Mathematics Departments at M.I.T. and Harvard University, with guest lecturers from other institutions.

Candidates who work in the field of pure mathematics will, aside from the Minor program, ordinarily take most of their subjects in the Mathematics Department. In addition to their advanced specialization, they will be encouraged to acquire breadth by taking basic subjects in analysis, algebra, geometry, and topology.

Candidates who work in the field of applied mathematics will be encouraged to study important aspects of one or more engineering or scientific fields closely related to research in applied mathematics, in addition to their studies in mathematics.

Assistance or even collaboration in problems in pure or applied mathematics which are being investigated by members of the staff may constitute part of graduate programs.

Entrance Requirements for Graduate Study

The admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions:

Chemistry: Students who present two semesters of college work in biology, geology, meteorology, or astronomy need not present GENERAL CHEMISTRY (5.01, 5.02) or its equivalent.

Mathematics: Students will normally be expected to present an undergraduate mathematics program approximating that required of undergraduate mathematics majors.

The Master of Science Degree

For the Master's degree, 96 units beyond the Bachelor's degree are required, including THEORY OF FUNCTIONS (M381, M382), two additional 12-unit graduate ("A") subjects offered by the Department, and thesis (usually 20–24 units). Each student is also expected to have completed, either in his undergraduate or graduate program, four subjects or their equivalents from the following group:

METHODS OF APPLIED MATHEMATICS (M39)
NUMERICAL ANALYSIS (M411)
ELEMENTARY DIFFERENTIAL GEOMETRY (M442)
LINEAR ALGEBRA (M62)
ANALYSIS (M831, M832)
INTRODUCTION TO THEORETICAL PHYSICS I (MECHANICS) (8.71)
INTRODUCTION TO HYDROMECHANICS (M42)
or
INTRODUCTION TO ELASTICITY (M78)

Of the four subjects elected from this group, two may be counted for credit toward the Master's degree if taken at M.I.T. while a graduate student.

The Doctorates

The general requirements for the Doctor of Philosophy and Doctor of Science degrees are those set forth in Section 3. As soon as possible after beginning graduate work, each student who plans to take a doctorate in mathematics should elect one of the following two plans of study:

Plan A. A written qualifying examination covers the material in the following four topics:

THEORY OF FUNCTIONS (M381, M382)
LINEAR ALGEBRA (M62)
ELEMENTARY DIFFERENTIAL GEOMETRY (M442)
ANALYSIS (M831, M832)

Students in this plan will take additional subjects chosen from INTRODUCTION TO HYDROMECHANICS (M42) *or* INTRODUCTION TO ELASTICITY (M78); and the Department's 12-unit subjects other than those included in the qualifying examination.

Plan B. A written qualifying examination covers the material in the following four topics:

THEORY OF FUNCTIONS (M381, M382)
METHODS OF APPLIED MATHEMATICS (M39)
NUMERICAL ANALYSIS (M411)
INTRODUCTION TO HYDROMECHANICS (M42)
or
INTRODUCTION TO ELASTICITY (M78)

Students in Plan B will also take these subjects:

THEORETICAL HYDROMECHANICS (M421, M422)
DIFFERENTIAL EQUATIONS (M571)
PARTIAL DIFFERENTIAL EQUATIONS (M591)
THEORETICAL AND APPLIED ELASTICITY (M791, M792)
and
INTRODUCTION TO THEORETICAL PHYSICS I (MECHANICS) (8.71)
or
APPLIED MECHANICS III (2.003)

An additional subject in hydromechanics, elasticity, or plasticity and an additional 12-unit subject given by the Department are also required.

In special circumstances a student may receive permission to work under another plan, in which regular course requirements and written examinations in mathematics subjects are omitted. Students admitted to this program are given occasional oral examinations on their general mathematical progress.

The Minor program may be in any field, other than mathematics, in which the Institute offers advanced work. It should be started early in the student's graduate career.

Doctoral candidates are required to demonstrate proficiency in two foreign languages, which are usually chosen from French, German, and Russian. The language requirements should also be fulfilled early in the student's program.

Before the student begins work on his thesis, he is asked to submit to the Departmental Graduate Committee a brief general outline on the proposed thesis, carrying the approval of the faculty member who is his thesis adviser. When the Committee has approved the thesis proposal, the Department names two faculty members to work with the student and his adviser. The thesis is expected to represent original research and to meet the standards ordinarily required for publication in one of the standard journals devoted to research in mathematics or in a closely allied field.

Fellowships and Assistantships

Fellowships and teaching and research assistantships are available to graduate students in mathematics. Detailed information about these opportunities may be obtained from the Department.

Department of Meteorology

HENRY GARRETT HOUGHTON, SC D.
Professor of Meteorology; in charge of the Department; Director of Laboratory of Earth Sciences
HURD CURTIS WILLETT, PH.D.
Professor of Meteorology
JULE GREGORY CHARNEY, PH.D.
Professor of Meteorology
VICTOR PAUL STARR, PH.D.
Professor of Meteorology
JAMES MURDOCH AUSTIN, SC.D.
Associate Professor of Meteorology; Director of Summer Session
DELBAR POULEUR KEILY, S.B.
Associate Professor of Meteorology
EDWARD NORTON LORENZ, SC.D.
Associate Professor of Meteorology
NORMAN ALTON PHILLIPS, PH.D.
Associate Professor of Meteorology
FREDERICK SANDERS, SC.D.
Assistant Professor of Meteorology

Technical Instructor
ETHAN ALLEN MURPHY

Research Associates
PAULINE MORROW AUSTIN, PH.D.
ALAN COGSWELL BEMIS, A.B., S.M.
SEIICHI MATSUMOTO, S.M., DR.SC.

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.

The first two phases of this preparation for meteorology are preferably covered in the undergraduate years. However, because emphasis is placed on a broad preparation rather than on specialization, the undergraduate curriculum in meteorology has been discontinued, except for the class of 1959. Other undergraduate students who are interested in meteorology are advised to register in Geology and Geophysics (Course XII). This curriculum is designed to provide both the basic foundation in physics and mathematics and an introduction to geology, oceanography, and meteorology. Students may choose to emphasize one or another of these fields but not to the exclusion of the others. A student who completes such an undergraduate program, at M.I.T. or elsewhere, is well prepared to embark on the professional study of meteorology at the graduate level.

THE UNDERGRADUATE PROGRAM

Meteorology (Course XIX)

Undergraduate students in the class of 1959 are permitted to complete the Course in Meteorology (Course XIX) according to the following curriculum:

FOURTH YEAR (*1958–59 only*)

First Term

19.51	SYNOPTIC LABORATORY I	15–0
19.601	INTRODUCTION TO THEORETICAL METEOROLOGY	3–6
19.83	OCEANOGRAPHY	2–4
	THESIS	3
	Humanities (see Section 2)	3–5
	Elective subject	*8*
		49

Second Term

19.44	SYNOPTIC METEOROLOGY I	3–6
19.62	DYNAMIC METEOROLOGY I	3–6
	THESIS	9
	Humanities (see Section 2)	3–5
	Elective subjects	*12*
		47

GRADUATE STUDY IN METEOROLOGY

Emphasis in graduate training is placed on the theoretical and quantitative approach, supplemented by empirical and experimental methods. This approach is based on the conviction that the progress of meteorology depends on the quantitative application to the atmosphere of the laws of physics. However, the Department recognizes that there is equal demand for individuals who are more concerned with applications and experimental studies. Such students need to understand the implications of the theoretical developments, while the theory-oriented students need an appreciation of the observational material.

Formal subjects of instruction are offered in all of the principal areas of meteorology. Subjects commonly taken by graduate students include:

19.14	LONG-RANGE WEATHER FORECASTING
19.22	METEOROLOGICAL INSTRUMENTS
19.32	MICROCLIMATOLOGY
19.33	APPLIED CLIMATOLOGY
19.45	SYNOPTIC METEOROLOGY II
19.46	NUMERICAL WEATHER PREDICTION
19.53	SYNOPTIC LABORATORY III
19.64	DYNAMIC METEOROLOGY II
19.71	RADAR METEOROLOGY
19.72	PHYSICAL METEOROLOGY

As this list suggests, facilities for instruction and research are available in all of the principal areas of meteorology. There are several radar systems and associated equipment together with a large and comprehensive file of radar data. Current weather data covering North America, Western Europe, and the adjacent oceans are available on teletypewriter circuits. Extensive files of weather data are available for most areas of the world; much of this is already in form for use on modern computing machines, and students have access to desk computers, I.B.M. card equipment, and the high-speed computing facilities of the Computation Center.

The Meteorological Instrumentation Laboratory contains standard and specialized instrumentation and special test equipment. Laboratory facilities are available for research in physical meteorology, especially in the fields of cloud and precipitation physics. The facilities of the Woods Hole Oceanographic Institution are available to qualified students who wish to undertake field or laboratory work in oceanography or marine meteorology. In addition to the above, the facilities of the newly established Laboratory of Earth Sciences are available to qualified students.

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 Center, 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.

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 DESCRIPTIVE METEOROLOGY I and II (19.01 and 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, Doctor of Philosophy in Meteorology, and Doctor of Science in Meteorology.

The Master of Science Degree

The 72 units of graduate ("A") subjects required for the Master of Science degree may be selected from those offered in meteorology and those in related fields offered by other departments. Undue specialization in one branch of the field is discouraged. All candidates for this degree will be expected to register for at least one term of METEOROLOGICAL SEMINAR (19.91, 19.911, or 19.912). There are no foreign language requirements for the degree.

The Doctorates

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 are required to demonstrate their ability to read scientific literature in English and in two other modern languages, at least one of which must be German or Russian. The second language must be one in which there is important meteorological literature. Among others, German or Russian (if not chosen as the first language), French, Norwegian, Swedish, Spanish, and Japanese satisfy this requirement.

Department of Physics

NATHANIEL HERMAN FRANK, SC.D.
Professor of Physics; in charge of the Department

GEORGE GRAHAM HARVEY, PH.D.
Associate Professor of Physics; Executive Officer; Associate Director of Research Laboratory of Electronics

GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D., D.ENG.
Professor of Physics; Dean of the School of Science

JOHN CLARKE SLATER, PH.D., SC.D.
Institute Professor; Harry B. Higgins Professor of the Solid State

ARTHUR COBB HARDY, SC.D.
Professor of Optics and Photography

PHILIP McCORD MORSE, PH.D., SC.D.
Professor of Physics; Director of Computation Center; Chairman of the Faculty

BERTRAM EUGENE WARREN, SC.D.
Professor of Physics

HANS MUELLER, D.SC.
Professor of Physics

WAYNE BUCKLES NOTTINGHAM, PH.D.
Professor of Physics

ROBLEY DUNGLISON EVANS, PH.D.
Professor of Physics

JERROLD REINACH ZACHARIAS, PH.D.
Professor of Physics

BRUNO BENEDETTO ROSSI, PH.D.
Professor of Physics

VICTOR FREDERICK WEISSKOPF, PH.D.
Professor of Physics

ALBERT GORDON HILL, PH.D. (*Absent*)
Professor of Physics

WILLIAM PHELPS ALLIS, SC.D.
Professor of Physics

FRANCIS BITTER, PH.D.
Professor of Physics; Associate Dean of the School of Science

MARTIN DEUTSCH, PH.D.
Professor of Physics; Chairman of Directing Committee, Laboratory for Nuclear Science

MILTON STANLEY LIVINGSTON, PH.D.
Professor of Physics

HERMAN FESHBACH, PH.D.
Professor of Physics

WILLIAM WEBER BUECHNER, PH.D., SC.D.
Professor of Physics

CLIFFORD GLENWOOD SHULL, PH.D.
Professor of Physics

GEORGE EDWARD VALLEY, JR., PH.D. (*Absent*)
Professor of Physics

BERNARD TAUB FELD, PH.D.
Professor of Physics

FRANCIS EUGENE LOW, PH.D.
Professor of Physics

FRANCIS LEE FRIEDMAN, PH.D.
Professor of Physics

DAVID HENRY FRISCH, PH.D.
Professor of Physics

ROBERT JEMISON VAN DE GRAAFF, PH.D., D.SC.
Associate Professor of Physics

CLARK GOODMAN, PH.D. (*Absent*)
Associate Professor of Physics

LASZLO TISZA, PH.D.
Associate Professor of Physics

SANBORN CONNER BROWN, PH.D.
Associate Professor of Physics

MALCOM WOODROW PERSHING STRANDBERG, PH.D.
Associate Professor of Physics

ROBERT WALTER WILLIAMS, PH.D. (*Absent*)
Associate Professor of Physics

FELIX MARC HERMAN VILLARS, D.SC.
Associate Professor of Physics

KARL UNO INGARD, PH.D.
Associate Professor of Physics

WILLIAM LESTER KRAUSHAAR, PH.D.
Associate Professor of Physics

DAVID ORVILLE CALDWELL, PH.D.
Associate Professor of Physics

JOHN GORDON KING, PH.D.
Associate Professor of Physics

LEE CARRINGTON BRADLEY, III, D.PHIL.
Assistant Professor of Physics

GEORGE WHIPPLE CLARK, PH.D.
Assistant Professor of Physics

GEORGE FRED KOSTER, PH.D.
Assistant Professor of Physics

JOHN FRANCIS COCHRAN, PH.D.
Assistant Professor of Physics

HARALD ANTON ENGE, DR.PHIL.
Assistant Professor of Physics
MARVIN HAROLD FRIEDMAN, PH.D.
Assistant Professor of Physics
URI HABER-SCHAIM, PH.D.
Assistant Professor of Physics
ARTHUR KENT KERMAN, PH.D.
Assistant Professor of Physics
JOHN DAVID LINSLEY, PH.D. (*Absent*)
Assistant Professor of Physics
ROY MURRAY WEINSTEIN, PH.D.
Assistant Professor of Physics
STANISLAW OLBERT, PH.D.
Assistant Professor of Physics
KERSON HUANG, PH.D.
Assistant Professor of Physics
HANS MICHAEL MARK, PH.D.
Assistant Professor of Physics
ROBERT ARVEL SCHLUTER, PH.D.
Assistant Professor of Physics
NATHAN SANDERS WALL, PH.D.
Assistant Professor of Physics
KENNETH ALAN JOHNSON, PH.D.
Assistant Professor of Physics
IRWIN ABRAHAM PLESS, PH.D.
Assistant Professor of Physics
ROLF PAUL SCHARENBERG, PH.D.
Assistant Professor of Physics

Lecturers

HERBERT SAGE BRIDGE, PH.D.
Research Physicist
PETER THEODORE DEMOS, PH.D.
Research Physicist;
Associate Director of the Laboratory for Nuclear Science
FREDERIC JOHN EPPLING, PH.D.
Research Physicist
LOUIS SHREVE OSBORNE, PH.D.
Research Physicist
DAVID MARK RITSON, DR.PHIL.

Instructors

WILLIAM MERRILL WHITNEY, PH.D.
GEORGE JACOB WOLGA, PH.D.
WILLIAM BERTOZZI, PH.D.
PAUL GERARD FEDERBUSH, PH.D.
EDWARD ROY PIKE, PH.D.
LAWRENCE ROSENSON, PH.D.

Research Associate

ROBERT AUGUR DUDLEY, PH.D.

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 natural and artificial radioactivity, of cosmic rays and "strange" particles, and of nuclear fission has led to a growing 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 acoustics and fluid dynamics have become revitalized. Physical tools acquired from researches in X-ray, electron, and neutron diffraction, electron microscopy, and modern optical spectroscopy have opened entirely new experimental approaches to problems in chemistry, metallurgy, and biology, as well as in technology as a whole. Applied nuclear physics, with its use of artificial radioactive tracers, plays a similar role in a multitude of scientific and technological disciplines. The day has passed when physics, or any branch of it, can be considered as merely of academic interest. The broad knowledge of physical principles and methods prepares a man uniquely and powerfully to tackle new problems of industry and modern technology.

The Physics Department is aware of the vital importance of maintaining an active research program of highest quality in the pursuit of

fundamental knowledge. Excellent research facilities are available, additional facilities are being developed, and extensive research programs are carried on in a large number of fields of active interest. Interdepartmental research laboratories, such as the Laboratory for Nuclear Science, the Research Laboratory of Electronics, and the Spectroscopy Laboratory serve to correlate the research in various departments in these fields; their facilities are available to students in physics as well as to the staff of the Department. Electronuclear machines capable of producing high-energy particles are available in the Laboratory for Nuclear Science; these include a cyclotron, electrostatic generators, and an electron synchrotron. A new 6 Bev electron accelerator is now being constructed under the joint auspices of Harvard University and M.I.T.; the facilities of this Cambridge Electron Accelerator will be available to graduate students in physics. There are active research programs in nuclear structure, cosmic rays, high energy physics, and applied radioactivity. The Research Laboratory of Electronics provides unequalled facilities for research in microwave electronics and in related fields of physics utilizing these techniques. The Laboratory is equipped to produce very high magnetic fields and very low temperatures, and these are used extensively in research programs. The Spectroscopy Laboratory is unique in the field of spectroscopic measurements and analysis and harbors programs of great interest to physics. Research is carried on actively in solid state and molecular theory, physical optics, X-ray diffraction and crystal structure, electron microscopy, and the structure of dielectrics. Construction of a nuclear reactor is under way, and a neutron diffraction research program will utilize this new facility.

THE UNDERGRADUATE PROGRAM

Physics (Course VIII)

The undergraduate Course in Physics trains students in both experimental and theoretical physics. The preparation is of sufficient depth and breadth so that the graduate is well equipped either to build a successful career in a field of applied physics in industry, or to enter a graduate program in preparation for more advanced work. There is a central core of requirements for the Bachelor's degree, but the curriculum allows each student to select a considerable variety of subjects and to proceed at a pace best suited to his individual desires and capabilities.

The Course leads to the degree of Bachelor of Science in Physics. The curriculum for the first year is described on page 151; the curriculum for the second, third, and fourth years is outlined below:

SECOND YEAR[1,2]

First Term

8.031	PHYSICS	5–5
21.03	HUMANITIES	3–5
M 21	CALCULUS	3–6
	[3]*Elective subjects*	*18*
		45

Second Term

6.10	ELEMENTARY ELECTRIC CIRCUIT THEORY	4–8
8.041	PHYSICS	5–5
21.04	HUMANITIES	3–5
M 22	DIFFERENTIAL EQUATIONS	3–6
	[3]*Elective subject*	*6*
		45

THIRD YEAR[2]

First Term

8.05	PHYSICS OF ATOMS, MOLECULES, AND NUCLEI I	4–6
8.08	ELECTRONICS	4–6
8.09	EXPERIMENTAL ATOMIC PHYSICS I	6–3
M 351	ADVANCED CALCULUS FOR ENGINEERS	3–6
	Humanities (see Section 2)	3–5
		46

Second Term

6.02	ELECTRONIC DEVICES AND CIRCUITS	7–5
8.06	PHYSICS OF ATOMS, MOLECULES, AND NUCLEI II	4–6
8.10	EXPERIMENTAL ATOMIC PHYSICS II	4–2
	Humanities (see Section 2)	3–5
	Mathematics elective subject	*9*
		45

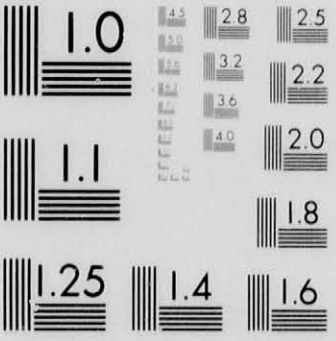
FOURTH YEAR[2]

First Term

8.11	[4]EXPERIMENTAL PHYSICS *and* THESIS	12–4
8.72	INTRODUCTION TO THEORETICAL PHYSICS II	4–8
	Humanities (see Section 2)	3–5
	[3]*Elective subjects*	*12*
		48

Second Term

8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4–6
8.71	INTRODUCTION TO THEORETICAL PHYSICS I	4–8
	Additional THESIS *or elective subject*	*12*
	Humanities (see Section 2)	3–5
	[3]*Elective subject*	*8*
		50



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1958/59

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[1] Students who have not already completed the 12-unit elective requirement for the first two years must finish it during the second year; these elective subjects will be in addition to the regular curriculum shown here.

[2] Substitution is not permitted for professional subjects in the second, third, and fourth years unless the proposed subject has practically the same subject content and objectives.

[3] Students are required to take one term of chemistry in addition to 5.01 and 5.02 GENERAL CHEMISTRY.

[4] Students will arrange with the instructor in charge of 8.11 the number of units to be devoted to THESIS in the first term. A thesis of at least 12 units is required for graduation.

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.

Half-time research assistantships are available in many of the research programs in physics. 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, MOLECULES, AND NUCLEI I AND II (8.05, 8.06)
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)
ELECTRONICS (8.08)

Twenty-four units in the following advanced undergraduate subjects may be credited toward and are required for advanced degrees:

EXPERIMENTAL PHYSICS AND THESIS (8.11)
INTRODUCTION TO THEORETICAL PHYSICS I and II (8.71, 8.72)

Deficiencies in subjects required for admission or for advanced degrees may be removed while engaged in graduate work; they must be made up before a student can register for advanced subjects dependent upon them.

The Master of Science Degree

In addition to general requirements set forth in Section 3, a reading examination in either scientific French or scientific German is required.

The Doctorates

The degree of Doctor of Philosophy or Doctor of Science requires examination for reading knowledge of scientific literature in either German and French or 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.

General Science (Course IX-A)

Under Special Administration

The Course in General Science (Course IX-A) has been discontinued except for members of the Class of 1959 who are already enrolled in it. Students registered in the Course in their fourth year follow the curriculum shown below, which leads to the degree of Bachelor of Science in General Science.

FOURTH YEAR ***(1958–59 only)***

First Term

THESIS	4
Humanities (see Section 2)	3–5
Elective subjects	*36*
	48

Second Term

THESIS	5
Humanities (see Section 2)	3–5
Elective subjects	*35*
	48

The subjects and descriptions given in this Section are subject to change. The final list of subjects to be given in 1958–59 is published with the class schedules prior to the beginning of each term.

(A) following the name of a subject indicates that it is given primarily for graduate students.

(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.

Immediately below the number and name of each subject are shown on a separate line, in sequence:

1. The number(s) of prerequisite subjects, if any. (Numbers in italics indicate subjects which may be taken simultaneously with the described subject.)
2. The name of the instructor in charge, when known at press time.
3. The time distribution of the subject, showing in sequence the units allotted to: recitation and lecture; laboratory, drawing, or field work; and preparation. This system of credits is explained at the beginning of the "Tabulation of Subjects." An asterisk (*) indicates that time units are specially arranged.

When two subjects are covered by one description, two lines may be used; the first applies to the lower-numbered subject.

1.
Civil and Sanitary Engineering

1.002 *Technology in Our Civilization*
—— *Lang* 2–0–4
Fundamental resources of civilization: power, materials, and man. Principal technological agencies of civilization: transportation, communications, environment control, and food production. Needs of civilization as they affect and are affected by technology and the technical professions.

1.01 *Surveying I*
M1.. *C. L. Miller* 2–6–0
Introduction to the principles and theories fundamental to the physical measurement of spatial quantities such as directions, distances, elevations, areas, and volumes. Spatial location of points, lines, planes, and objects. Functional components of physical measurement systems and instruments. Error analysis approach to engineering measurements. Field experiments and office problems to illustrate basic principles.

1.02 *Surveying II*
1.01 *C. L. Miller* 2–6–0
Fundamental engineering applications of the theories and principles developed in Surveying I. Spatial reference and coordinate systems, horizontal and vertical control surveys, topography and mapping, modern surveying systems and instruments, alignment curve geometrics, photogrammetric analytics and models, spatial data requirements for engineering projects. Emphasis on developing basic concepts and sound approaches to problems of engineering measurements. Field and office work to illustrate problems discussed in lectures.

1.04 *Applied Surveying*
1.02 *C. L. Miller* 2–3–4
Modern methods of planning, location, design, and construction surveys for highways, airports, bridges, dams, and other civil engineering projects. Survey planning and design, methods analysis, economics of surveys, and specifications. Advanced methods and instrumentation for control and layout surveys. Applications of aerial photography and photogrammetry to engineering surveys. Special surveys and engineering measurement problems. Case studies of current civil engineering projects to illustrate modern professional practice and the responsibilities of the engineer.

1.06 *Photogrammetric Engineering*
—— *C. L. Miller* 2–2–4
Introduction to theoretical and applied photogrammetry as a method of making space measurements and obtaining technical data. Aerial photography, ground control surveys, aerial triangulation, theory of automatic stereoplotters, stereotopographic mapping, non-topographic photogrammetry, interpretation of aerial photographs. Planning and design of photogrammetric engineering projects and civil engineering applications.

1.12 *Special Studies in Photogrammetry* (A)
1.06 *C. L. Miller* 2–2–4
Advanced theoretical and applied photogrammetry. Individual and group study of topics arranged by the instructor in charge. Special reading assignments, consultation, and original investigations. Experimental work in the Photogrammetry Laboratory.

1.201 *Transportation Planning*
—— *Roggeveen* 3–3–3
Principles of planning, finance, operation, administration, regulation, and design for highway, railway, and air transportation with some attention to pipe lines and waterways. Traffic studies, location problems, and economic considerations. Relationship of transportation planning to regional and city planning. Mass transportation in metropolitan areas. Coordination of different forms of transportation. Field trips and planning problems.

1.202 *Transportation Engineering*
1.02 *Bone* 3–3–3
Design, construction, and maintenance of transportation facilities. Highway and airport design criteria, layouts, drainage, pavements, materials, and construction. Railway track construction and maintenance of way. Problems in highway, railway, and airport design. Field trips and laboratory demonstrations.

1.251T *Traffic Engineering* (A)
1.201 or 1.202 *Bone* 3–0–6
Application of engineering principles to the flow of highway traffic. Characteristics of vehicles, drivers, and pedestrians. Traffic counts, origin and destination surveys, accident studies, traffic estimates, application to planning studies. Highway and intersection capacities. Traffic control, signs, signals, and markings. Geometric design principles for highways and intersections. Parking studies and layout of parking facilities.

1.252T *Highway Location and Geometric Design* (A)
1.201 or 1.202 *Bone* 2–1–4
Principles of highway location, rural and urban, with applications to specific problems. Geometric design of intersections, rotaries, and interchanges. Economic considerations, evaluation of alternate designs.

1.261 *Airport Planning and Administration* (A)
1.201 or 1.202 *Bone* 2–0–4
Basic data required for the design of an airport and its terminal, including air traffic potentials, development of future aircraft, air traffic control, and airport zoning. Field and terminal layouts, passenger and cargo circulation, apron activities, highway access, automobile parking, airport management, finance, and maintenance.

1.262 *Airport Design* (A)
1.201 or 1.202 *Roggeveen* 2–4–0
Development of a layout for an airport, including the location of runways and taxiways; zoning of runway approaches; design of airport paving, drainage, and lighting systems; and site planning for terminal area, access roads, and parking lots.

1.27 *Special Studies in Transportation Engineering* (A)
1.201 or 1.202 *Roggeveen* 2–0–4
Advanced study of a particular phase of highway, railway, or airport engineering, selected with the approval of the instructor.

1.271 *Transportation Seminar* (A)
1.201 or 1.202 *Roggeveen* 1–0–2
Group discussion of various transportation topics led by the staff and guest experts.

1.282T *Highway and Airport Pavements* (A)
1.201 or 1.202 *Bone* 2–2–4
Soils explorations and base courses; thickness design formulas for flexible and rigid types. Current research on pavement design. Design and control of bituminous concrete mixes. Design of concrete paving mixes, joints, and reinforcing. Airport paving requirements. New developments in construction methods. Laboratory work in pavement technology.

1.29 *Management Problems of the Transportation Industry* (A)
1.201 or 1.202 *Roggeveen* 3–0–3
Case study and discussion of management problems in the air, highway, rail, and water transport industries including organization, operation, financing, purchase of plant and equipment, promotion and scheduling of services, labor relations, government regulation, competition, safety, and other topics.

1.30 *Soil Mechanics*
1.41 *Lambe* 3–3–6
Soil engineering fundamentals for undergraduate civil engineering students. Basic physical and mechanical properties affecting soil action in engineering problems: soil identification and classification; permeability and compressibility and their application to the settlement of structures located above buried compressible soil strata; shearing strength and its application to bearing capacity of footings and pile foundations. Survey of other soil engineering problems.

1.31 *Soil Engineering*
1.30 *Roberts* 3–0–6
Practical application of soil engineering principles introduced in 1.30; case studies of practical soil engineering problems: foundations, embankments, and retaining walls. The content is determined in part by special interests of students.

1.361 *Advanced Soil Mechanics* (A)
1.30 *R. V. Whitman* 3–0–6
An introduction to advanced soil engineering for all graduate students, emphasizing the validity of assumptions common to soil engineering practice. Detailed study of mechanical properties of soils: permeability, capillarity, stress-strain-time characteristics under static and dynamic loading, strength characteristics of cohesionless and cohesive soils; theories of elasticity and plasticity as applied to soil; subsoil exploration.

1.362 *Earth Structures* (A)
1.361 *R. V. Whitman* 3–0–6
For students specializing in soil, hydraulic, or highway engineering. Design and construction of embankments, natural slopes, earth dams, and highway and airfield bases and subgrades; stability analysis, control of seepage, compaction, and construction control.

1.364 *Foundations* (A)
1.361 *Roberts* 3–0–6
For graduate civil engineering students specializing in soil or structural engineering. Theoretical and practical aspects of various foundation engineering subjects determined in part by the special interests of students; settlement problems and remedial procedures including preloading and sand drains; bearing capacity of footings, piles, and other foundation types; retaining structures; case studies of actual soil engineering problems.

1.367 *Soil Technology* (A)
—— *Lambe* 2–0–4
A background in soil behavior for the soil engineering specialist. Effect of geological origin, composition, and particle surface characteristics on the engineering properties of soil. Colloidal phenomena in soils; soil mineralogy; ion exchange reactions; compositional analysis of soils; alteration of soil properties with trace additives; and alteration of soil behavior by changes in geological environment.

1.37 *Soil Mechanics Laboratory* (A)
1.361 *Ladd* 3–0–6
Techniques and interpretation of soil tests. Conventional tests for specific gravity, limits of consistency, grain size, permeability and compaction; soil sampling; field identification and classification; methods of obtaining consolidation and shear strength characteristics of soils.

1.39 *Soil Engineering Seminar* (A)
1.361, 1.367 *Lambe* 1–0–2
Group discussions of topics of current interest, led by the staff and guest experts.

1.40 *Statics and Dynamics*
8.02, M12 *Biggs* 3–0–5
Fundamental engineering mechanics for civil engineering sophomores. Engineering applications of the analysis of static equilibrium and of plane dynamics of particles and rigid bodies. Kinematics of particles and rigid bodies in translation, rotation, and plane motion.

1.41 *Materials and Mechanics*
1.40 *McGarry, Heger* 4–2–6
Introduction to elastic analysis through concepts of stress and strain in tension, torsion, compression and flexure. Development and applications of Mohr's circle construction; analytical and graphical methods of determining bending and shear stresses and deflections in beams and columns under a variety of loading and support conditions; combined stress and the resultant deformations commonly encountered in beams and columns; mechanical properties (yielding, work hardening, fatigue, creep, and theories of strength) of common structural materials; anisotropy arising from inherent structure or mechanical working. Laboratory work on materials testing and photoelastic techniques to develop judgment in the choice of structural materials.

1.42 *Materials and Mechanics*
1.41 *J. A. Murray* 4–2–6
Properties of masonry materials, woods and metals and their influence on the uses of the materials in engineering and structural applications. *Masonry Materials:* Physical and chemical properties of cements and aggregates, brick, tile, and stone. Design of concrete mixes and effect on workability, strength, and durability; interrelations between properties of units, mortars, and unit masonry with emphasis on factors causing efflorescence, wet walls and lack of durability. Laboratory work on the preparation of mortars, plain and air entrained concretes, and the physical and mechanical testing of concretes, mortars and units. *Wood:* Mechanical and physical properties of wood and characteristics of laminated timber and plywood. *Metals:* Mechanical and metallurgical properties of ferrous and certain non-ferrous materials with emphasis on their structural applications and behavior; effects of alloy content, heat treatment, fabrication process, and joining methods such as welding; corrosion problems and remedies.

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

1.43 *Advanced Materials*
1.42 *Dietz, J. A. Murray* 2–0–4
Materials of construction supplemental to those studied in 1.42T. Inorganic, non-metallic construction materials such as ceramic tile, glass, ornamental terra cotta, plasters, stuccoes, wall and plaster boards, and insulating materials; fire resistance, acoustical behavior, and thermal insulating characteristics; effects of thermal and moisture expansion, porosity, and soundness upon cracking, discoloration, and deterioration. Properties of laminated materials such as plywood, reinforced plastics, and coatings. Uses of plywood as plates, stressed skin or covers and as components in built-up beams.

1.44 *Elementary Structural Engineering*
1.42 *Hansen* 3–3–2
Initial subject of a sequence of five undergraduate subjects in structural engineering: 1.44, 1.451, 1.441, 1.442 and 1.452, the first four of which are required for all civil engineering undergraduates. Application of the tools of static analysis, structural mechanics and behavior of materials to solve simple structural design problems. Fundamentals of design in wood, concrete, and steel. Development of proper perspective of analysis and design in the solution of structural engineering problems. Laboratory work with qualitative models to develop understanding of the behavior of typical structural types.

1.441 *Structural Design*
1.44, *1.451* *Mirabelli* 2–4–0
Extension of elementary concepts of structural design introduced in 1.44 to design of typical steel and wood structures involved in bridge and building construction. Design of steel beams, plate girders, frames and trusses, and of timber beams, trusses, and laminated frames. Riveted, welded, and bolted connection details.

1.442 *Reinforced Concrete Design*
1.44, *1.451* *Holley* 2–4–0
Extension of elementary concepts of structural design introduced in 1.44, with application to the design of specific reinforced concrete structures such as retaining wall, footing, beam bridge, one-way slab, two-way slab, flat slab, arch, or rigid frame. Introduction to elementary concepts of plastic theory and prestressed concrete.

1.443 *Structural Design*
1.44, 1.451 *Mirabelli* 3–4–2
For civil engineering seniors with particular interest in structural engineering. More comprehensive treatment of subject matter of 1.441, including both elastic and plastic design methods for statically indeterminate structures.

1.444 *Reinforced Concrete Design*
1.44, 1.451 *Holley* 3–4–2
For civil engineering seniors with particular interest in structural engineering. More comprehensive treatment of subject matter of 1.442.

1.451 *Structural Analysis*
1.44 *Mirabelli* 3–0–6
Introductory theory of stress analysis of civil engineering structures such as buildings and bridges. Analysis of elastic and plastic behavior of both statically determinate and statically indeterminate structures including computation of reactions, shears, bending moments, and axial stresses and deflections. Influence line concept introduced to evaluate maximum effects produced by moving load systems. Deflection computations by method of virtual work, moment-area theorems, and Williot-Mohr method. Analysis of indeterminate structures by superposition equations and moment distribution method. Approximate methods of analyzing statically indeterminate structures such as building frames. Statically determinate structures including three-hinged arches and cantilever bridges.

1.452 *Structural Analysis*
1.451 *Norris* 3–0–6
Elective subject for civil engineering seniors interested in structural engineering; prerequisite for all graduate subjects in structural engineering. Continuation of 1.451, featuring a more comprehensive and extensive discussion of the stress analysis, and the elastic and plastic behavior of statically indeterminate structures. Statically determinate structures not discussed previously in detail such as cables, suspension systems, space frameworks, and gravity dams. Brief introduction to advanced structural mechanics including analysis of plates and shells, buckling behavior, and response of structures to dynamic loading.

1.521 *Structural Laboratory* (A)
1.452 *Hansen* 2–3–1
Lectures, conferences, assigned reading, and laboratory work, covering the theory and practice of structural analysis by the use of models. Fundamentals of the entire field.

1.531 *Special Problems in Structural Engineering* (A)
1.571, 1.572 *Norris* *
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.

1.541, 1.542 *Advanced Reinforced Concrete Design* (A)
1.44, 1.452 *Holley* 2–4–0
1.541 *Holley* 2–4–0
Theory underlying the design of reinforced concrete structures in general; brief review of elementary theory; deflections, torsion, shrinkage, plastic flow, ultimate strength theories, and prestressed structures. Application of theory to the design of civil engineering structures such as precast decking, slabs, rigid frames, arches, tanks, hipped-plate roofs, etc.

1.551 *Advanced Structural Design* (A)
1.44, 1.452 *Biggs, Wilbur* 2–0–4
Problems encountered by structural designers; choice of type, general proportions, economics, methods of preliminary design, organization of design procedure, influence of erection methods. Statically indeterminate structures.

1.552 *Advanced Structural Design* (A)
1.44, 1.452 *Biggs* 2–0–4
Analysis and design of Vierendeel trusses, irregular slabs, and tall building frames. Approximate preliminary design methods for indeterminate structures. Practical design application of the theory of elastic stability and its correlation with standard buckling specifications Theory to supplement design procedures as required

1.561, 1.562 *Advanced Structural Mechanics* (A)
1.452, M22 *Norris* 3–0–6
Problems in advanced mechanics with applications to structural analysis. Theory of elasticity, plastic behavior of structures, buckling of structural members, thin plates and shells, and response of structures to dynamic loads.

1.571, 1.572 *Statically Indeterminate Structures* (A)
1.452 *H. Simpson* 4–0–8
1.452 *H. Simpson* 2–0–4
Rigorous treatment of the analysis of statically indeterminate structures; review of elementary theory and analysis of internally indeterminate trusses, continuous trusses, arches, building frames, suspension bridges, etc. Effect of variable stiffness and the subject of secondary stresses. Methods of virtual work, Castigliano, slope deflection and moment distribution.

1.58 *Structural Engineering* (A)
1.44 *Biggs* 4–0–8
For civil engineering graduate students with a secondary interest in structural engineering. Review of the design of structural members of wood, steel and reinforced concrete; analysis and design of simple and cantilever trusses, three-hinged arches, space frames, gravity dams and retaining walls; computation of deflections; analysis of indeterminate structures by energy methods and moment distribution; approximate analysis of highly indeterminate structures; design of steel and reinforced concrete building frames; ultimate strength design of steel and reinforced concrete structures; design of prestressed concrete beams.

1.59 *Structural Engineering Seminar* (A)
1.571 *Norris* 1–0–2
Practice in presenting technical papers and discussion of subjects of current interest.

1.591, 1.592 *Numerical Methods of Structural Analysis* (A)
M22 *Namyet* 2–0–4
Application of approximate and numerical methods of analysis including relaxation, iteration, perturbation, finite difference, and variational methods to problems in structural analysis covering equilibrium, buckling, and vibration of lumped-parameter and continuous systems. Hand and machine methods of computation. Structural analysis techniques especially appropriate for machine computation.

1.601, 1.602 *Fluid Mechanics*
1.40 *Ippen, Daily* 2–0–4
1.601 *Ippen, Daily* 3–0–6
Elementary mechanics of incompressible and compressible fluids. Properties of fluids; fluids at rest, geometry of fluid motion, general equations of motion; dynamic similarity of inertia, gravity and viscous forces, laminar and turbulent flow, skin friction, lift and form-drag; basic principles applied to steady flow through orifices, nozzles, and other flow meters; fluid flow in pipes and open channels; flow through pipe systems; dynamics of immersed bodies, circulation and lift, cavitation, and theory and operation of hydraulic machinery; non-uniform flow in open channels, hydraulic jump, and backwater curves; unsteady flow in open and closed conduits, water-hammer problems.

1.611 *Fluid Mechanics*
2.002 *Harleman* 3–0–6
Elementary mechanics of incompressible and compressible fluids. Properties of fluids. Fluids at rest, geometry of fluid motion, general equations of motion. Dynamic similarity for inertia, gravity and viscous forces, laminar and turbulent flow, skin friction, lift and form-drag, theory and operation of turbomachinery. Basic principles applied to steady flow through orifices, nozzles and other flow meters. Fluid flow in pipes and open channels.

1.612 *Fluid Mechanics*
2.002 *Eagleson* 3–0–6
Introduction to theoretical fluid mechanics. Forces on floating and submerged bodies, equations of motion, dynamic similarity, laminar and turbulent flow, skin friction, flow resistance in conduits, cavitation and propulsion, drag, lift, circulation, and principles of turbomachinery.

1.613 *Fluid Resistance and Turbulent Diffusion*
2.002 *Harleman* 3–0–6
Fundamental dynamics of real fluids; the physical processes of fluid resistance, turbulent diffusion and mixing common to many fields of technology. Principles of kinetic theory, fluid mechanics, and dynamic similarity applied to turbulent diffusion, mass transfer, and jet mixing. Fluid resistance in laminar and turbulent motion, boundary layer development, separation and secondary flow phenomena.

1.621 *Fluid Mechanics Laboratory*
1.602 *Eagleson* 0–6–0
Experiments on basic flow phenomena, such as surface resistance, lift and drag forces, and waves and surges, as well as on engineering applications such as pressure conduits, open channel flow, fluid meters, pumps, and turbines.

1.63 *Applied Hydromechanics* (A)
1.602 or 1.612 *Daily* 3–0–6
General equations of motion, potential flow, conformal mapping applied to hydraulic structures, laminar and turbulent motion in conduits, boundary layer phenomena, surface and form resistance, theories of turbulence, turbulent mixing and transfer of matter in fluid streams.

1.64 *Hydraulic Machinery* (A)
1.612 *Daily* 2–0–4
Various turbomachinery types of hydraulic machines, including centrifugal and axial flow pumps; blowers and fans; and impulse, reaction, and propeller turbines. Basic theory of turbomachinery and its application, performance analyses of the several types, design criteria and procedures, field requirements, and selection of machinery.

1.65 *Free Surface Flow* (A)
1.602 *Ippen* 3–0–6
Steady and unsteady flow in open channels, boundary resistance for uniform and non-uniform flow. Surface curves in natural and artificial channels, standing waves in supercritical flow, hydraulic jump, surges and waves, internal currents due to density variations.

1.66 *Design of Hydraulic Structures* (A)
1.65 *Ippen, G. R. Williams* 0–6–0
Preparation of integrated designs of selected hydraulic structures such as penstocks, siphons, tunnels, spillways, stilling pools, movable weirs and gates, shore protection works, canals, locks, and river improvements.

1.67 *Seminar in Hydromechanics* (A)
1.602 *Ippen* 1–0–2
Recent advances in all fields of hydromechanics; application of developments in related branches of fluid mechanics. Lectures and reports.

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1.681 *Experimental Hydromechanics* (A)
1.602 *Harleman* 2–0–4
Theory of dynamic similarity, dimensional analysis, and correlation of experimental data. Practical methods of establishing dynamic similarity in models; models of hydraulic structures; shape and roughness effects in distorted models. Movable bed, wave, tidal, salinity, and hydraulic machinery models. Instrumentation and experimental techniques.

1.682T *Experimental Hydromechanics* (A)
1.681 *Harleman* 0–8–1
Experimental studies of fundamental phenomena such as turbulence, boundary-layers, surface and form resistance, wave motion, bed-load movement, and density currents. Use of models in hydraulic design exemplified by investigations selected from studies on spillways, bridge piers, river channels, harbor-basins, and hydraulic machinery.

1.683 *Experimental Hydromechanics* (A)
1.63 *Harleman* 0–6–0
Abridgment of 1.682 primarily for naval architects. Experiments on basic flow phenomena involving turbulence, boundary layers, turbulent diffusion, resistance of submerged bodies, cavitation, and wave characteristics.

1.69 *Rivers and Harbors* (A)
1.65 or 1.681 *Ippen* 2–0–4
Hydraulics of river flow, sediment transportation, navigation and flood control measures, tides and tidal currents in estuaries, wave action, beach erosion and shore protection, breakwaters, layout of harbor basins.

1.701 *Hydrology and Hydraulic Engineering*
1.602 *G. R. Williams* 3–0–6
Introductory application of hydrology and fluid mechanics to hydraulic engineering structures. Elements of hydrology, including related meteorologic principles, climatology, hydrologic cycle, evaporation, rainfall-runoff relations, hydrograph analysis, rational method. Design of flood channels, conduits, culverts, chutes, spillways, stilling basins, and canals.

1.702 *Hydrology and Hydraulic Engineering*
1.701 *G. R. Williams* 3–0–6
Advanced hydrologic principles, including statistical analysis of hydrologic data, measurement of runoff, winds and waves, ground-water theory, use of mass curves and duration curves, design storms, flood routing, erosion, and sedimentation. Design of arch, buttress, earth, rockfill, and gravity dams. Spillway gates and control structures, seepage losses in canals, water power plants, and hydraulic turbines.

1.71 *Hydrology* (A)
—— *G. R. Williams* 3–0–6
Comprehensive treatment of hydrologic theory and practice. Meteorologic principles, climatology, analysis of the hydrologic cycle, statistical analysis of hydrologic data, ground water, unit-hydrograph, storage requirements, flood flows and routing, design storms, rational method of drainage design.

1.731 *Water Power Engineering* (A)
1.702 or 1.71 *G. R. Williams* 2–3–4
Application of hydrology and fluid mechanics to design of water power projects. Adaption of general plan to topographic features; use of storage and pondage; introduction of economics in hydraulic design of penstocks, tunnels, surge tanks, and power houses; water hammer; design of penstock anchorages; selection of turbine types; cavitation in turbines.

1.732 *Water Resources Development* (A)
1.702 or 1.71 *G. R. Williams* 2–3–4
Seminar on engineering and economic problems relating to multiple-purpose utilization of river basins. Advanced developments in design of dams, power plants, and turbines; tidal power, pump-storage plants; relation of water power to thermal power in planning, operation, and economic justification of power systems; allocation of costs in multiple-purpose developments.

1.781 *Sanitary Science*
5.02 *McKinney* 3–0–6
Basic subject for seniors interested in broadening their scientific background for work in sanitary engineering. Lectures, demonstrations and field studies on elements of sanitary science. Broad physical, chemical, and biological aspects of sanitary engineering practice, such as development and control of water resources; disposal of gaseous, liquid, and solid wastes; and control of environment to prevent transmission of disease.

1.782 *Sanitary Engineering*
1.701 *Symons* 3–0–6
Survey for seniors specializing in sanitary engineering and with broad interests in hydraulic engineering. Should be taken with 1.701. Water consumption; water sources and their development, including wells, dams, reservoirs, and supply and distribution mains; procedures for estimating sewage quantities; principles of water and sewage treatment and design and construction of water and sewage treatment works.

1.811 *Advanced Sanitary Engineering* (A)
1.781, 1.782 *Symons* 3–0–6
Basic subject for graduate students majoring in sanitary engineering. Scientific and engineering principles of unit operations such as aeration, coagulation, sedimentation, filtration, demineralization, and scale and corrosion control employed in processing municipal and industrial water supplies.

1.812 *Advanced Sanitary Engineering* (A)
1.781, 1.782 *McKinney* 3–0–6
Basic subject for graduate students majoring in sanitary engineering. Principles of unit operations for the treatment of sewage and industrial wastes, including screening, sedimentation, biological coagulation and oxidation by trickling filters and activated sludge, chlorination, anaerobic fermentation, sludge filtration, and drying. Characteristics of inorganic and organic waste waters. Development of design criteria for waste treatment processes correlated with stream pollution control problems.

1.821 *Sanitary Engineering Laboratory* (A)
1.782, *1.831* *Eliassen, McCarty* 2–3–4
Graduate subject for sanitary and chemical engineers interested in the operation of treatment plants for municipal and industrial water supplies. Water supply and purification: rapid sand filtration, sedimentation, chemical coagulation, water softening, demineralization, chlorination, corrosion control, and microbiology.

1.822 *Sanitary Engineering Laboratory* (A)
1.782, 1.831 *Symons, McCarty* 2–3–4
Graduate subject for sanitary and chemical engineers concerned with the operation of treatment plants for municipal sewage and industrial wastes. Sewage treatment and purification: sludge digestion, sludge gas analysis, chemical treatment, biology, biochemical oxygen demand, sludge conditioning for filtration, nitrogen analyses, grease analysis, activated sludge plant operation, and plant efficiency studies.

1.831 *Sanitary Chemistry*
5.02, 1.781 *Eliassen, McCarty* 2–4–4
Basic subject for all graduate students in sanitary engineering and sanitary science. Chemical principles, analyses and control tests involved in purification of water and treatment of sewage and industrial wastes. Discussion of the applications, limitations and interpretation of the tests as used in practice.

1.832 *Chemistry and Industrial Waste Treatment* (A)
1.831 *McKinney, McCarty* 2–4–4
Survey for graduate sanitary engineers interested in industrial wastes. Principles of physical and organic chemistry applied to sanitary engineering unit operations. Treatment processes for several types of industrial wastes, including laboratory work on methods of analysis and experiments with various unit operations.

1.84 *Sanitary Microbiology*
1.781 *McKinney* 3–3–4
Basic subject for all graduate students in sanitary engineering. Fundamental and applied aspects of sanitary microbiology covering bacteria, protozoa, fungi, and algae. Laboratory work on application of microbiology to water supply and purification, sewage and industrial waste purification, and stream pollution from engineering and public health viewpoints.

1.85 *Sanitary Biochemistry* (A)
1.84 *McKinney* 3–3–4
Comprehensive subject for graduate sanitary and chemical engineers who will be engaged in developing processes for the treatment of organic industrial wastes. Fundamental biochemistry of microorganisms involved in waste treatment processes and its relationship to the practical design of waste treatment units. Laboratory work involving biochemical analytical techniques as applied to sanitary engineering and biochemical unit operations in waste treatment.

1.86 *Public Health Engineering* (A)
1.781 *Eliassen* 3–0–6
Survey for graduate sanitary engineers who may be employed by state, federal, and international health agencies. Epidemiology of communicable diseases and the application of engineering principles to the control of the environment for the health of mankind. Design of refuse disposal systems, rural sanitation facilities, housing, and public health. Radiological health and radioactive wastes disposal.

1.861 *Air Pollution* (A)
1.86 *Eliassen, H. L. Hardy* 3–0–6
Survey for graduate sanitary and chemical engineers interested in the field of air-borne as well as liquid industrial wastes. Causes and effects of atmospheric pollution within industrial plants and communities; engineering principles of cleaning industrial effluents of various types; legislative, economic and health factors involved in community air pollution control; organization and operation of air pollution control agencies.

1.881 *Advanced Sanitary Design* (A)
1.811 Eliassen 1–5–2
Basic subject for sanitary engineers who will practice consulting engineering. Application of unit operations studied in 1.811 to the functional design of water treatment plants for municipal and industrial water supplies.

1.882 *Advanced Sanitary Design* (A)
1.812 Eliassen 1–5–2
Basic subject for sanitary engineers who will practice consulting engineering. Application of unit operations studied in 1.812 to the functional design of treatment plants for municipal sewage and industrial wastes.

1.883, 1.884 *Special Studies in Sanitary Engineering* (A)
1.811, 1.812, 1.831, 1.84 *Staff* *
Advanced studies aimed at coordinating certain theoretical, experimental, and practical phases of sanitary engineering and sanitary science. Some choice in selection of problems with approval of instructor.

1.891, 1.892 *Sanitary Engineering Seminar* (A)
1.811 or *1.812 Symons* 1–0–2
Requirement for all graduate students majoring in sanitary engineering and sanitary science. Experience in the preparation and presentation of technical papers and opportunity to discuss matters of current interest.

1.901, 1.902 *Civil Engineering Projects I and II*
—— *G. R. Williams* 2–4–4
—— *G. R. Williams* 2–2–2
Introduction to the civil engineering profession by study of general features of planning, design, and construction of civil engineering projects; assigned studies and exercises, field inspections, laboratory exercises, and class discussions in structural, transportation, hydraulic, foundation, and building engineering to demonstrate the need of a broad approach to civil engineering problems.

1.911 *Engineering Construction*
1.902 *Babcock, McCreery* 3–2–4
Construction of buildings, highways, airports, dams, waterworks and sewer projects, including economic comparisons, financing, engineering organizations, contracts, and specifications. Methods and equipment for earthmoving, foundations, steel, and reinforced concrete. Quantity surveys for construction projects and field trips.

1.921 *Building Construction*
1.911 *Heger* 3–0–3
Engineering and architectural details within the framework of a building; relation of framework and interior details; floor and roof systems and materials; masonry bearing and non-bearing walls; prefabricated curtain wall construction; relationship of the mechanical trades to the building engineer. Selected field trips. Staley, *Semi-Fireproof Construction.* Voss, *Fireproof Construction.*

1.922 *Construction Management*
1.911 *McCreery* 3–0–3
Heavy and building construction; owner-engineer-architect-contractor relationships; contract types and relations, including subcontracts; job planning and organization, supervision, superintendence, job records, labor relations and safety procedures. Quantity surveying and estimating.

1.931 *Dwelling House Construction*
—— *Dietz* 3–0–3
Conventional and mass production methods for the construction of residential buildings. Assembly of materials, sequence of erection, use of new materials, advanced methods in construction techniques, insulation and condensation problems, planning and field techniques, and modular coordination of building materials and framing details. Relation of mechanical services and equipment to building structure. Selected field trips. Dietz, *Dwelling House Construction.*

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2.
Mechanical Engineering

2.001 *Applied Mechanics I*
8.02, M12 *Crandall* 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.

2.002 *Applied Mechanics II*
2.001 *Dahl* 3–0–5
Introduction to engineering applications of dynamic behavior of rigid and deformable systems. Kinematics of particles, rigid bodies in translation, rotation and plane motion. Impulse-momentum equations and applications to jets, rockets and gyroscopes. Work-energy equations and applications to both static and dynamic situations. Stresses and deflections in deformable bodies subjected to dynamic loading.

2.003 *Applied Mechanics III*
2.002, M22 *Rona* 4–0–8
Introduction to advanced methods in mechanics with application to elasticity, gyroscopes, and vibrations of linear systems. Extremum principles in elasticity and dynamics. Generalized coordinates, constraints, and Lagrange's equations. Principles of vibration analysis and control. Transients and dynamic stability in mechanical systems.

2.04 *Strength of Materials*
2.001 *Dahl* 3–0–6
Elementary analysis of stress and strain in two dimensions. Torsion of circular bars. Theory of bending, including shearing and bending stresses. Deflection of beams. Statically indeterminate problems in bending. Combined loading. Column theory. Theories of strength.

2.046 *Strength of Materials and Dynamics*
—— *Dahl* 6–0–8
Elementary analysis of stress and strain in two dimensions; torsion of circular bars; bending of beams; statically indeterminate problems; theories of strength; strain energy; kinematics of particles and rigid bodies; dynamics of particles and rigid bodies in plane motion; work and energy; impulse and momentum. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*)

2.06 *Vibrations*
2.003 *Crandall* 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.

2.07 *Dynamics*
2.002 or 2.04 *Reswick* 3–0–6
Formulation of differential equations in mechanical, electrical, hydraulic, and other systems with emphasis on rigid body dynamics. Solutions and engineering applications of single degree of freedom systems. Vibration measurement and isolation. Simple control systems. Multiple degree of freedom systems without damping. Distributed mass systems. Analog computer demonstrations. Gyroscopes.

2.081 *Mechanics of Materials*
2.001 *Den Hartog* 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.

2.082T *Mechanical Engineering Problems*
2.003; 2.25; 2.42 or 2.421 *Dahl* 2–0–4
Broad review of the several fields of mechanical engineering. Problems from industry requiring the application of more than one of the principal mechanical engineering disciplines. Lectures by senior members of the Department faculty dealing with the professional areas of special interest to the lecturers.

2.11 *Industrial Plant Engineering*
2.002 or 2.04 *Schwarz* 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.

2.125 *Research in Experimental Stress Analysis* (A)
2.126 *W. M. Murray* *
Application of experimental methods to the solution of special problems; current development of theory and technique.

2.126 *Experimental Stress Analysis*
2.081 *W. M. Murray* 2–3–4
Common experimental methods of analyzing stress distributions. Photoelasticity, brittle lacquers, strain gage techniques and instrumentation, and analogies, as applied to problems involving static, dynamic, and residual stress distributions.

2.211 *Advanced Mechanics* (A)
2.081 *Den Hartog* 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. Bending of flat plates. Energy methods in elasticity. Elastic stability problems. Applications to stress analysis of important engineering structures.

2.212 *Advanced Mechanics* (A)
2.003 or 2.06 *Den Hartog* 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. Applications to important engineering problems of dynamics and vibration.

2.213 *Gas Turbines* (A)
2.252 or 2.47; 2.42 or 2.421 *E. S. Taylor* 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. Special problems encountered in aircraft applications.

2.214 *Gas Turbines* (A)
2.213 *E. S. Taylor* 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.

2.215 *Methods of Engineering Analysis* (A)
M351 *Crandall* 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. Introduction to digital and analog computers.

2.216 *Plates and Shells* (A)
2.211 *Dahl* 3–0–6
Bending stresses and deformation in flat plates of circular and rectangular shapes. Large deflections in plates. General theory of curved thin-walled shells with applications to engineering structures.

2.217 *Gyroscope Applications* (A)
2.782 or 6.213 or 16.30 *R. H. Cannon* 3–0–9
Dynamic behavior of mechanical systems in three dimensions. Gyroscopic phenomena and dynamic coupling, with applications to vibration problems, speed governors, rotating machinery, inertial instruments, stable platforms, helicopter rotors, and control systems for vehicles in three-dimensional space. Emphasis on dynamic stability and response to command signals and disturbances, including noise.

2.221 *Plasticity* (A)
2.002 or 2.04 *McClintock* 3–0–9
Mechanics of the plastic state of materials. General discussion of yield criteria and stress-strain relations, including experimental evidence. Applications to the deformation and residual stresses in bars, beams, and tubes. Problems in plane strain. Limit design. Other engineering applications of current interest. R. Hill, *Mathematical Theory of Plasticity.*

2.222 *Seminar in Plasticity* (A)
2.221 *McClintock* *
Further study in branches of plasticity of special interest to the student. Discussion by students of their problems, progress, and results.

2.225 *Physics of Strength and Plasticity* (A)
2.37, 3.11 *Orowan* 3–0–9
Cohesive forces in solids; elasticity. Fracture of brittle materials; Griffith theory of fracture. Ductile types of fracture. Notch brittleness. Cyclic and static fatigue phenomena. Permanent deformations in amorphous materials; viscosity. Grain boundary viscosity in metals.

2.226 *Physics of Strength and Plasticity* (A)
2.225 *Orowan* 3–0–9
Mechanism of plastic deformation in crystals. Plasticity of polycrystalline metals. Dynamics of slip; dislocation theory. Strain hardening; anelastic effects. Creep and creep testing. Theory of transient creep; dependence of the stress-strain curve upon strain rate and temperature. Mechanical behavior of polymers. Recrystallization and recovery. Martensitic transformations.

2.228 *Research in Materials* (A)
2.37 *Orowan* *
Undergraduate and graduate students carry out experimental or theoretical research work on mechanical properties (strength, plasticity, etc.) of metallic and nonmetallic materials.

2.25 *Fluid Mechanics*
2.002; *2.40* or *2.403;* M22 *Erickson* 4–0–8
General introduction to dynamics of fluid motion. Hydrostatics; kinematics; concept of the control volume; continuity equation; momentum theorem; theorem of momentum of momentum; dynamics of inviscid fluid; Bernoulli equations; dimensional analysis; energy equation; viscous and turbulent flow; head losses; fluid meters; fluid machinery; lift; drag; boundary layer.

2.252 *Fluid Mechanics*
2.25 *Erickson* 3–0–6
Introduction to gas dynamics. One-dimensional compressible flow, with applications to problems associated with the design of turbojets, ramjets, rockets, combustion chambers, supersonic inlets, supersonic wind tunnels, gas turbines, and steam turbines. Unsteady fluid motions, with applications to problems of water hammer, detonation, and the inlet and exhaust ducts of reciprocating machinery. Two-dimensional and three-dimensional flows at subsonic and supersonic speeds.

2.261 *Lubrication and Friction*
2.25 *Rightmire* 2–0–4
Presented in two parts: (a) hydrodynamic lubrication covering the Petroff and Sommerfeld equations; criteria for load capacity of bearings; factors for side leakage; and heat balance in a bearing; (b) boundary lubrication covering the effects of lubricant composition, surface finish and bearing materials on bearing performance.

2.262 *Research in Lubrication* (A)
2.261 *Rightmire* *
Opportunity for the student to select a research problem (which may be independent of or closely related to the program in progress in the Lubrication Laboratory), such as lubrication proper, bearing design, surface finish, and fundamental studies of mechanism of friction from both the experimental and theoretical standpoints.

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2.263 *Lubrication and Friction* (A)
2.25 *Rightmire* 3–0–6
Derivation of a generalized Reynolds' equation and its application to analysis of sliders, tilting pad bearings, journal bearings, partial bearings, thrust bearings, externally pressurized bearings, dynamic loading; heat balance in bearings; effect of constitution of lubricant, including molecular structure, surface geometry and nature of the bearing surfaces on boundary lubrication; current theories and critical experiments on dry and boundary friction and their relation to wear.

2.28T *Fluid Machinery*
2.25 *Erickson and Stenning* 3–0–6
Unified treatment from a fundamental point of view of different types of liquid and gas-handling machinery: displacement-type pumps, compressors, and motors; centrifugal and axial pumps and compressors; radial, axial, and mixed-flow turbines; propellers; jet pumps.

2.32T *Mechanical Properties of Non-Metallics*
2.002 or 2.04; 3.11 *Orowan* 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.

2.37 *Mechanical Behavior of Materials*
2.002 or 2.04; 3.11 *Shank* 3–2–4
Introduction to methods of experimental stress analysis. Methods of stress and strain measurement and mechanical testing. Structure and interaction of atoms and molecules. Cohesive forces in various types of matter. Yield of criteria, elements of plasticity mechanics. Elementary physics of plasticity and strength, including dislocations and single crystal behavior; creep, fatigue, notch brittleness. Discussion of metals, ceramics, glass, textiles, high polymers, and rubber.

2.40 *Heat Engineering*
8.02, M21 *Svenson* 4–0–5
First law of thermodynamics. Energy. Properties of liquids, vapors and gases. Second law of thermodynamics. The temperature scale and entropy. Applications to closed systems and to fluids in steady flow, including vapor cycles.

2.401 *Heat Engineering*
2.41 or 8.07 *Svenson* 4–0–5
For students who have taken thermodynamics or heat engineering but whose preparation is not sufficient to cover 2.40 and 2.42.

2.402 *Heat Engineering*
—— *Wadleigh* 4–0–8
Same as 2.40 with, in addition, applications to heat engine cycles and turbine processes. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*)

2.403 *Thermodynamics I*
8.02, M21 *Keenan* 4–0–8
Expansion of 2.40, including mixtures of gases and vapors.

2.404 *Thermodynamics II*
2.403 *J. A. Fay* 3–0–6
First and second laws applied to chemical reactions. Thermochemical equilibrium, and the third law of thermodynamics. Elementary kinetic theory of gases, transport properties, distribution function. Elements of statistical mechanics. Heat conduction and radiation.

2.405 *Thermodynamics of Rate Processes*
2.404 *Hatsopoulos* 3–0–6
Review of uncoupled transfer processes; heat conduction, radiation, mass transfer. Heat convection. Thermodynamics of electric and magnetic phenomena; equilibrium, chemical potential, the Gibbs' equation. Onsager's principle. Coupled transfer processes; heat conduction in anisotropic materials, diffusion and effusion, thermoelectricity, thermionic phenomena, gaseous thermoelectricity. Applications to unconventional heat engines.

2.41 *Heat Engineering*
802, M21 *Svenson* 4–0–5
Fundamental laws and concepts of engineering thermodynamics; properties of liquids, vapors, gases, gas mixtures, and mixtures of air and water vapor. Applications to closed systems and to fluids in steady flow, including steam turbines and engines, air compressors, internal combustion engines, gas turbine cycles, vapor cycles and refrigeration cycles. Brief discussion of the principles of heat transmission and humidity problems.

2.411 *Heat Engineering*
2.41 or 8.07 *Svenson* 5–0–7
For students who have taken thermodynamics or heat engineering but whose preparation is not sufficient to cover 2.403 and 2.421.

2.42 *Heat Engineering*
2.40 *Svenson* 3–0–6
Steady-state heat transfer through resistances in series and between flowing streams. Discussion of steam engines, steam turbines and internal combustion engines. Applications of steady flow to gas turbine cycles and refrigerating cycles. Properties of mixtures of air and water vapor and applications to humidity problems. Thermodynamics of chemical reactions.

2.421 *Heat Engineering*
2.403 *Svenson* 3–0–6
Steady-state heat transfer through resistances in series and between flowing streams. Discussion of steam engines and steam turbines. Applications of steady flow in gas turbine cycles and refrigerating cycles. Availability. Thermodynamics of chemical reactions and chemical equilibrium.

2.422 *Heat Engineering*
2.402 *Wadleigh* 2–1–4
Power-plant cycles, refrigeration cycles, gas turbine processes, elements of turbo-machinery, elementary chemical thermodynamics and combustion. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*)

2.43 *Heat Engineering*
2.25; 2.40 or 2.403 *Kaye* 3–0–6
Heat transfer comprising steady-state and unsteady-state conduction, analogies between heat transfer and momentum transfer, convection, correlations of experimental data, radiation, and applications. Mass transfer comprising molecular diffusion in gases, liquids, and solids, eddy diffusion, analogies, correlations of experimental data, and applications. McAdams, *Heat Transmission.*

2.451 *Advanced Engineering Thermodynamics* (A)
2.40 or 2.403; *M351* *Keenan* 3–0–9
First and second laws of thermodynamics, their applications to simple systems and to flow processes; partial differential relations for the pure substance; the relation between pressure, volume, and temperature and its development; thermodynamics of chemical reactions; the equilibrium constant; availability.

2.452 *Advanced Engineering Thermodynamics* (A)
2.451 *Keenan* 3–0–9
Continuation of 2.451. Binary mixtures and rectification; the criteria of equilibrium; equilibrium of a pure substance; supersaturated vapor and super-heated liquid; chemical equilibrium; thermodynamics of coupled flows.

2.453 *Advanced Projects in Thermodynamics* (A)
2.451 *Collins, Keenan, Kaye* *
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 arranged on an individual basis in consultation with instructor.

2.46 *Statistical Mechanics* (A)
2.451 *J. A. Fay* 3–0–9
Introductory subject for graduate engineering students. Review of thermodynamics. Quantum mechanical concepts, molecular energy levels. Most probable distribution. Calculation of thermodynamics functions and equilibrium constants. Black body radiation. Elements of kinetic theory, transport properties, Boltzmann equation.

2.48T *Gas Turbines and Jet Propulsion*
2.28T *E. S. Taylor* 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.

2.49 *Advanced Fluid Mechanics* (A)
2.25, *M351* *A. H. Shapiro* 3–0–9
Survey of principal concepts and methods of fluid dynamics. Statics. Continuity and momentum relations for continuous fluids. Kinematics of fluid motion. Governing equations for motion of non-viscous fluid. Vorticity and circulation. Kelvin's theorem. Helmholtz' 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 aerodymanics.

2.491 *Compressible Fluid Mechanics* (A)
2.403, 2.49, *M352* *A. H. Shapiro* 3–0–9
Survey of high-speed gas dynamics. One-dimensional compressible flow, with effects of area change, friction, heat transfer, combustion, gas injection. Supersonic diffusers and wind tunnels. Compression shocks. Method of small perturbations for subsonic and supersonic flow. Method of characteristics for supersonic flow. Hodograph methods. Unsteady wave motion in gases. Experimental methods.

2.492 *Advanced Topics in Fluid Mechanics* (A)
2.49 *A. H. Shapiro* *
Selected subjects of current interest in incompressible, subsonic, transonic, supersonic and hypersonic flow. Friction and heat transfer in the compressible boundary layer. No formal lectures; assigned reading and special problems arranged on an individual basis in consultation with instructor.

2.493 *Viscous and Turbulent Flows* (A)
2.49, 2.491, M352 *A. H. Shapiro* 3–0–9
Viscosity; the Navier-Stokes equation, its formulation, its properties, and some exact solutions; boundary layers; turbulence; turbulent boundary layers; boundary layer control; thermal boundary layer; compressible boundary layer; laminar stability and transition to turbulence; separated flows, jets, and wakes; creeping flows at low Reynolds number; drag.

2.494 *Dynamics of Rarefied Gas Flows* (A)
2.49, M351 *A. H. Shapiro* 3–0–9
Introduction to the fluid dynamics of gases in the free-molecule and slip regimes, with application to flight at high altitudes and to industrial processes under high vacuum. Concepts of kinetic theory and of molecular models. Boltzmann equation. General transfer equations. Maxwellian distribution of molecular velocities. Isentropic equilibrium flows. Equations of conservation of mass, momentum, and energy for slightly non-equilibrium flows: phenomena of mass diffusion, the Navier-Stokes stress tensor, and heat conduction. The Knudsen number. Momentum and thermal accommodation coefficients. Skin friction, normal pressures, heat transfer, and diffusion in free molecule and slip ranges. G. N. Patterson, *Molecular Flow of Gases.*

2.495 *Magnetohydrodynamics* (A)
2.49, *M352* *Mawardi* 3–0–9
Maxwell's equation for the electromagnetic field. Relativistic equations of motion of a fluid in a conducting fluid. Stress tensor in the fluid. Conservation theorems for a hydromagnetic field. Hydromagnetostatics, forceless fields and stability considerations. The analogue of Helmholz vorticity theorem in hydromagnetics. Bullard's theorem. The liquid sodium pump and generator. Helmholz and Taylor instabilities. Hydromagnetic waves. Numerous applications to illustrate the theory. Slater and Frank, *Electromagnetism;* Cowling, *Magnetohydrodynamics.*

2.496 *Hydromagnetics of Compressible Fluids* (A)
2.495, *M352* *Mawardi* 3–0–9
Motion of a particle in an electromagnetic field. Larmor's radius. Boltzmann's equation and distribution function for a gas. Transport phenomena. Macroscopic equations of motion for a gas in an electromagnetic field. Electroacoustic oscillations of a highly ionized gas. Hydromagnetic waves, shocks.

2.50 *Heat Transfer*
2.40 or 2.403 or 3.01 *Rohsenow* 2–2–4
Steady and unsteady state conduction; natural and forced convection; heat exchangers with steady and intermittent flow; batch heating processes; solidification; radiation from solid surfaces and gases; errors in pyrometry. Laboratory work as a supplement to lectures.

2.501 *Heat Transfer*
—— *Rohsenow* 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.)*

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2.521 ***Advanced Heat Transfer*** **(A)**
2.42 or 2.421; *M351* *Rohsenow* 3–0–9
Radiation from luminous and non-luminous gases. Review of analogies among heat transfer and friction and mass transfer. Free and forced convection from theoretical and experimental viewpoint. Heat transfer coefficients at high velocities. Heat transfer-friction relationship in heat exchangers. Film and dropwise condensation. Boiling with forced and natural convection.

2.522 ***Advanced Heat Transfer*** **(A)**
2.42 or 2.421; *M351* *Rohsenow* 3–3–6
Steady state and transient state conduction problems are solved for various constant and fluctuating boundary conditions. Problems in rectangular, cylindrical and spherical coordinates are considered. Thermal stresses resulting from non-uniform temperature distribution. Solution of the differential equations are accomplished by formal mathematics, relaxation method, potential field mapping, method of images, and methods of analogy.

2.53 ***Heat Measurements***
2.43 or 2.50 *Rohsenow, Kaye* *
Selected experiments with laboratory investigation of problems connected with the industrial application of heat, such as thermal conductivity, thermal expansion, specific heat, ceramics, etc.

2.56T ***Power Plant Engineering***
2.42 or 2.421 *Holt* 3–0–6
Discussion of the steam power plant for the generation of electric power together with the production of steam for industrial processes. Thermodynamic, economic, and operating problems involved in selecting the prime movers and auxiliary equipment. Lectures supplemented by a trip to a neighboring power station.

2.57 ***Advanced Power Plants*** **(A)**
2.56T *Holt* 3–0–9
Modern power plants, including a study of the design and installation of high-pressure boiler, economizers, air preheaters, modern fuel-burning furnaces and automatic combustion controls. Study of the various steam cycles and types of auxiliary drive to show their effect on station heat balance. Discussion of deaërators, evaporators, condensers, heater, etc., including turbine and machinery foundations and layouts. Lectures and problems supplemented by trips.

2.58 ***Heat Transfer***
2.25, 2.421 *Rohsenow* 3–0–6
Steady-state and transient heat conduction, with and without heat sources in one and two dimensions. Heat transfer in fins and through finned surfaces. Neutron diffusion and solutions for neutron flux distribution in bodies of various shapes. Critical condition in a nuclear reactor. Solutions by finite differences and electrical analogy. Heat transfer with free- and forced-convection in laminar and turbulent flow including liquid metals. Heat exchanger design. Boiling. Condensation. Radiation.

2.581 ***Nuclear Power Plant Engineering I***
2.003, 2.25, 2.37, 2.421 *Wadleigh* 3–0–6
Applications of the principles of thermodynamics, applied mechanics and fluid mechanics to problems arising in the design of nuclear power plants. Analysis of power cycles incorporating nuclear heat sources and various working media; discussion of the engineering properties of special materials; structural analyses involving the behavior of materials at high and non-uniform temperatures; study of pressure drops in compressible, incompressible, two-phase and two-component flows. Survey of mechanical problems associated with nuclear power plants and a case study of a typical mechanical design problem, e.g., high-pressure vessel closures, remote handling devices, control rod drives, shaft seals.

2.582 ***Nuclear Power Plant Engineering II*** **(A)**
2.581, 22.21 *Wadleigh* 3–3–3
Design of nuclear power plants as systems. Optimization concepts applied to heat exchanger design; balancing temperature differences and pressure drops, selecting optimum surface areas. Assigning performance and dynamic characteristics to typical plant components and synthesis of off-design and control characteristics therefrom. Major design project in which the principal features of a nuclear power plant for a specific application are developed.

2.601, 2.602 ***Food Engineering***
8.04 *Hesselschwerdt* 2–2–2
2.601 *Hesselschwerdt* 2–2–2
Primarily for students in Food Technology. Fundamental principles of thermodynamics with specific application to problems in heat transfer, refrigeration, and air conditioning as related to food processing and preservation. Discussion of methods, materials, and equipment used for food processing and preservation. Laboratory work and plant trips as supplement to lectures.

2.621 ***Refrigeration***
2.41 or 2.42 or 2.421 *Svenson* 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.

2.642 ***Low Temperature Refrigeration*** **(A)**
2.40 or 2.403 *Collins* 3–3–6
Thermodynamic processes for producing low-temperature refrigeration. Problems of heat exchangers, insulation and rectification. Applications of low-level refrigeration to the purification of oxygen and nitrogen. *(Not offered 1958–59.)*

2.661 ***Heating and Ventilation***
—— *Hesselschwerdt* 2–0–4
Primarily for students in Architecture. Physiological and practical aspects of the problems in producing a comfortable environment. Thermal relationships of the enclosure to climate and weather. Load estimates, insulation, and the techniques of heating, heat generation, and their control.

2.662 ***Heating and Ventilation***
2.661 *Hesselschwerdt* 2–0–4
Continuation of 2.661. Air handling equipment, duct systems, and air distribution within the space. Fundamental principles and techniques for cooling and dehumidification for comfort. Equipment and control systems.

2.663 ***Air Conditioning***
2.40 or 2.403 or 2.41 *Hesselschwerdt* 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.

2.671 ***Advanced Air Conditioning*** **(A)**
2.663 *Hesselschwerdt* 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.

2.68 *Engineering Laboratory*
2.25; 2.40 or 2.403 or 2.41 or 10.29 *Wadleigh*
1–3–4
General mechanical engineering laboratory for Course II seniors. Focus on principles of engineering measurement: determination of properties; dynamometry; flow metering; similarity; research methods; applications of the First Law. Exercises embodying these elements, providing contacts with representative mechanical engineering apparatus and an introduction to the elements of report writing. Project investigations of some depth pursued by small student groups during the final period of several weeks.

3.685 *Applications of Statistics to Mechanical Engineering*
M21 *McClintock* 1–0–1
Probability. Frequency distributions of one variable and functions of variables. Small sample prediction limits and confidence limits for the median of a population. Presentation of statistical answers to probiems suggested by the students from their other work.

2.693 *Refrigeration and Air Conditioning Laboratory*
2.621; 2.663; 2.68 or 2.681 *Hesselschwerdt*
0–3–6
Experimental work involving application and research problems in air conditioning and refrigeration; with equipment including standard condensing units, air washer, heating and cooling coils, constant temperature rooms, and equipment of special design. Facilities available for the use of more than one refrigerant.

2.73 *Machine Design*
2.002 *T. P. Goodman* 2–2–2
Lectures, drafting room exercises, and a design project covering the kinematic design of the basic mechanisms. Introduction to dynamics of machine elements.

2.731 *Machine Design*
2.002 or 2.04; 2.73; 3.11 *Reswick* 2–3–4
Original design by each student of a simple high-performance *machine* demonstrating the applicability of previous fundamental studies in the synthesis of the device. Statement by each student of the required function of a mechanism, its innovation with necessary analyses and integration into a finished design, taking into consideration such things as form, utility, cost and reproducibility. Small groups, with active guidance from staff members professionally competent in design. Corollary lecture material from basic consideration of design criteria for major machine elements, gears, shafts and bearings. Case studies illustrating roles of analytical, experimental, empirical, and intuitive phases of design.

2.732 *Machine Design*
2.731 *R. W. Mann* 2–2–5
Analytical aspects of machine design. Influence of dynamics and material limitations, illustrated by a study of intermittent motion devices. Development of component representation and system synthesis techniques for energy conversion, control and utilization equipment. Problems of professional caliber and association with design groups in academic laboratories to encourage ingenuity and ability to reduce broad problem statements to useful analytical expressions.

2.735 *Human Factors in Design*
—— *Reswick* 0–6–3
Man as a component in a physical system. Fundamental concepts pertaining to the measurement of sensation, and the transmission and processing of information through the human organism. Physiological and psychological characteristics of the human input and output channels and the design of displays and controls in the physical environment for most efficient matching to the organism. Practice in comprehensive design utilizing a variety of problems in which the man interacts with the machine. Limited registration.

2.751 *Analysis and Design of Engineering Systems I* (A)
2.003 or 2.07; 2.25; 2.403 *Paynter* 3–0–9
Application of system concepts to wide range of physical processes. Emphasis on variable flow of matter, energy, and information, directed toward predicting performance for specified designs. Study of interactions in terms of ordinary and partial differential equations, block and schematic diagrams, analogies, and computing machines. Lectures and problem work on electrical, mechanical, fluid, thermal, chemical, biological, and nuclear systems.

2.752 *Analysis and Design of Engineering Systems II* (A)
2.751 *Paynter* 3–0–9
Continuation of 2.751 with emphasis on synthesis and design aspects of systems used to accomplish specific tasks. Allotment of major portion of time to original studies on a team basis with appropriate use of available computing machinery.

2.78 *Hydraulic and Pneumatic Controls*
2.003 or 2.07; 2.25 *S. Y. Lee* 2–3–4
Theory and design of hydraulic and pneumatic controls and their applications in industry. Problems in the control and measurement of pressure, flow, speed, position, torque, and power. The matching of load to prime power source. Application of basic principles to component and system design. Use of schematic and block diagrams. Introduction to analog computation. Selected laboratory projects.

2.782 *Introduction to Automatic Control*
2.003 or 2.07; 2.25; M22 *Shearer* 3–0–6
Introduction to system analysis applied to control systems. Engineers' approach to understanding the unsteady behavior of basic components and processes with emphasis on dynamic response and automatic control. Significance of feedback effects in a wide variety of physical systems. Transient and frequency response applied to the solution of system differential equations; criteria of stability; linearization, root locus, and analog techniques. Introduction to machine computation.

(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.

2.783 ***Advanced Automatic Control*** **(A)**
2.003 or 2.07; 2.403; 2.751 or 2.78 or 2.782
Shearer 3–0–9
General theory of automatic control. Advanced problems in the control temperature, pressure, flow, speed and position control. Studies of the dynamics of industrial processes and physical systems. Use of analytic techniques in the design of systems for high dynamic performance. Linear and nonlinear systems, lumped and distributed parameter systems. Use of random input-output data in the determination of system characteristics. Formulation of dynamic relationships for complex systems.

2.784 ***Instruments for Measurement and Control*** **(A)**
2.003 or 2.07 *S. Y. Lee* 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.

2.79 ***Elementary Internal Combustion Engines***
2.002 or 2.04; 2.40 or 2.403 or 2.41 or 10.29
Rogowski 3–0–6
For students not specializing in this field. Spark ignition and Diesel cycles. Combustion, friction, cooling, carburetion, and other factors affecting power, efficiency, and general performance.

2.791 ***Internal Combustion Engines***
2.002 or 2.04; 2.42 or 2.421 *Rogowski* 3–0–6
For students specializing in this field. Analysis of thermodynamics cycles, combustion, fluid flow and friction problems in a complex machine. Effects of operating and design factors on performance.

2.792 ***Internal Combustion Engines***
2.79 or 2.791 *Rogowski* 3–0–6
Continuation of 2.791 or 2.79. Application of engine theory to rational design procedure. Choice of optimum thermodynamic cycle, cooling, shape and size to meet a given performance specification. Effect of consideration of engine balance, stresses, materials, and fatigue on design.

2.7941 ***Internal Combustion Engine Laboratory***
2.79 or *2.791* *Rogowski* 0–2–2
Supplement to the classroom work of 2.791. Experimental investigation of selected problems, demonstration of basic principles, and experience in modern methods of measurement and rational analysis of data.

2.7942 ***Internal Combustion Engine Laboratory***
2.7941 *Rogowski* 0–2–2
Continuation of 2.7941. More advanced work including short experimental studies formulated and carried out by the student groups.

2.797 ***Advanced Internal Combustion Engines*** **(A)**
2.79 or 2.791 *C. F. Taylor* 3–0–9
For students with previous training or experience in this field. Analytical approach to problems of the Diesel engine, gasoline engine, and other types. Fluid flow, thermodynamics, combustion and performance. Taylor and Taylor, *The Internal Combustion Engine*, revised edition, 1948.

2.798 ***Advanced Internal Combustion Engines*** **(A)**
2.797 *C. F. Taylor* 3–0–9
Continuation of first-term subject. Analysis of problems connected with friction, lubrication, fuel injection, supercharging, balance, torsional vibration, detail design of parts.

2.80 ***Automotive Vehicles***
2.003 or 2.07 *C. F. Taylor* 3–0–6
Analytical approach to vehicle performance, spring suspension, transmission, brakes, etc. Study of a special problem related to vehicle design by each student.

2.801 ***Special Problems in Internal Combustion Engines*** **(A)**
2.48 or 2.79 or 2.791 *C. F. Taylor* *
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 summarized in written report.

2.821 ***Combustion Aerodynamics*** **(A)**
2.25 or 16.02 *Toong* 3–0–9
Fundamental treatment of problems in gas dynamics involving simultaneous occurrence of chemical reaction and transfer of heat, mass, and momentum. Combustion thermodynamics. Applied chemical kinetics. Transport coefficients in reacting mixtures. Conservation equations considering chemical reaction and 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.

2.822 ***Advanced Topics in Combustion*** **(A)**
2.821 or 10.70 *Toong* 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. Flame propagation near a heat sink. Flame stabilization in boundary layers. Interactions among burning fuel droplets. Combustion instability. Similitude rules.

2.83 ***Research in Combustion*** **(A)**
2.821 or 10.70 *Toong* *
Selected analytical or experimental problems in combustion, such as flame propagation, flame instability and stabilization, ignition, limits of inflammability, burning of fuel droplets, diffusion flames, combustion in rockets and engines, etc. Work arranged on an individual basis in consultation with instructor.

2.855 ***Theory of Metal Cutting*** **(A)**
2.862, 3.11 *M. C. Shaw* 3–0–6
Basic mechanics of the cutting process. Influence of physical properties of work and tool materials upon their cutting characteristics. Thermodynamic conditions at the point of a cutting tool. Importance of friction in the cutting process; role of cutting fluids in facilitating the removal of metal. Nature of the surface produced: surface finish, residual stresses and surface damage, Application of principles to special problems in turning, milling, drilling, grinding and polishing. Survey of current technical literature and special topic assignments. Demonstrations of selected current laboratory techniques.

2.858 *Research in Machine Tools and Metal Cutting* (A)
2.85 or 2.851 *M. C. Shaw* *
Opportunity for the student to work in the Machine Tool or Metal Cutting Laboratories on a research problem in a representative area such as: the mechanics of cutting and chip formation; fundamentals and problems associated with the grinding, milling, turning, drilling, or planing processes; residual stresses produced in machining; vibrations in machine tools; precision measurements and surface finish.

2.859 *Manufacturing Technology*
2.85 or 2.851 *M. C. Shaw* 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.

2.861 *Design and Manufacture*
—— *Mann, Shaw* 4–4–4
Design principles applied to machine elements. Philosophy of design stressing the creative approach to engineering problems. Mechanics of cutting processes. Application of economic principles to manufacturing. Synthesis of manufacturing technology and functional requirements in a comprehensive term project.

2.862 *Machine Tool Fundamentals*
2.85, 3.11 *P. A. Smith* 2–1–2
Mechanism of chip formation and importance of such items as: tool geometry, physical properties of metal cut, and friction between chip and tool, with regard to tool design and performance. Metallurgical aspects of machining, cutting demonstrations and exercises involving metal cutting dynamometers and thermoelectric apparatus. Application and limitation of current manufacturing processes. Manufacturing economics including selection of equipment. Industrial organization and personnel problems associated with manufacturing.

2.863 *Experimental Techniques*
2.701 and 2.85; or 2.861 *Cook, Rabinowicz* 2–1–5
Experimental techniques presented for observation and measurement of fundamnetal 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.

2.901, 2.902 *Principles of Fabric Structure*
8.02 *Schwarz* 3–0–6
Discussion of the properties of fibers as related to the properties of yarns and fabrics; properties of yarns as related to fabrics; construction and finishing of fabrics to produce certain desirable characteristics in these materials. Material dealing with principles of woven fabric structure together with the formation of knitted, braided, twisted, and felted materials.

2.903 *Elements of Textile Manufacturing*
8.02 *Schwarz* 3–0–6
Production and properties of textile raw materials and operations basic to the manufacture of cotton, wool, silk, flax, jute and rayon.

2.904 *Principles of Textile Manufacturing*
2.903 *Schwarz* 3–0–6
Continuation of 2.903 covering the combination of operations such as blending, carding, combing, drafting, twisting, etc., into processes as for cotton, woolen, worsted, spun and thrown filament, and bast fiber materials; includes mill organization studies.

2.905 *Textile Engineering Analysis* (A)
2.002 or 2.04; 8.03 *Backer* 3–0–6
Analytical approach to problems of textile materials, textile processes and their interaction. *Fiber rheology:* principles of elasticity, viscoelasticity, creep and relaxation, time-temperature effects, static and dynamic testing. *Textile structures:* differential geometry of twisted yarn, translation of fiber properties into yarn structures, role of fiber variability.

2.906 *Textile Engineering Analysis* (A)
2.905 *Backer* 3–0–6
Fiber rheology: molecular structure of fibers, bond strength, dependence of mechanical properties on structure, discussion of X-ray, infrared and electrical measurements. *Textile structure:* cloth geometry, interaction of yarn and fabric structures, mechanical behavior of woven and knitted materials, flow through porous textiles. *Process statistics:* product irregularity, drafting statistics, breakage probabilities. *Process dynamics:* analysis of ring spinning mechanics, balloon dynamics, traveller-ring interaction, spindle vibration, dynamics of weaving.

2.907, 2.908 *Textile Microscopy* (A)
8.04 *Schwarz* 2–3–2
2.907 *Schwarz* 2–3–2
Application of optical and microscopical equipment to technical analysis of textiles. Lectures and laboratory on the types of equipment, their use and the technique of textile microanalysis for fiber, yarn and fabric. Opportunity for intensive research on projects involving quantitative determinations; development of technique; application of photomicrography, polarized light, fluorescence, swelling technique, etc., to textile microscopy.

2.911 *Textile Research Laboratory* (A)
2.905, 2.93 *Backer, Morgan* 0–6–2
Introduction to modern instrumentation used in textile research. Emphasis on engineering and statistical planning of experiments, analysis of test mechanisms, interpretation and presentation of results.

2.912 *Textile Research Laboratory* (A)
2.906, 2.911 *Backer, Morgan* 0–6–2
Application of the research group method to the solution of textile behavior problems.

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2.913, 2.914 ***Textile Technology Seminar*** **(A)**
2.905, 2.907 *Backer, Schwarz* 2–0–2
2.906, 2.908 *Backer, Schwarz* 2–0–2
Opportunity for students and staff members to present critical discussions of important problems in fiber technology, textile analysis and textile microscopy together with reviews of the current literature, and the results of researches in these fields at the Institute.

2.93 ***Experiment Planning and Analysis*** **(A)**
M22 *Schwarz* 3–0–6
The philosophy and methods underlying the design and interpretation of experiments and the presentation of results. Choice of variables, selection of specimens, size and type of experiment, presentation of data in the form of tables, charts, graphs, and equations, statistical analysis of variable data, comparisons of two or more things subject to interactions, correlation, and the interpretation of quality indices.

2.951, 2.952 ***Industrial Practice***
—— *W. M. Murray* 40 h.p.w.
Approximately six months of practical work carried out by the Cooperative students in manufacturing, engineering, research, and developments at the plants of the organizations participating in the Cooperative program.

3.
Metallurgy

3.00 ***Extractive Metallurgy***
—— *Gaudin* 4–2–4
Introduction to the processing by which ores and minerals are transformed into metals or semi-finished mineral products. Separation of one phase from another, as of a solid from a liquid, a liquid from a liquid, or of one solid from another frequently involving preparatory mechanical and chemical changes in the matter under process to make the separations go as desired. Principles of a selected group of processes and integration of unit operations into complete industrial processes.

3.01 ***Metallurgical Engineering I***
5.61 *Elliott* 4–0–4
Extractive metallurgy considered as a series of unit operations, involving physical separations, and unit processes, involving chemical reactions or changes in state. Treatment of the engineering fundamentals of unit processes. Metallurgical stoichiometry and thermo-chemistry. Material and heat balances. Fuels and combustion. Fluid flow and heat transfer. Metallurgical furnaces. Introduction to the physical and chemical bases for phase separation in unit processes.

3.011 ***Metallurgical Engineering Laboratory I***
3.01 *Elliott* 0–3–1
Laboratory experiments to acquaint the students with apparatus of measurement and to illustrate engineering principles underlying the processes of extractive metallurgy.

3.02 ***Metallurgical Engineering II***
3.01 *T. B. King* 4–0–4
Fundamental study of the unit processes of extractive metallurgy. Stoichiometric and thermodynamic treatment of some simplified unit processes. Consideration of apparatus requirements as to design and operating variables. Gas-solid processes such as drying, roasting, and reduction of metal oxides; simple smelting and blast furnace smelting; converting and distillation processes; refining processes; electro-metallurgical processes; kinetics of unit processes.

3.021 ***Metallurgical Engineering Laboratory II***
3.02 *T. B. King* 0–3–1
Laboratory exercises to illustrate the significant variables in typical metallurgical processes and to measure thermodynamic quantities in related chemical reactions.

3.03 ***Metallurgical Engineering III***
3.02 *T. B. King,* 3–0–6
Study of integrated metallurgical processes. Application of the fundamental treatments of 3.01 and 3.02 to the extractive metallurgy of the more common metals such as iron and copper, and of some less common metals such as titanium and zirconium.

3.10 ***Metallurgical Plant Visits***
—— *C. M. Adams* 0–3–1
One week of metallurgical plant visits to observe the methods and equipment for the production of iron, steel, and non-ferrous metals, as well as metal fabricating processes. Meeting of students and instructor about one week before the opening of the fall term. (*Restricted to students who have completed the third year of Course* III.)

3.11 ***Engineering Materials***
—— *Wulff, Spacil* 4–2–4
Introduction to the study of the atomic, micro- and macrostructure of solids commonly used in engineering. Fundamentals of chemical bonding, crystallography, nucleation and growth, diffusion, rates of reaction, and equilibrium diagrams. Effect of composition, thermal, and mechanical history of a solid on its structure and properties. Dependence of corrosion, elastic, plastic, fracture, wear, electrical, and magnetic properties on structure. Laboratory and class work on the casting, forming, and joining of metals and non-metallic solids.

3.113 ***Engineering Materials***
—— *Wulff, Spacil* 4–0–4
Same content as 3.11 omitting laboratory.

3.13 *Foundry Engineering*
3.11 or 3.31 *H. F. Taylor* 2–0–4
Theory and modern development of ferrous foundry processes. Sizing, grading and handling of mold materials, flow and solidification of molten metal, heat flow in mold and metal, and gases in metals as related to the production of sound castings. Standard and new methods of molding, melting, alloying, gating, risering, cleaning, cutting, testing and inspection. Comprehensive treatment of casting design.

3.15 *Welding Engineering*
3.11 or 3.31 *C. M. Adams* 2–0–4
Detailed treatment of the joining of metals by brazing, and by gas, atomic hydrogen, helioarc, resistance and thermit welding; studies of stress concentration and stress relief, inspection and testing, engineering design and metallurgical aspects of the subject.

3.16 *Powder Metallurgy*
3.11 or 3.31 *Wulff* 2–0–4
Introductory survey of the manufacture of metal powders and products. Physical and chemical methods for the production of finely-divided metals. Theory and practice of sintering, emphasizing functions of surface energy and diffusion. Study of flow sheets for the production of typical products including bearings, carbide tools, magnets, and electrical contacts.

3.18 *Plastic Working of Metals*
3.11 or 3.31 *Backofen* 2–0–4
Principles of plastic deformation introduced both from the viewpoint of the physical metallurgist and the materials engineer. Principles applied to study of industrial metal forming processes, such as: wire, rod, and tube drawing; deep drawing; extrusion, rolling, and forging; die-less tension forming; shearing and metal cutting; bending. Relation of friction, wear, corrosion, and their control to the fabrication and use of metals.

3.20 *Metallurgical Thermodynamics*
5.62 *Elliott* 4–0–4
Thermodynamics emphasizing topics useful in metallurgical operation. Free energies of substances at elevated temperatures and activities of metals in solid and liquid alloys, used in interpreting metallurgical phenomena and in determining the feasibility and limitations of metallurgical processes.

3.21 *Thermodynamics in Process Metallurgy* (A)
3.20 *Chipman* 3–0–6
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.

3.22 *Thermodynamics of Metallic Solutions* (A)
3.20, 3.32 *Elliott* 2–0–4
Study of the current literature covering the entropy and energy functions in solid and liquid metallic solutions and their application to phase diagrams. (*Alternates with 3.26.*)

3.25 *Experimental Methods in Metallurgy* (A)
5.62 or 8.04 *Grant* 1–2–0
Special experimental techniques and methods used in metallurgical research, such as: vacuum melting and casting; attainment of extremely high temperatures; special casting methods such as precision casting; vacuum fusion and special chemical analytical techniques; ceramic and refractory evaluation and application; optical and thermocouple temperature reading; temperature control, etc. (*Suggested for all new graduate students in the Department of Metallurgy.*)

3.26 *Kinetic Problems in Metallurgy* (A)
—— *T. B. King* 2–0–4
Advanced treatment of the rate of metallurgical reactions determined by diffusion in solid and liquid phases, gaseous diffusion, transport processes due to fluid flow, and phase boundary reactions. Illustration of the general principles by reactions involving diffusion of hydrogen, nitrogen, or carbon from a gas phase as donor into solid metals, the oxidation of metals and alloys at elevated temperatures, the reduction of metal oxides and sulfides, roasting processes, and metal-slag reactions. (*Alternates with 3.22. Not offered 1958–59.*)

3.31 *Physical Metallurgy I*
5.02, 8.04 *Bever, D. A. Thomas* 4–3–4
Principles of physical metallurgy, covering such basic subjects as the characteristic properties of metals, solid solutions, intermetallic compounds and aggregates thereof; construction and metallographic interpretation of equilibrium diagrams; plastic deformation and rupture of metals; phenomena of recovery, recrystallization and grain growth; kinetics and mechanism of phase changes in the solid state. Commercial non-ferrous alloys used as a basis of discussion wherever possible.

3.32 *Physical Metallurgy II*
3.31 *M. Cohen, D. A. Thomas* 3–3–6
Continuation of 3.31, using iron, steel and ferrous alloys to illustrate principles of physical metallurgy. Ternary phase diagrams, metastable equilibrium, theory of nucleation and growth applied to phase transformations, martensitic reactions, heat treatment of steel, hardenability, quenching and transformation stresses, surface hardening, properties and uses of iron-base alloys.

3.33 *Physical Metallurgy III*
3.32 *Floe* 2–4–4
Lectures and laboratory conferences on applications of metallography to industrial problems. Examination of microstructures of normal and defective commercial alloys. Critical résumé of the fundamentals of modern physical metallurgy essential to the proper interpretation of the microstructures.

3.34T, 3.35T *Advanced Physical Metallurgy* (A)
3.20, 3.32, 3.50 *Bever, Averbach* 4–0–6
Advanced treatment of important subjects within the general field of physical metallurgy, including stable and metastable alloy systems, 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.

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3.391, 3.392 *Properties of Metals*
—— *Floe* 2-1-3
3.391 *Bever* 2-1-3
Metallurgical properties of metals and alloys with reference to materials used in ship construction. The making, microstructure, processing, heat treatment, joining and corrosion resistance of non-ferrous and ferrous alloys. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*)

3.396 *Nuclear Metallurgy*
3.11 or 3.31 or 3.391 *Ogilvie* 2-0-4
Description of physical and nuclear requirements of materials which may be used in reactors. Discussion of metallurgical processes and techniques required to handle these materials, followed by detailed study of uranium, beryllium, graphite, etc. Examination, from a materials viewpoint, of general problems such as heat removal, radiation damage, power generation, and breeding.

3.42 *Electrochemistry*
5.62 *Uhlig* 2-0-4
Fundamental principles of electrochemical theory, with illustrations of their applications in practice. Electroanalysis, electroplating, electrowinning of metals, primary and secondary cells, electrophoresis, alkalichlorine production, and related processes.

3.43 *Corrosion* (A)
5.62 *Uhlig* 2-0-4
Theories of corrosion; general principles of corrosion control; selection of metals for use at low and high temperatures. Corrosion testing.

3.44 *The Behavior of Metals at Elevated Temperatures* (A)
3.32 *Grant* 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.

3.50 *X-ray Metallurgy*
3.31 *J. T. Norton* 2-2-4
Use of X-rays in the study of metals. Radiographic examination of metal parts, X-ray diffraction study of the structure and texture of metals.

3.51 *Physics of Metals*
3.50 *J. T. Norton* 2-0-4
Modern theories of the metallic state and their relations to the physical properties of metals.

3.52 *Advanced Physics of Metals* (A)
3.50 or 3.396 *Ogilvie* 2-0-4
Various problems of the crystalline metallic state and the dependence of physical properties upon structure. Laboratory work in the form of short research problems. A continuation of 3.51.

3.53 *Advanced X-ray Metallurgy* (A)
3.50 *J. T. Norton* *
Conferences and laboratory work covering all of the important X-ray diffraction techniques used in the study of metallic structures.

3.54 *Radiographic Inspection*
—— *Ogilvie* 1-3-2
Theory of the radiographic problem and the application of X-rays and gamma rays to industrial radiographic inspection. X-ray and gamma ray sources, formation of the X-ray image, method of recording the image and a detailed treatment of the problems of contrast, definition, and sensitivity. Questions of industrial specification based on radiographic inspection and the cost of such inspection on an industrial basis. Laboratory experiments to demonstrate the practical techniques for the inspection of weldments, castings and assembled devices.

3.61T *Electric and Magnetic Materials* (A)
3.11 or 3.31; 8.051 *Averbach* 2-0-4
Physical basis of the electric and magnetic properties of metals, semiconductors and ceramics. Effects arising from imperfections, impurities, domains, grain boundaries, and sub-boundaries.

3.62 *Special Problems in Metallurgy* (A)
—— *Staff* *
Minor investigation in one of the special branches of metallurgy. (*Open only to graduate students properly qualified in the special field.*)

3.70 *Ceramics*
5.02, 8.04 *F. H. Norton* 2-0-4
Introduction to the more advanced ceramic subjects. Selection of ceramic materials, molding, drying and burning, as well as the physical properties of finished products.

3.701 *Ceramics Laboratory*
3.70 *Kingery* 0-3-0
Laboratory work to accompany 3.70 with commercial processes carried out on a small scale.

3.71, 3.72 *Ceramics Seminar* (A)
3.70 *Economos* 1-0-2
3.71 *Economos* 1-0-2
Selected topics in ceramics, varying from year to year, presented by the students and staff, each topic being of group interest and followed by group discussion.

3.73 *Fundamentals of Ceramic Processes I* (A)
3.70, 5.62 *F. H. Norton* 3-0-4
Principles concerned with raw materials, forming, drying, melting, firing and decorating in the ceramic industry.

3.74 *Fundamentals of Ceramic Processes II* (A)
3.73 *F. H. Norton* 3-0-4
Application of ceramic principles to the manufacture and testing in the fields of glass, whitewares, refractories, abrasives, heavy clay products, and enamels.

3.75 *Special Problems in Ceramics* (A)
3.70 *F. H. Norton* *
Advanced work in this field. Time devoted to lectures, conferences, assigned readings, or laboratory work.

3.77 *Advanced Ceramics Laboratory* (A)
3.70 *Kingery* 1-5-4
Fundamentals underlying ceramic processes demonstrated by illustrative experiments.

3.79 *Advanced Ceramic Products* (A)
3.70 *Kingery* 3–0–6
Treatment of various subjects concerned with the thermal, mechanical, optical, electrical, and magnetic properties of ceramic products, including recent publications on these topics. Effects of composition and microstructure on properties.

3.81 *Mineral Engineering I*
8.04 *de Bruyn* 3–3–6
Introduction to the preparation for further metallurgical treatment or direct use of mineral substances from the unit-process and unit-operation points of view. A subject designed to give an idea of operations and processes employed to utilize solid fuels, ores, and minerals and to extract metals from low grade ores. Limited number of laboratory exercises to illustrate the more important principles and to teach the student useful experimental techniques of general applicability to fields of mineral engineering and metallurgy.

3.82 *Mineral Engineering II*
3.81 *de Bruyn* 3–3–6
Unit operations used in the separation of valuable minerals from the worthless material in the ore as mined. Physical principles involved and their importance to sound engineering design. Principles relating to particle size distribution, surface area determinations, fracture of brittle material, energy distribution during comminution, and the hydrodynamical behavior of solid-liquid systems. Unit operations covering comminution, screening, classification, thickening, filtration, gravity concentration, and magnetic separation.

3.83 *Mineral Engineering III*
3.82 *de Bruyn, Gaudin* 3–0–6
Physical-chemical and surface chemical principles which characterize the flotation and leaching processes. Application of these chemical principles to typical flotation and leaching systems. Physical variables affecting operation and design of continuous flotation and leaching circuits. Laboratory exercises on the important variables in typical mineral engineering problems illustrating small-scale testing of industrial operations. Laboratory work on material covered in this subject and 3.82T.

3.85 *Quantitative Mineragraphy*
3.82 *de Bruyn, J. H. Brown* 1–4–2
Illustration of the usefulness of microscopical investigations of opaque and non-opaque minerals and other important laboratory techniques in the quantitative appraisal of a specific mineral engineering operation. Preparation for microscopic study of products from an actual operation by use of laboratory techniques such as sizing, heavy liquid separation, isodynamic separation, and briquetting. Microscopic identification of the minerals and evaluation of the degree of liberation of the ore mineral. Laboratory work supplemented by lectures on the elements of optical mineralogy.

3.86 *Quantitative Mineragraphy* (A)
3.83 *J. H. Brown* *
Advanced subject in mineragraphy in which the quantitative approach is stressed.

3.87 *Ore Testing*
3.83 *de Bruyn, J. H. Brown* 0–10–0
Practice in choosing concentration methods for specific ore samples, in developing laboratory testing technique, and in preparing reports.

3.89 *Mineral Dressing Design* (A)
3.83 *Gaudin* *
A specific problem in mill design, covering the development of the quantitative flowsheet and the drawing up of specifications for and the general arrangement of the equipment. Taggart, *Handbook of Mineral Dressing.*

3.90 *Advanced Mineral Engineering* (A)
3.83 *Gaudin, de Bruyn* 3–0–6
Informal discussion of topics selected according to the needs of the students. Examples of suitable topics: application of fluid mechanics to gravity concentration, of physical chemistry to flotation, of colloid chemistry to flocculation and thickening, of elasticity and plasticity to comminution.

3.901 *Advanced Mineral Dressing Laboratory* (A)
3.83 *Gaudin* *
Study of an ore, a process, or a machine in the field of mineral dressing.

(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.
Architecture and Planning

4.00 *Structure of the City*
—— *Hudnut* 3–0–3
Lectures, field trips, and readings to familiarize students with their physical environment; to suggest some of the means for its improvement; and to sharpen observation and the sense of design. Greater Boston as an example of urban structure: its historical development, current physical problems, and future possibilities of its industry, commerce, living areas, public institutions, and related services.

4.02 *Form and Design*
—— *Filipowski* 0–9–11
Study of visual and structural form in the areas of design where art, science, and technology are interdependent. Studio and shop experiments on the proportion of spaces, scale, shape, volume, structure, texture, line, plane, or color. Emphasis on imagination, materials, and techniques directed to enlarge the individual's capacity to create an aesthetic form.

4.031 *Visual Design Problems*
H22 *Preusser* 2–6–0
Introduction to creative art. Development of imagination and observation. Analysis of visual elements and their organization. Drawing and painting in the studio, supplemented by lectures.

4.032 *Visual Design Projects*
21.04 *Preusser* 2–6–0
Creative work in painting. Application of visual art principles. Projects encouraging individual expression and inventive use of media. Lectures relating studio work to the role of art in bringing aesthetic order to industrial society.

4.04 *Light and Color*
4.02 *Kepes* 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.

4.06 *Advanced Visual Design* (A)
4.04 *Kepes* *
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 presentation of environmental situations and ideas by graphic means.

A note about the subjects in Architectural Design
The sequence of undergraduate subjects in Architectural Design provides cumulative experience with a large number of design problems, ranging over the whole field of architectural practice. In general, each problem is presented as a design situation in a complete context; it requires an evaluation of all pertinent factors of site, climate, purpose and social setting, and provides scope for the application of the student's growing knowledge of materials and building techniques, his skill in arranging space, his sense of relative values, and his artistic sensitivity. This learning by doing is reinforced by class discussions, individual and group criticism, and exhibition and evaluation of completed work. Through a combination of collaborative and individual tasks, the student learns the value of cooperative effort as well as the responsibility for independent creative work. While at all times the need for a broad view of all design considerations is stressed, the several successive terms focus in different ways on major areas of emphasis.

4.11 *Architectural Design*
—— *Staff* 0–9–11
Use of small-scale problems of familiar subject matter to establish the basic concepts of architectural order through harmonious relationships between use and form, building and land, structure and space, materials and appearance. Emphasis on acquisition of skill in the conventional methods of representing architectural form with orthographic, perspective, and freehand drawing and by models.

4.131, 4.132 *Architectural Design*
4.11 *Staff* 0–9–11
4.131 *Staff* 0–9–11
A series of projects for simple buildings, to develop, as rapidly as possible, awareness of the principal issues facing the contemporary architectural designer and the range of possibilities available to him for effective satisfaction of the common environmental needs of our culture. Work on separate building units with definitely stated use patterns with ample opportunity for experimental study of appropriate structural systems and search for the uses of building materials most expressive of their physical properties.

4.141, 4.142 *Architectural Design*
4.132, 4.32 *Staff* 0–12–8
4.141 *Staff* 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.

4.151 *Architectural Design*
4.142 *Staff* 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.

4.161, 4.162 *Architectural Design* (A)
4.151 *Staff* 0–15–15
4.161 *Staff* *
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.

4.17 *Architectural Design, Special Problems*
—— *Staff* *
Supplementary work in architectural design on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.

4.18 *Collaborative Design*
4.142 *Staff* 0–9–11
Project work on design problems of such nature as to benefit by collaboration between architects and city planners or between these groups and other disciplines.

4.233 *Representation*
—— *Lynch* 0–5–1
Use of graphic techniques to record or control the environment and to express ideas: freehand drawing, elementary drafting, three-dimensional models, surveying and mapping, diagrams, graphic presentation. The common principles underlying these techniques and their use as tools in analysis. For entering planning students without background in design fields.

4.241T *Community Planning Design*
4.233, 4.51T Lynch 0–12–6
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.

4.261 *City and Regional Planning* (A)
4.241T *Greeley, Kelly* 0–12–12
Practical application of city and regional planning theory to towns, cities, and regions, including problems of replanning, redevelopment, and urban renewal in existing communities. Individual problems, supplemented by group projects worked out in collaboration. Work in field, library, and studio leading to written, oral, and graphic presentations.

4.262 *City and Regional Planning* (A)
4.261 *Kelly, F. J. Adams* 0–12–12
Advanced problems in city and regional planning, including pioneering studies and studies in specialized areas.

4.31 *Structural Analysis*
2.002 or 2.04; 4.11 *Gelotte* 2–6–0
Principles of statics and strength of materials applied to the analysis of elementary architectural structures and details of assembly. Consideration of loads in the qualitative analysis of continuous beams and frames. Design and analysis of a simple truss given concurrently with Architectural Design.

4.32 *Structural Analysis*
4.131, 4.31 *Gelotte* 2–6–0
Design and analysis of elementary reinforced concrete floor systems, beams, columns, and footings, including a qualitative analysis of continuity in building frames. Building types in steel and reinforced concrete and design and analysis of their principal elements. Application to a problem given concurrently in Architectural Design.

4.33, 4.34 *Structures Seminar*
4.32 *Weidlinger* 2–0–4
4.33 *Weidlinger* 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.

4.41 *Architectural Acoustics*
8.02 *Newman* 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.

4.42 *Special Problems in Architectural Acoustics* (A)
4.41 *Newman* *
Broad study of functional acoustic design in architecture (based on project work in actual buildings where possible), sound distribution and diffusion in rooms, and sound transmission through building structures. Conducted in the Acoustics Laboratory.

4.43 *Industrialized House* (A)
4.142 *C. Koch* 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, and preparation of papers and sketches.

4.51T *Characteristics of Basic Land Uses*
—— *Lynch* 3–0–3
Physical nature and layout of such use areas as residence, commerce, industry, institutions, etc. Fundamentals of site planning for these uses: land use and circulation planning, building grouping, site engineering, landscape. Brief exercises in the analysis of existing sites and the possibilities of new types.

4.53 *City Planning Principles*
—— *Greeley, F. J. Adams* 2–0–4
Historical background of the modern city planning movement. Evolution of the modern city and relation of architecture and engineering to problems of city development and civic design. Fundamental principles of city and regional planning.

4.54 *City Planning Techniques*
4.53 *J. T. Howard* 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. Seminar discussion, collateral reading, written reports.

4.55 *City Planning Techniques* (A)
4.54 *J. T. Howard* 3–0–6
Methods and practices of plan effectuation: subdivision regulations, zoning techniques, urban renewal, capital improvement programming, tax policy. Seminar discussion, oral and written reports.

4.56 *Regional Planning Seminar* (A)
4.55 *Greeley* 2–0–4
Critical review of regional, state, and national planning experience in the United States; analysis of principal regional planning problems and investigation into significant current trends in regional planning.

4.57 *Urban Landscape* (A)
4.53 *Lynch* 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. Field observation, group projects, and seminar discussion. (*Not offered 1958–59.*)

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4.58 *Theory of City Form* (A)
4.53 *Lynch, Rodwin* 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 with limited registration.

4.59 *Planning Theory and Research* (A)
4.53 *Rodwin, Lynch* 2–0–6
Current theories and research in planning, planning organization and action, and the relationship of physical planning to the general theory and process of planning. Required papers and other exercises. Registration limited.

4.61 *Architecture of Cities*
21.04 *Hudnut* 3–0–5
The cities of the western world considered as functional and aesthetic patterns.

4.63 *Technics and Civilization* (A)
—— *Mumford* 2–0–4
A wide-ranging survey, on a loose historic background, of the interrelation of technical achievements and the other fields of human development; from religion and politics to art and communication. Open to a limited number of qualified graduate students.

4.65 *Introduction to Art and Architecture*
21.04 *Bush-Brown* 3–0–5
Italian Renaissance period, with comparative study of the Ancient, Medieval and Baroque periods. Formal, social, and philosophical studies of art and architecture. Lectures, group conferences, museum visits.

4.66 *Modern Art and Architecture*
21.04 *Bush-Brown* 3–0–5
Art and architecture as expressions of the period since 1750. Emphasis on problems in the physical environment of industrial society. Lectures, group conferences, museum visits, site trips.

4.67 *Theories of Architecture* (A)
4.65 or 4.66 *Bush-Brown* *
Chief theories of architectural design since the Renaissance. Seminar with trips to sites.

4.68 *Architectural Criticism* (A)
4.65 or 4.66 *Bush-Brown* *
Seminar concerned with questions of quality, expression, and utility in contemporary architecture.

4.70 *Urban Sociology*
—— *Greeley* 2–0–4
Social characteristics of urban and rural communities; problems arising in cities in connection with facilities for housing, industry, government, education, recreation, and transportation.

4.71 *Planning Legislation* (A)
4.54 or 14.941 *Kelly* 2–0–4
Broad review of public and private legal controls over land development; development of modern planning agencies and their tools: the master plan, official map, capital budget, subdivision control, urban redevelopment and renewal, zoning, and eminent domain; legal problems involved in elastic administration of legal controls through planning boards and boards of appeal; study of leading cases indicating problems faced by the courts in balancing private property interests against the general welfare of the community; comparison with planning controls employed in other countries.

4.77 *Housing Problems* (A)
4.53 or 14.01 *Rodwin* 2–0–5
The meaning and scope of housing problems. The market mechanism for producing housing; evaluation of unsolved economic, social, technical, design, administrative, and legislative problems. The changing and broadening perspective of housing policy in the United States and other countries. Extensive readings and paper. (*Not offered 1958–59.*)

4.78 *Housing Seminar* (A)
4.77 *Abrams* 3–0–6
Open to a limited number of students who have taken 4.77 or have the equivalent experience or background. Examination of selected housing problems and research topics with guest speakers for many of the sessions. Extensive readings and written reports. (*Offered in conjunction with the Harvard Graduate School of Design.*)

4.81 *Land Economics*
14.01 *Abrams* 2–0–6
Economics of the urban land market, and its institutional framework; resulting land use problems and issues of policy. Role of the market mechanism and other forces in patterning the structure and growth of land uses in metropolitan areas.

4.82 *Land Economics Seminar* (A)
4.81 *Rodwin* 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.

4.84 *Land-Use Problems in Developing Areas* (A)
4.81 *Rodwin* 2–0–6
The problems of urbanization in developing countries: patterns of urban growth, problems of resource allocation, efficient distribution of activities. Legal and other techniques of general applicability for solving or forestalling these problems. Open to students from a number of fields, such as law, economics, and city and regional planning. Registration limited to 15. Discussion of papers by three to five experts on aspects of these problems. (*Not offered 1958–59.*)

4.85 *Real Estate Economics*
14.01 *Abrams* 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.

4.95 *Thesis Research* (A)
4.261 *F. J. Adams* 0–6–0
Selection of thesis subject, definition of method of approach, and preparation of preliminary thesis outline. Independent study, supplemented by frequent individual conferences with staff members.

4.96 *City Planning Research* (A)
—— *Kelly* 0–6–0
Selected topics in city and regional planning. Supervised study, with conferences, readings, and reports. No lectures.

4.97 *Office Practice*
4.54 *F. J. Adams* 0–30–0
Work in the office of a planning commission. Problems in design or research having a definite relation to the activities of the planning commission concerned. Supervision at regular intervals by an instructor.

5.
Chemistry

GENERAL CHEMISTRY
Undergraduate Subjects

5.01 *General Chemistry*
—— *Stephenson* 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.

5.02 *General Chemistry*
5.01 *J. S. Waugh* 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 rate and equilibrium to chemical reactions; structural chemistry of crystals and of molecules; acid-base systems; introduction to the chemistry of carbon; nuclear reactions. Laboratory work with emphasis on the important chemical facts of the elements. Use of facts and principles to develop a scheme for the qualitative separation of the elements. Analysis of unknown mixtures.

INORGANIC CHEMISTRY
Undergraduate Subjects

5.03 *Principles of Inorganic Chemistry*
5.02, 5.42 *Cotton* 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.

5.031 *Inorganic Chemistry Laboratory*
5.03 *Gamble, Irvine* 1–4–1
Selected experiments in inorganic chemistry to illustrate basic procedures in synthesis, reaction, mechanisms, complex formation, and tracer separation. Introduction to inorganic research. (*Not offered 1958–59.*)

5.04 *Principles of Inorganic Chemistry II*
5.02, 5.62 *Cotton* 2–0–4
Development of a number of topics beyond the level of 5.03 including radio-chemistry, complex ion chemistry, compounds of the nonmetals, organometallic compounds, solid-state problems. Emphasis on structural, kinetic, and quantum mechanical principles.

INORGANIC CHEMISTRY
Graduate Subjects

5.065 *Advanced Inorganic Chemistry* (A)
5.04 *Seyferth* 2–0–4
Extended treatment of special topics of current interest in modern inorganic chemistry, e.g. organometallic compounds, hydrides, fluorine compounds, clathrate compounds, etc., in terms of modern electronic and structural theory. (*Alternate years.*)

5.067 *Topics in Theoretical Inorganic Chemistry* (A)
5.04 *Cotton* 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 1958–59.*)

5.071T, 5.072 *Special Topics in Inorganic Chemistry*
5.04 *Coryell, Seyferth* 1–0–2
5.071T *Coryell, Seyferth* 1–0–2
Presentation in sets of one to three lectures of special topics in inorganic chemistry, with emphasis on recent developments in the field of inorganic and nuclear chemistry and on experimental techniques useful in inorganic chemistry.

5.09 *Radiochemistry* (A)
5.03, 5.62 *Coryell, Irvine* 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.

5.091 *Radiochemistry Laboratory* (A)
5.09 *Coryell, Irvine* 0–3–2
Laboratory study of special topics including radiochemical analysis, the fission process, and the reactions following nucleogenesis.

ANALYTICAL CHEMISTRY
Undergraduate Subjects

5.14 *Analytical Chemistry I*
5.03, 5.41 *S. G. Simpson* 3–0–3
Principles of quantitative separations and determinations. Application to the determination of inorganic constituents and organic functional groups. Practice in stoichiometrical calculations.

5.141 *Analytical Chemistry Laboratory I*
5.14 *S. G. Simpson* 1–8–0
Application of volumetric and gravimetric methods to the determination of typical inorganic constituents and organic functional groups. An original study of a special analytical problem.

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5.142 ***Analytical Chemistry Laboratory I***
5.14 *S. G. Simpson* 1–4–0
Abridgement of 5.141.

5.15 ***Instrumental Analysis***
5.42, 5.62 *Hume, Rogers* 2–0–2
Theory and application of modern optical and electrical instruments in the solution of chemical problems. Polarography, potentiometry, conductometry, radio frequency conductometry, thermal conductivity of gases; ultraviolet, visible and infrared spectrophotometry; colorimetry, turbidimetry, nephelometry, fluorimetry, flame photometry, and automatic instruments.

5.151 ***Instrumental Analysis Laboratory***
5.15 *Ross* 0–4–2
Laboratory coordinated with the topics in 5.15.

5.16 ***Analytical Chemistry II***
5.14, 5.62 *Hume, Rogers* 3–0–3
Instrumental analysis. Theory and application of modern optical and electrical instruments in the solution of chemical problems. Polarography, potentiometry, conductivity of gases; ultra-violet, visible and infra-red spectrophotometry; colorimetry, turbidimetry, nephelometry, fluorimetry, flame photometry, and automatic instruments. (*Not offered 1958–59.*)

5.161 ***Analytical Chemistry Laboratory II***
5.16 *Ross* 1–4–2
Laboratory coordinated with the topics in 5.16. (*Not offered 1958–59.*)

ANALYTICAL CHEMISTRY
Graduate Subjects

5.192 ***Advanced Analytical Chemistry I*** **(A)**
5.14 *Rogers* 2–0–4
Separation methods. Theory and application of separations based upon partition between two phases or upon differences in rates including volatilization and condensation, solvent extraction, precipitation, chromatography, ion exchange, and diffusion.

5.193 ***Advanced Analytical Chemistry II*** **(A)**
5.14 *S. G. Simpson* 2–0–4
Analytical Chemistry of the less familiar elements. Problems encountered in the analysis of technical products. Correlation of analytical methods.

5.194 ***Advanced Analytical Chemistry III*** **(A)**
5.14 *Hume* 2–0–4
Application of statistical methods to analytical problems with emphasis upon significance testing, control chart methods, analysis of variance, fitting of equations to experimental data and the design of experiments. (*Not offered 1958–59.*)

5.196 ***Advanced Analytical Chemistry IV*** **(A)**
5.14 *Biemann* 2–0–4
Quantitative organic analysis by chemical and physical methods with emphasis on the determination of functional groups and the application of ultraviolet, visible and infrared spectroscopy, mass spectrometry, etc. (*Not offered 1958–59.*)

ORGANIC CHEMISTRY
Undergraduate Subjects

5.41 ***Organic Chemistry I***
5.02, 8.02 *Sheehan* 4–0–4
Introduction to the chemistry of carbon compounds. Survey of the principal classes of aliphatic and aromatic compounds and their reactions.

5.412 ***Organic Preparations I***
5.02, *5.41* *Nelson* 1–4–0
Application of the techniques of synthetic organic chemistry to the preparation and purification of simple organic compounds.

5.416 ***Organic Preparations I***
5.41 *Ashdown, Swain* 1–5–0
Preparation and purification of a series of simple organic compounds by typical reactions illustrating the synthetic techniques of organic chemistry.

5.42 ***Organic Chemistry II***
5.41 *F. D. Greene* 4–0–4
Continuation of 5.41. Study of organic reactions emphasizing the relation between structure and reactivity.

5.422 ***Organic Preparations II***
5.412, *5.42* *Nelson* 1–4–2
Introduction to the literature of organic chemistry. Advanced preparations involving special techniques.

5.426 ***Qualitative Organic Analysis***
5.416 *Nelson, F. D. Greene* 1–5–0
Identification and separation of mixtures of organic compounds by chemical and physical means.

5.428 ***Qualitative Organic Analysis***
5.42, 5.422 —— 2–7–1
Identification of organic compounds, including current research techniques used for the determination of the structure of organic molecules.

5.43 ***Organic Chemistry III***
5.42 *F. D. Greene* 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.

5.44 ***Organic Chemistry IV***
5.43 *Sheehan* 2–0–4
Discussion and evaluation of general synthetic methods of organic chemistry with emphasis on the isolation, characterization and synthesis of products of biological significance (antibiotics, peptides, steroids, and alkaloids).

ORGANIC CHEMISTRY
Graduate Subjects

5.51 ***Advanced Organic Chemistry: Synthesis*** **(A)**
5.44 *House* 2–0–4
Organic reactions and the methods by which they are applied to synthetic problems in organic chemistry.

5.54 ***Advanced Physical Organic Chemistry*** **(A)**
5.43 *Swain* 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.

5.55 ***Organic Chemistry: Natural Products*** **(A)**
5.44 *Buchi* 2–0–4
The chemistry and physiological action of natural products. Methods of isolation; determination of structures and synthesis.

PHYSICAL CHEMISTRY
Undergraduate Subjects

5.60 *Physical Chemistry*
5.02, 8.02, *M21* *Beattie* 3–0–6
Physical states of matter; first and second laws of thermodynamics; properties of gases and elementary kinetic theory; properties of solutions; electrolytic conduction.

5.61 *Physical Chemistry I*
5.02, 8.03, M21 *Stockmayer* 4–0–4
Properties of gases and elementary kinetic theory; first and second laws of thermodynamics; properties of solutions; phase equilibrium; chemical equilibrium and the third law of thermodynamics.

5.611 *Physical Chemistry Laboratory I*
5.61 *Shoemaker, Garland* 0–4–2
Laboratory coordinated with the topics of 5.61.

5.613T *Physical Chemistry Laboratory I*
5.61 *Shoemaker, Garland* 0–6–3
Laboratory coordinated with the topics of 5.61.

5.62 *Physical Chemistry II*
5.61 *Amdur* 4–0–4
Continuation of 5.61. Electrolytic conduction, ionic equilibria, and voltaic cells; introduction to molecular structure; elementary statistical thermodynamics; rates of chemical reactions.

5.621 *Physical Chemistry Laboratory II*
5.611, *5.62* *Shoemaker, Garland* 0–4–2
Laboratory coordinated with the topics of 5.62.

5.623T *Physical Chemistry Laboratory II*
5.613T, *5.62* *Shoemaker, Garland* 0–6–3
Laboratory coordinated with the topics of 5.62.

5.67 *Introduction to Atomic and Molecular Structure*
5.62 *Lord* 2–0–4
Use of spectroscopic methods to determine the structure of atoms and molecules; elementary theory of atomic spectra; atomic structure and the Periodic Table; theory of molecular spectra. Technique of chemical spectroscopy; analysis of chemical elements by emission spectra; use of infrared and Raman spectra in chemical analysis and in determination of the structure of organic compounds; ultraviolet absorption of molecules and their electronic structure.

5.68 *Kinetics of Chemical Reactions*
5.62 *Amdur* 2–0–4
The kinetic theory of gases with emphasis on the calculation of collision frequencies, and consideration of theoretical and experimental aspects of the kinetics of homogeneous and heterogeneous reactions in gaseous and liquid systems.

PHYSICAL CHEMISTRY
Graduate Subjects

5.70 *Introduction to Statistical Thermodynamics* (A)
5.62 *J. S. Waugh* 2–0–4
Elementary statistical mechanics, with applications to simple physical and chemical systems.

5.71 *Chemical Thermodynamics I* (A)
5.62 *Beattie* 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.

5.72 *Chemical Thermodynamics II* (A)
5.71, *M351* *Beattie* 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.

5.73T *Theory of Solutions* (A)
5.70, 5.71, M351 *Stockmayer* 3–0–6
Topics in thermodynamic and molecular theory of equilibrium and transport properties of solutions, including high polymers and electrolytes.

5.74 *Elementary Theory of Valence* (A)
5.75, *M352* *J. S. Waugh* 3–0–6
Many-electron atoms. Symmetry properties of wave functions. Rudiments of the valence bond and molecular orbital descriptions of chemical binding. Hybridization. Crystal field theory. Attempts at accurate theories. Applications to magnetism, spectra, and other properties of molecules.

5.75 *Introduction to Quantum Theory* (A)
5.62, 8.04 *L. Harris* 2–0–4
Introduction to the principles of wave mechanics with applications to simple atomic and molecular systems.

5.76 *Molecular Spectra and Molecular Structure* (A)
5.75, M351 *Lord* 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.

5.77 *Crystal Structure and the Chemical Bond* (A)
5.75 *Shoemaker* 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.

5.78 *Statistical Mechanics* (A)
5.70, 5.71, 5.75, M351 *Garland* 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.

5.79 *Kinetic Theory* (A)
5.71, M351 *Amdur* 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.

RESEARCH

5.90 *Special Problems in Chemistry* (A)
—— *Sheehan* *
Directed research and study of special chemical problems. *For graduate students only.*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

5.912 ***Seminar in Inorganic Chemistry*** **(A)**
—— —— 1–0–2
Discussion of recent publications of interest to the inorganic chemist. Scope of these topics more limited than those given in 5.071.

5.913, 5.914 ***Seminar in Organic Chemistry*** **(A)**
—— *Cope* 1–0–2
5.913 *Cope* 1–0–2
Discussion of current journal publications in organic chemistry by graduate students and staff members.

5.915, 5.916 ***Seminar in Analytical Chemistry*** **(A)**
—— *Biemann* 1–0–2
—— *Ross* 1–0–2
Discussion of topics of current interest in analytical chemistry by graduate students and staff members.

5.931, 5.932 ***Seminar in Physical Chemistry*** **(A)**
—— *Shoemaker* 1–0–2
Discussion of topics of current interest in physical chemistry by staff members and students.

5.941, 5.942 ***Research Conference in Inorganic Chemistry*** **(A)**
5.066 *Cotton, Irvine* 1–0–2
5.941 *Cotton, Irvine* 1–0–2
Discussion of current research in the field of inorganic and nuclear chemistry by graduate students and staff.

5.951, 5.952 ***Research Conference in Analytical Chemistry*** **(A)**
—— *Ross* 1–0–2
—— *Biemann* 1–0–2
Discussion of research problems under investigation by graduate students and staff.

Research **(A)**
—— *Staff* *
Research for any of the advanced degrees in inorganic, analytical, organic or physical chemistry.

6.
Electrical Engineering

6.00, 6.01. ***Introductory Circuit Theory***
8.031, M21 Guillemin, Searle, Thornton 4–3–5
6.00 *Guillemin, Searle, Thornton* 4–3–5
Two-term sequence for students majoring in electrical engineering. Network topology and topological aspects of duality, Kirchhoff's laws, volt-ampere relations for the elements, and sources of excitation. Equilibrium equations and methods for their solution. Step function and impulse response of simple circuits, and their complex natural frequencies. Sinusoidal steady-state behavior. Impedance as a function of applied and natural frequencies and its geometrical interpretation in the complex frequency plane. Resonance phenomena, amplitude and frequency scaling, vector diagrams, reciprocal and complementary impedances. Energy storage and dissipation; active and reactive power. Mutual inductive coupling. Polyphase circuits. Usefulness of the duality principle given prominence throughout the discussions. Closely correlated laboratory work accompanying lectures and recitations.

6.001 ***Introductory Circuit Theory***
8.031, M21 Guillemin 4–0–5
Classroom part of 6.00.

6.002 ***Introductory Circuit Theory Laboratory***
6.001 *Searle, Thornton* 0–3–0
Experimental aspects of 6.00 taught in the laboratory.

6.011 ***Introductory Circuit Theory***
6.001 *Guillemin* 4–0–5
Classroom part of 6.01.

6.012 ***Introductory Circuit Theory Laboratory***
6.002, 6.011 *Searle, Thornton* 0–3–0
Experimental aspects of 6.01 taught in the laboratory.

6.02 ***Electronic Devices and Circuits***
6.01 *Zimmermann, Searle, Thornton* 4–3–5
Basic subject for students majoring in electrical engineering. Circuit models for electronic devices such as transistors, vacuum tubes, gas tubes, etc. Analysis of basic electronic circuits using nonlinear curves or piecewise-linear approximation for nonlinear operation and incremental models for linear operation. Associated laboratory

6.021 ***Electronic Devices and Circuits***
6.01 *Zimmermann* 4–0–4
Classroom part of 6.02.

6.022 ***Electronic Devices and Circuits Laboratory***
6.021 *Searle, Thornton* 0–3–1
Experimental aspects of 6.02 taught in the laboratory.

6.03 *Fields, Energy, and Forces*
6.01; 8.041; M22 or *M351* *Haus* 4–3–5
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; forces between bodies in relative motion; the physical bases of electromechanical energy conversion. Coordinated laboratory and classroom work.

6.05 *Electronic Circuits and Signals*
6.02 *Mason, Searle, Thornton* 4–3–5
Basic subject for students majoring in electrical engineering. Fourier representation of signals. Modulation, amplification and generation of electrical signals. Limitations on signal transmission imposed by inherent energy storage, noise, and saturation in electronic systems. Associated laboratory.

6.051 *Electronic Circuits and Signals*
6.02 *Mason* 4–0–4
Classroom part of 6.05.

6.052 *Electronic Circuits and Signals Laboratory*
6.051 *Searle, Thornton* 0–3–1
Experimental aspects of 6.05 taught in the laboratory.

6.06T *Electromechanical Energy Conversion*
6.03 *Woodson* 4–3–5
Required subject for electrical engineering students. Rigid body dynamics in electromagnetic fields; transition between fields and lumped parameters for selected models of electromechanical devices; analytical mechanics and state function concepts in electromechanics; mathematical techniques for analyzing the dynamics of electromechanical energy converters as individual devices and when interconnected into systems.

6.063 *Electrical Energy Conversion*
6.03 *White* 3–4–5
Required subject for VI-B students. Forces in polarizable matter subjected to a variety of force fields; energy functions and state functions of thermodynamics and analytical mechanics; selected examples of energy converters drawn from the above and treated in terms of equivalent lumped parameters; dynamics of interconnected energy conversion systems.

6.07, 6.073 *Energy Transmission and Radiation*
6.03, M351 *Kyhl* 3–3–6
6.03, M351 *Adler* 3–3–6
For undergraduates 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. Relations between lumped-circuit and dynamic field concepts; steady-state and transient wave motion on transmission lines; related interpretations of resonance in the time and frequency domains, and in terms of field distributions in space and energy considerations; uniform plane waves; radiation and reception by dipole antennas.

6.071 *Energy Transmission and Radiation*
6.03, M351 *Kyhl* 3–0–6
Classroom part of 6.07.

6.072 *Energy Transmission and Radiation Laboratory*
6.071 *Kyhl* 0–3–0
Experimental aspects of 6.07T taught in the laboratory.

6.073 *See 6.07.*

6.08 *Molecular Engineering*
6.03, 6.06T *Epstein* 4–3–5
Core curriculum subject. Interaction between fields and materials in relation to problems of energy storage, conversion and control. Treatment of material properties in terms of basic physical processes. Conduction in gases, liquids and solids; electric and magnetic polarization; frequency and temperature dependence of dielectric constant and loss; nonlinear dielectrics; dielectric breakdown; temperature and frequency behavior of magnetic properties; transient phenomena in ferroelectric and ferromagnetic materials. Applications to modern devices including transistors, dielectric and magnetic amplifiers.

6.083 *Molecular Science and Engineering*
6.03, 6.063, 8.052 *Epstein* 4–3–5
Required subject in Course VI-B. Treatment of the materials of electrical engineering in terms of underlying atomic and molecular phenomena. Behavior of individual atoms and molecules in electromagnetic fields; classical treatment and quantum effects; statistics of a system of particles in thermal equilibrium; conduction in metals, semiconductors and superconductors; electric and magnetic polarization; equation of state for electric and magnetic materials. Ferroelectricity and ferromagnetism; electromechanical and magnetomechanical effects; circuit representations for bulk material; influence of material properties on storage, conversion and control of energy.

6.10 *Elementary Electric Circuit Theory*
8.031, M21 *Huffman* 4–0–8
Survey subject for physics students which begins with Kirchoff's laws and leads to an understanding of the relationship among impulse response, natural frequencies and the impedance concept. Use of equivalent circuits and the importance of Thevenin's theorem, linearity and superposition, cut and tie-sets, duality, reciprocity, energy storage, orthogonality, response to complex exponential excitation, elementary signal analysis, and the superposition integral.

6.11, 6.12 *Seminar*
—— *Adler* 2–0–4
Special activity for students in Course VI-B. Study and evaluation of professional literature, oral presentation and active open discussion of topics drawn from and extending beyond those treated in the regular curriculum. Flexible organization, comprising a few students and staff with common areas of interest, under guidance of a staff member in an appropriate field.

6.16 *Electricity*
8.03 *Eager* 3–0–6
Brief survey subject for students not majoring in electrical engineering. Fundamental principles of electric and magnetic circuits with application to theory of operation of d-c and a-c motors, transformers, and associated devices. Design of and computation of loads on wiring systems; safe wiring practices, National Electric Code.

6.17 *Illumination*
8.03 *Moon* 2–0–4
For architects and engineers interested in the latest developments in the principles of architectural lighting. Daylight, lamps, calculation of light distributions, interflections, vision, color

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6.18 *Fundamentals of Electrical Engineering*
8.03, M22 *Frazier, Kingsley* 3–1–6
Introductory subject in electrical engineering techniques for students not majoring in electrical engineering. Principles of electric circuits with applications to theory and performance of components and systems for power, control, and instrumentation. Laboratory work to illuminate practical and theoretical questions considered in classroom.

6.19 *Fundamentals of Electronics*
6.18 *Eager* 3–1–6
For students not majoring in electrical engineering. Graphical and incremental methods for analysis of thermionic tubes and semi-conductor devices. Study of rectifiers, basic triode and transistor amplifiers, basic feedback circuits, and elementary oscillators. Laboratory exercises complementing classroom presentation.

6.20 *Electronic Control and Measurement*
6.05 *Gray* 3–0–6
Analysis and design principles of electronic systems for control and measurement as applied to phototube devices, pH measurement, vacuum-tube voltmeters, high-speed recording instruments, flash-photography apparatus, strain gages, vibration meters, etc. Input and output conversion transducers; grid current and its effect in high-impedance circuits; direct- and resistance-capacitance-coupled amplifiers; differentiating and integrating circuits; amplitude, frequency, phase and pulse modulation for measurement and control; frequency-selective amplifiers; phase- and frequency-sensitive detectors; emphasis on nonlinear properties of electron tubes and transistors either as limitations or as useful characteristics.

6.211 *Analysis of Nonlinear Systems*
6.06, 6.07 *Boehne* 3–0–6
Graphical analysis of engineering problems involving arc phenomena, ferro-resonance, nonlinear parameters and associated with the protection of electrical systems. Treatment of traveling wave problems by graphical slopeline techniques. Study of arc phenomena, glow discharge and post arc conduction as related to modern arc interruption techniques. Overvoltage phenomena peculiar to the switching of large capacitive KVA. Special studies using computer techniques for solution of nonlinear problems. Thesis opportunities.

6.213 *Feedback Control Principles*
6.06T or 6.18; M351 *Gould* 3–2–5
An elective, terminal subject for seniors. Theoretical background for quantitative analysis and synthesis of feedback control systems. Laplace transform techniques for the formulation of transfer functions and manipulation of block diagrams of physical systems. Pole-zero configurations in the complex plane and transient response. Frequency response with emphasis on exact and approximate graphical techniques using logarithmic representation of transfer functions. Stability. Compensation to improve system behavior. Introduction to the study of discontinuous systems. Nonlinear systems studied through the use of describing function and phase-plane techniques. Case studies to illustrate engineering applications. Regular laboratory exercises.

6.216 *Dynamics of Electric Machines* (A, except for Course VI)
6.06T *Kingsley* 3–0–6
Treatment of rotating electric machines with emphasis on their dynamic performance in feedback systems. Basic theory in terms of interacting magnetic fields. Matrix formulation of the equations of motion and transformations of the equations. Equivalent-circuit models and block diagrams for synchronous, induction, and d-c machines, including metadynes. Case studies to illustrate engineering applications. Part of the problem work will be solution of a dynamic problem on an analog computer.

6.227 *Engineering Electrodynamics*
6.03 *Moon* 3–0–6
For undergraduates in electrical engineering. Applications of Maxwell's equations, particularly in the time-varying case. Electromagnetic waves, skin effect, superconductivity, waveguides, antennas. Alternate approach to electrodynamics by methods of Ampere, Gauss, and Ritz.

6.231 *Circuit and Field Analogs and Models*
6.03, 6.06T *Frazier* 3–0–6
Study of electrical, mechanical, thermal and composite systems or devices through use of electric circuit and electric or magnetic field analogs and models. Exploitation of the principle of duality. General treatment of dimensional analysis with special attention to model theory. Instruction largely through use of problems relating to static or dynamic behavior of instruments, structures or machines, including study of flow, pressure, stress, temperature, and energy distribution.

6.232 *Electromechanical Control Components*
6.03, 6.06T, 6.08 *Frazier* 3–0–6
Problems of design and analysis of devices such as various types of servo motors, hysteresis motors, synchros, resolvers, differential transformers, tachometers, accelerometers, vibrometers, torque or force motors, trigger magnets, and relays. Illustrations based on actual apparatus.

6.241 *Engineering Problems*
6.06T C. E. Tucker, White, Adler 3–0–6
Elective subject given by notable practicing engineers to show the whole problem faced by the engineer including the influence of such matters as economic, legal, public relations, manufacturing, sales, and servicing considerations as well as technical engineering. Registration Officers to be consulted about the field and instructor.

6.25T *Introduction to Digital Computers*
6.05 or M352 *Arden, Arthurs* 3–0–6
Introduction to logical design and application of general purpose digital computers. Interpreting, compiling, and translating routines. Numerical solution of differential equations. Propagation of round-off and truncation error. Stability of extraneous solutions. Systems of simultaneous equations. Conditioning. Linear programming.

6.251 *Principles of Machine Computation*
—— *Verzuh* 3–1–5
Presentation of basic principles of machine computation by actual laboratory use of the following equipment: card punch, sorter, reproducer, and accounting machines. Survey and evaluation of small, intermediate-sized, and large-scale computers. Treatment and use of flow charts, block diagrams, and automatic coding techniques. Discussion and use of selected numerical analysis formulae and techniques for the solution of simultaneous linear equations and ordinary differential equations. Actual coding and programming of internally stored program equipment by student use of the Type 704 Computer.

6.252 *Digital Systems Engineering*
6.05 *Susskind* 3–0–6
Introduction to the electronic design and system engineering of digital information-processing machines. Brief treatment of coding of information, computer organization, and logical design. Utilization of tubes, magnetic cores, and transistors as bi-valued elements. Organization of these elements into subsystems such as arithmetic and control elements, memory units, and peripheral data links. Case studies of complete systems, with emphasis on industrial and control applications.

6.254 *Principles of Switching Circuits*
6.01 or 6.18; M22 *Caldwell* 3–1–6
Ideas and methods underlying design of switching circuits as formed from two-valued elements and applied in many types of control systems and digital computers. Analysis and synthesis techniques based on algebraic representations of input-output relations in combinational circuits, using both relay contacts and electronic components. Algebraic methods for simplifying circuits. Basic procedures for the synthesis of sequential circuits, including circuits with pulse inputs. Laboratory exercises on switching components and circuits.

6.281 *Principles of Wire Communications*
6.02 *C. E. Tucker* 3–0–6
Brief discussion of the principal telephone switching systems including the nation-wide toll-switching plan. Transmission characteristics of long lines with distributed parameters as a function of frequency; networks, loading, communications transformers, repeaters, balancing networks, insertion loss, carrier-current systems, distortion and its correction. Economic considerations effecting alternative plans are considered.

6.291 *Radar-System Engineering*
6.05, *6.07* *Reintjes* 3–0–6
Professional elective subject for undergraduates majoring in electrical engineering. Emphasis on engineering design of simple and complex electronic and electromechanical systems, with radar as a vehicle of study. Analysis and synthesis of master-pulse oscillators, cathode-ray-tube sweep generators, high-power pulse modulators, wide-band small signal amplifiers, antenna-control systems, r-f transmission and radiation systems. Factors influencing performance of the over-all system. Problems resulting from interconnection of subsystems.

6.30 *Communication and Control Circuit Theory*
6.01, *6.05* *Guillemin* 3–0–6
Undergraduate elective for students majoring in electrical engineering. Continuation of discussions begun in 6.00 and 6.01; with emphasis on problems arising in the communications and electronic control fields. Correlation of the classical differential equation approach to time and frequency domain interrelationships with Fourier and Laplace methods, and application of these concepts to typical problems in the communications and control art. Numerical evaluation methods including impulse-train techniques. Introduction to network synthesis including conventional filter theory.

6.311 *Principles of Communication*
6.05 *Elias* 3–0–6
Basic requirements for communication. Discrete probability and amount of information. Efficient coding of messages. Noise in discrete systems. Error-correcting codes. Reduction of continuous signals to discrete sequences: sampling, quantizing. Continuous probability. Quantization noise and physical noise. Interchange of bandwidth and signal-noise ratio in PCM. Other modulation systems. Bandwidth requirements and noise behavior of AM, FM. Capacity of a noisy channel.

6.312 *Communication System Engineering*
6.20 or 6.311 *Granlund* 3–0–6
Generation of radio frequencies, modulation, radiation, transmission and detection in communication systems. Interrelationship between the various components of a communication system in the light of the system application and the limitations imposed by the transmission medium and the available components. Investigation of a specific communication system problem to provide a common theme for the term's work.

6.322 *Electromagnetic Waves*
6.07 *Chu* 3–0–6
Application of electromagnetic theory to communication problems. Uniform plane waves, non-uniform plane waves, and their physical properties. Wave guides of closed and open structures, periodic structures, cavity resonators. Transmitting and receiving properties of antennas. Introduction to theory of propagation.

6.35 *Communications Acoustics*
6.01, M22 *Stevens* 3–1–5
Derivation of the acoustic wave equation and solutions for elementary cases. Radiating systems and radiation patterns. Network theory (analysis) for electromechano-acoustic systems. Moving coil and electrostatic loud-speakers and microphones. Instrumentation for acoustic measurements. Introduction to hearing, psycho-acoustics and speech communication. Selected problems and laboratory.

6.351 *Engineering Acoustics*
6.10, M22 *Stevens* 2–2–5
For naval engineering graduate students, XIII-A. Same as 6.35 except sections on loud-speakers and baffles replaced by material on sound in rooms, noise from ventilating systems, and sound transmission through structures. Selected problems and laboratory.

6.36 *Engineering Acoustics*
6.35 or 6.07 *Stevens* 3–1–5
Solution of acoustic wave equation for complex boundary conditions and spherical waves. Propagation of sound in acoustical materials, ducts, horns. Sound waves in rooms, sound transmission through structures. Non-linear effects in sound propagation, acoustic resonators. Psycho-acoustic criteria. Selected applications and problems; laboratory.

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6.38 *Pulse Circuit Analysis*
6.05 *Zimmermann* 3–0–6
Analysis of wave shaping and pulse generating circuits common to radar, television, pulse communication, electronic computation and cathode-ray instrumentation.

6.50 *Electrical Engineer Seminar* (A)
—— *Reintjes* 2–0–4
Oral presentation of student's objectives and work in the field of his specialty, and participation in group discussions of reports by others. Designed to develop competence in the orderly and creative application of electrical science and technology in engineering. For electrical engineer degree candidates.

6.521 *Electrical Energy Conversion Devices* (A)
6.06T *Kusko* 3–2–6
Translation of the principles of energy conversion into physical devices using a synthesis approach. Utilization and limitations of new and existing materials. Heat transfer and cooling of electrical devices. Model theory. Development of relationships between dimensions and material properties of conversion devices and their performance. Exploration of the realization of new energy-conversion devices from nonconventional methods of energy conversion.

6.522 *Dynamics of Rotating Machine Systems* (A)
6.06T or 6.063 *White* 3–2–6
Treatment of rotating electromagnetic energy converters by matrix, tensor, and model concepts; dynamics of direct-current and alternating-current machines in control systems and electric power systems; performance and design of electrical apparatus to meet specifications in feedback control systems and power systems, taking into account the general physical limitations of materials.

6.524 *Nonlinear Impedances as Control Elements* (A)
6.02; 6.06T or 6.063 *Woodson* 3–2–6
Treatment of amplifiers, modulators, and oscillators utilizing material nonlinearities; nonlinear materials—ferromagnetic, ferroelectric, and semiconductor rectifiers and transistors; devices — magnetic amplifiers, dielectric amplifiers, magnetic modulators, switching-transistor-saturable-reactor multivibrators, etc.; use of idealized components in piecewise-linear analyses; effect of physical components on operation; dynamic behavior as switching devices (difference equations) and as continuous devices (differential equations).

6.531 *Discrete Systems* (A)
6.254 or 6.537 or M352 *Arden, Arthurs* 3–0–6
Algebra of events. Finite state models and their descriptions. Equivalence, homomorphic and reduced models. Terminal experiments on finite state models. Infinite state systems and their description. Turing machines. Equivalence and homomorphism. Universal machines. Computability and the notion of an algorithm. Mathematical models of languages. Computability by probabalistic machines.

6.534 *Sequential Processes* (A)
6.531 or M76 *Arden, Arthurs* 3–0–6
Stochastic learning models. Dynamic programming. Relation to games in extensive form. Sequential decision theory. Approximation in policy space and computational methods. Inventory type control problems. Linear and quadratic programming. Applications to diode networks, optimal allocation, minimum cost and maximum profit programs.

6.537 *Switching Circuits* (A)
6.254 or M351 *Caldwell* 3–2–7
Basic principles governing interconnection of two-valued switching elements to form networks and systems for manipulation of binary information. Development and interpretation of switching algebra and its application in analysis and synthesis of combinational circuits. Procedures for minimization of switching functions and realization of functions by contact networks or by networks using electronic, semiconductor, or magnetic components. Analysis and synthesis of sequential circuits using all types of switching components. Pulsed sequential circuits. Hazards in the synthesis of sequential circuits. Laboratory experiments on physical characteristics of switching components and synthesized circuits.

6.538 *Electronic Computational Laboratory* (A)
M22 *Verzuh* 3–1–5
Basic principles of digital computation by actual student use of the following equipment: card punches, sorters, reproducers, and accounting machines. Actual programming and operation of internally stored program equipment by the solution of several problems on the Type 650 magnetic drum calculator, and the Type 704 electronic calculator. Classroom lectures and research studies on scientific computation encountered in the solution of simultaneous algebraic equations, inversion of matrices, solution of differential equations, etc. Treatment of business-data-handling problems encountered in the banking, brokerage, insurance, public utilities, and traffic control fields. Student use of the Type 650 and Type 704 calculators. (*Not offered 1958–59.*)

6.54 *Pulsed-Data Systems* (A)
6.56 or 6.581 or M39 *Widrow* 3–0–6
Development and application of linear analysis techniques to the design of discrete systems and to related problems. The processes of sampling continuous data and of smoothing sampled data. Feedback systems employing sampled-error data including stability studies of such systems. Study of continuous systems by numerical methods. Digital computer operations as data filtering, analysis and synthesis of linear digital computer programs in the frequency domain. Development of a circuit theory for sampled and mixed systems making use of flow graphs. Comparison between techniques of numerical analysis and control system design. Design of systems involving digital computers as components. Comparisons between analog and digital computers. Response of sampled-data systems to random inputs. Study of quantization and round-off noise in numerical solution and real-time control. Analysis of errors in computation. Study of random Markov processes by sampled-data analogs. Design of statistically optimum discrete systems and adaptive systems.

6.55 *Linear System Analysis* (A)
6.01 *Guillemin* 3–0–6
Methods of analysis useful in the study of signals, systems and their response. Linear transformations and linear constraint relations, topological versus dynamic independence, energy relations, duality, normal coordinates and normal coordinate transformations, passivity and stability. Impedance and admittance properties relating the frequency and time domain aspects of physical circuit behavior. Fourier methods and their use in

analysis and synthesis, including such topics as: convergence and approximation properties of Fourier series, their ability to characterize both aperiodic sampled functions as well as ones that are periodic and continuously defined. Approximation by finite trigonometric polynomials; Cesaro and other methods of summation. The concept of band-limited functions. Fourier and Laplace transforms and a comparison of network analysis by these methods with the classical differential equation solution showing their complete identity. Numerical evaluation methods using impulse-train techniques. Real part sufficiency and related topics. Introduction to network synthesis including conventional filter theory.

6.56 ***Mathematical Methods in Electrical Engineering*** **(A)**
M351 *Guillemin* 3–0–6
A subject emphasizing the physical and geometrical interpretations and their effective use in engineering analysis, rather than the abstract symbolic formalism of mathematical methods. Selected topics from: theory of determinants, matrices, linear transformations and quadratic forms; functions of a complex variable emphasizing the basic aspects for analysis of problems in the general field of electrical engineering as well as in the fields of communications and the electronic control art; approximation and convergence properties of Fourier, Laplace and Hilbert transforms, analytic and numerical methods for their evaluation.

6.561, 6.562 ***Network Analysis and Synthesis*** **(A)**
6.30 or 6.55; 6.56 *Guillemin* 3–0–6
6.561 *Guillemin* 3–0–6
Advanced treatment of linear passive network theory with primary emphasis upon synthesis aspects; application to design of networks for prescribed driving-point and transfer characteristics; fundamental work of Foster, Cauer, Brune, and Darlington, as well as collaterally significant topics, illustrated with examples; synthesis of coupling networks for prescribed transfer characteristics, including RC as well as RLC, minimum-phase and non-minimum-phase types, filters, constant-resistance filter groups, and questions regarding the ultimate response characteristics obtainable from linear passive networks. Frequency and time domain aspects of the pertinent approximation problem.

6.568 ***Switching Circuits*** **(A)**
6.567 *S. H. Caldwell* 3–1–6
Switching codes and their manipulation. Synthesis of iterative circuits as sequences in space. Analysis and synthesis of time-sequential switching circuits. Development and manipulation of the flow diagram, assignment of secondary (memory) elements, and the reduction of sequential problems to combinational problems. Use of electronic and solid-state components in sequential switching circuits. Elimination of hazards. Synthesis of pulsed sequential circuits. Circuits for performing specific functions and their combination into systems in which response is a function of the combination and sequence of discrete input conditions. Individual and group laboratory projects.

6.571 ***Statistical Theory of Communication*** **(A)**
6.30 or 6.561 or 6.581 *Y. W. Lee* 3–0–6
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 means of normal and orthogonal functions.

6.573 ***Statistical Theory of Noise and Modulation*** **(A)**
6.30 or 6.311 or 6.55 *Wiesner, Siebert* 3–0–6
Introduction to probability and statistics. Derivation of statistical properties of shot noise. Noise in linear systems. Noise figures of amplifiers. Noise through nonlinear devices. Quadratic and linear detectors and mixers. Application of the characteristic function method to more general nonlinear devices. Detection of threshold signals.

6.574 ***Statistical Theory of Information*** **(A)**
6.573 or M76 *Fano* 3–0–6
Introduction for graduate students to the quantitative study of communication processes. Definition of a measure of information and study of its properties; representation of messages; efficient coding, transmission in the presence of random disturbances, channel capacity; coding to increase the reliability of transmission. Extension of the theory to continuous channels; signal detection in the presence of disturbances.

6.575 ***Advanced Topics in Information Theory*** **(A)**
6.574 *Elias* 3–0–6
Further work in information theory based on 6.574. Current problems, solved and unsolved. Several staff members may participate. Term paper required.

6.581 ***Transients in Linear Systems*** **(A)**
6.01, M351 *Gardner* 3–0–6
Elective for first-year graduate student majors in electrical engineering, as well as those in mechanical and aeronautical engineering, applied physics, and mathematics. Formulation of integro-differential equations and expression of initial conditions of transient problems arising in electrical, mechanical, and combined electrical-mechanical systems, stressing expression of physical concepts in mathematical relations; electrical analogs. Development of the Laplace transformation; its use to relate time functions to their associated functions of a complex variable and to the complex plane; its use to relate linear differential equations to algebraic equations in the complex variable; use of its basic properties for time scaling and for checking at stages in the solution process. Applications to pulse response, switching transients, feedback control, amplifier response, and transient vibration of lumped-parameter mechanical and electromechanical systems.

6.582 ***Transients in Linear Systems*** **(A)**
6.581 *Gardner* 3–0–6
Further development of the useful properties of the Laplace transformation including convolution operations in both real and complex domains with applications to transient analysis. Formulation of jump functions, modulated impulse trains, sampled time functions, and the Laplace transforms of these functions. Formula-

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tion of difference equations, differential-difference equations, and their solution by Laplace transform methods. Formulation of partial differential equations of the wave and diffusion types for distributed-parameter systems; their solution by Laplace transform methods with specified initial and boundary conditions. Transmission line traveling waves; terminal and junction reflection functions; error function solutions in heat flow and diffusion processes.

6.583 *Foundations of Electromagnetic Theory*
6.07 or 8.72 *Chenea* 3–0–6
Fundamental equations of electromagnetic theory developed at macroscopic level, with due consideration for connection with thermodynamics, mechanics, and relativity. General theory, reduced to important special cases of engineering interest, with particular attention to assumptions involved. Problems of energy conversion and the coupling of electromagnetic fields with thermal and mechanical fields.

6.586 *Engineering Applications of Field Theory* (A)
M22 *Moon* 3–0–6
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.

6.59 *Bioelectric Signals* (A)
—— *Rosenblith* 3–0–6
Introduction for graduate students in the physical and communications sciences. Basic phenomena of the electrophysiology of the nervous system. Electrical activity related to sensory stimuli with emphasis upon the auditory and visual systems. Evoked responses at various levels of the nervous system and their relation to ongoing activity. Electronic recording and computing devices in the study of bioelectric signals. Mathematical models for the behavior of sensory systems. Organisms in communication processes and systems.

6.602 *Nonlinear and Time-Varying Systems* (A)
6.571 or 6.573 or 6.605 *Seifert* 3–0–6
Description of signals. Review of statistical concepts. Superposition integral and optimization theory for time-varying linear systems. Quasi-linear approximations for nonlinear systems with sinusoidal and random inputs. Phase-plane analysis of second-order nonlinear systems. Transient control of saturating systems. Design of final-value systems.

6.604 *Feedback Control Theory and Applications*
6.605, M351 *Newton* 3–2–6
Same content as 6.605, with laboratory added.

6.605, 6.606 *Feedback Control Theory and Application* (A)
6.05, M351 *Newton* 3–0–6
6.605 *Newton* 3–0–6
Trial-and-error design procedure including: linear models for physical systems, block diagrams, Laplace transforms, stability criteria, transient response, frequency response, performance indices, and compensation schemes. Analytical design procedure including: parameter adjustment for minimum integral-square error, stochastic signals, variational procedure, minimization of mean-square error for fixed and free configurations, use of constraints, effects of fixed elements, saturable elements, and bandwidth limitation. Components used in systems including: sensing devices, electric and hydraulic servo motors, gearing, amplifiers, carrier and noncarrier compensating networks. Case studies illustrate problems in mechanical, electrical and process control fields. Supplementary theory including: correlation of transient response with frequency response, error coefficients, contactor, sampled data, and nonlinear systems. Newton, Gould, Kaiser, *Analytical Design of Linear Feedback Controls*. Registration for 6.604 recommended for students without laboratory experience.

6.607 *Feedback Control Laboratory* (A)
—— *Newton* *
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 professor in charge.

6.61 *Production and Application of Atomic Radiations*
8.031 or 8.041 *Trump* 3–0–6
Fundamental electrical processes in such superior voltage-insulating media as high vacuum and compressed gases; principles and engineering features of machine accelerators, including the Van de Graaff electrostatic accelerator, resonance transformer, betatron, microwave linear accelerator, and synchrotron; the properties of high-energy electrons, X-rays, positive ions, and neutrons; methods of controlling and measuring these forms of ionizing energy; the nature of their interaction with living and non-living matter. Physics and techniques in the application of atomic particles to the diagnosis and treatment of disease, the radiographic examination of metal sections, the sterilization of drugs and of tissue for surgical use, the preservation of foods, the production by accelerators of neutrons and isotopes, the polymerization and crosslinking of hydrocarbons.

6.621 *Microwave Circuits* (A)
6.07 *Haus* 3–2–6
Analysis of electromagnetic wave propagation in uniform cylindrical waveguides; reduction of waveguide and discontinuity problems to equivalent transmission line and network problems; study of electromagnetic wave propagation along periodic structures; matching elements, cavity resonators and multiple waveguide junctions; fundamentals of microwave network design. Laboratory experiments.

6.622 *Antennas* (A)
6.07 *Chu* 3–0–6
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.

6.623 *Principles of Pulse Circuits* (A)
6.20 or 6.311 *Zimmermann* 3–0–6
Graphical methods and piecewise-linear approximations applied to analysis and design of driven and freely oscillating high-speed circuits.

6.626 *Modulation Theory* (A)
6.311 *Baghdady* 3–0–6
Survey of modern systems of modulation and multiplexing, their comparative merits and applications. Techniques of signal representation and analysis. Analysis of modulated sinusoidal and pulse carriers, and of the response of linear filter to AM and FM signals. Study of important modulation, multiplexing, and demodulation techniques and circuits. Critical evaluation of the sensitivity of modern communication systems to random noise, impulsive disturbances, and interference (or jamming). Study of capture phenomena in the light of the characteristics of AM and FM disturbances and noise as compared with characteristics of message modulation; exchange of bandwidth for S/N ratio. Improving reception by linear and nonlinear filtering techniques. Introduction to modern detection and decision theory.

6.629 *Radar System Engineering* (RA)
6.02, 6.213 *Reintjes* 3–0–6
Fundamental principles of pulsed radar; discussion of the radar as a data-gathering device in a fire-control system; analysis of radar-system components with emphasis on those components used in fire-control radars. Current developments in radar. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*)

6.631 *Gaseous Discharge Phenomena* (A)
6.20 *Edgerton* 1–3–5
Theory and practice of gas discharge phenomena, especially concerning devices now used or proposed for actual applications in science and engineering. Ionization, radiation, voltage breakdown phenomena, volt-ampere characteristics and related subjects, with the experimental investigation of devices such as glow tubes, electronic flash lamps, gas filled phototubes, spark gaps, mercury pool rectifiers, thyratrons, and air arcs.

6.632 *Electronic Instrumentation and Control* (A)
6.05 *Gray* 3–0–6
Principles of analysis and design of electronic instrumentation for control involving measurement of small currents or of randomly occurring pulses, illustrated by nuclear measurements and nuclear-reactor control. Survey of detectors including nuclear particle detectors, direct-current amplification, pulse amplification, counting circuits, count-rate devices, coincidence circuits.

6.633 *Active Circuit Theory* (A)
6.02 *Mason* 3–0–6
Topological methods and matrix methods in the analysis of linear nonreciprocal circuits. Phase-plane analysis of oscillations in nonlinear circuits.

6.635 *Transistors* (A)
6.05; 6.08 or 6.64 or 8.051 or 8.08 *Adler* 3–0–9
Primarily for graduate students in electrical engineering. Physical foundations of transistor action, developing the terminal properties of the transistor as an electronic device. Brief qualitative introduction to the concepts of free electrons and holes in semiconductors; elementary quantitative treatment of electrical conductivity as a function of impurity concentration and temperature; drift, diffusion and continuity relations governing carrier flow out of thermal equilibrium; derivation of the d-c and incremental a-c electrical characteristics of the planar junction diode and junction transistor; equivalent circuits; implications of the model for device performance and limitations; additional physical factors affecting small- and large-signal performance; related and improved devices, as time permits.

6.637 *Beam-Type Microwave Tubes* (A)
6.07 or 6.322; 8.08 *Smullin* 3–0–6
Electron kinematics in combined a-c and d-c fields. Space charge. Electron beam as a propagating medium. Small-signal kinetic power theorem. Coupling of modes in propagating systems. Klystrons, traveling wave amplifiers, backward wave oscillators. Slow wave structures. Beam focusing problems.

6.64 *Insulators, Semiconductors, and Metals* (A)
8.04 or 8.041 *von Hippel* 3–0–9
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 engineering.

6.67 *Principles of Control Systems* (A except for Course VI)
8.03, M22 *Gyftopoulos* 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. Distributed parameter systems. Discussion of non-linear problems.

6.68 *Special Problems in Electrical Engineering* (A)
—— *Gardner* *
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.

6.692 *Advanced Engineering Acoustics* (A)
6.35 *Baruch* 3–0–6
Application of network techniques to the design of loudspeakers, microphones and enclosures. Control and utilization of wavefront geometry; directivity, distance localization. Analysis of noise fields in the space, time and frequency domains, classical statistics, correlation, filtering and scanning. Power flow considerations, handling of power flow, concept of a balanced noise-control solution. Geometric acoustics, ray diagrams, image spaces and absorption perturbations. Analysis of logical and physical conditions covering scaling and model theory, dimensional analysis. (*Alternate years. Not offered 1958–59.*)

(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.

6.695 ***Special Problems in Acoustics*** **(A)**
—— *Beranek* *

Advanced problems in acoustics, electro-acoustics or vibrations. Opportunity for individual study in the Acoustics Laboratory under a staff member.

6.696 ***Hearing, Speech, and Language*** **(A)**
6.35 *Rosenblith, Halle* 3–0–6

For graduate students and well-qualified seniors interested in speech communication. Properties of signals in audio communication systems in the light of characteristics of listeners and speakers. Auditory thresholds, masking, perception of complex acoustic stimuli. Production of natural and synthetic speech. Physical methods of speech analysis. Effects of filtering and clipping. Linguistic units of analysis. Statistical properties of speech signals. Intelligibility criteria for audio communication systems. Integration of experimental data on hearing and speech with recent developments in linguistics and information theory.

6.73 ***Advanced Electrical Circuits and Electronics Laboratory*** **(A)**
6.02 *Searle, Thornton* *

Advanced laboratory problems in electrical circuits, electronics, or electrical measurements.

6.74 ***Advanced Electrical Energy Conversion Laboratory*** **(A)**
6.06T *White* *

Graduate subject planned for the individual student; special problems on electrical energy converters and modulators.

6.80 ***Electrical Circuits and Electronics Laboratory***
—— *Searle, Thornton* *

Laboratory problems in electrical circuits, electronics, or electrical measurements.

6.86 ***Electrical Energy Conversion Laboratory***
6.01 or 6.18 *Woodson* *

For electrical engineering students who wish laboratory work in addition to that included in 6.03, 6.04, and 6.06, and other students requiring a special program in energy-conversion laboratory. Arranged to suit the requirements of the individual student.

6.901–6.904 ***Industrial Practice at the Plants of the General Electric Company***

6.905–6.908 ***Industrial Practice at the Plants of the International Business Machines Corporation***

6.911–6.914 ***Public Utilities Practice at the Boston Edison Company***

6.921–6.924 ***Special Industrial Practice***

Assignments to companies outside the regular Cooperative program to afford industrial experience to non-citizens. Work of the same standard as required of other Cooperative students.

6.931–6.934 ***Industrial Practice at the Plants of the Raytheon Manufacturing Company***

6.941–6.944 ***Industrial Practice at the Bell Telephone Laboratories, Inc.***

6.951–6.954 ***Industrial Practice at the General Radio Company***

6.961–6.964 ***Industrial Practice at the Philco Corporation***

6.971–6.974 ***Electric Power System Design and Practice at the Plants of the American Electric Power Corporation***

6.981–6.984 ***Research and Development at the Naval Ordnance Laboratory***

6.991–6.994 ***Research and Development at the Air Force Cambridge Research Center***

7.
Biology

7.00 *Perspectives in Life Science*
—— *Wall* 3–0–3
Lectures and demonstrations presenting the place of man in the world of living organisms; factors important in man's successful adaptation to his external environment, animate and inanimate; and the processes which make possible the various functions of man's body in health and disease including major concepts of genetics, growth, development, and physiology. Concluding lectures on the growing importance of biophysics and biochemistry in the shaping of modern biological concepts — (biology at the molecular level) and the outlook for theoretical biology.

7.01, 7.02 *General Biology I and II*
—— *Herbert* 3–0–4
7.01 *Rich* 3–0–4
Introduction to the study of plant and animal organisms, including man. *First Term:* Nature of life, physical and chemical structure of protoplasm; form and structure of plants; cells and cell structure; relations and structure of cells, tissues and organs of plants; plant physiology; review of plant kingdom; systems of the animal body (anatomy-physiology). *Second Term:* Review of the animal kingdom, growth and reproduction in plants and animals, heredity, evolution, plant and animal classification, principles of ecology, plant and animal diseases, immunity, viruses, history and perspectives of biology.

7.011, 7.021 *General Biology Laboratory I and II*
—— *Herbert* 0–3–0
7.01 *Rich* 0–3–1
Laboratory exercises to illustrate the principles in 7.01, 7.02.

7.03 *Genetics and Cytology*
7.02, 7.021 *H. W. Lewis* 2–4–4
The cell as a structural and functional unit, with an introduction to the principles of cytochemistry. Discussion of the roles of both the nucleus and cytoplasm in cellular processes and in relation to the phenomenon of heredity, variation and mutation in organisms.

7.04 *Developmental Biology*
7.03 *Bell* 2–6–4
Basic concepts and principles of growth and differentiation with emphasis on the experimental method in the development of animals from germ cells to organ systems.

7.05, 7.06 *General Biochemistry and Physiology I and II*
5.41, 5.62 *Buchanan* 3–0–6
7.05 *D. F. Waugh* 3–0–6
Contributions of physiology, biochemistry, and biophysics toward an understanding of the structure and functioning of organisms, organs, tissues, and cells. Cell and tissue components, the chemistry of biological constituents, the physical-chemical basis for the structure and colloidal properties of protoplasm, biophysical and biochemical methods and concepts used in the examination of biological materials, intermediary and general metabolism, also physiological phenomena such as secretion, excretion, permeability, irritability, and contractility.

7.051, 7.061 *General Biochemistry and Physiology Laboratory I and II*
7.05 Gould, G. M. Brown 0–8–0
7.06 Jenerick 0–6–0
Laboratory exercises to illustrate the principles discussed in 7.05, 7.06.

7.08 *Introduction to Biophysics*
5.02; 7.00 or 7.02; 8.04 *Levinthal* 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.

7.13 *Genetics*
7.02 *H. W. Lewis* 2–0–4
Facts and theories of heredity and their relation to the present state of biological theory in general.

7.31, 7.32 *Biology Seminar* (A)
7.06 *Bell* 1–0–2
Designed to give graduate students experience in critical evaluation of research and in public speaking by presenting oral reports before staff and students.

7.35 *Cellular Physiology* (A)
7.06 *Jenerick* 2–0–4
Recent advances in one of the following fields: contractility, transport, coordination (nerve and endocrines), or growth and development. Selection of a different topic each year.

7.36 *Advanced Neurophysiology*
7.06 *Wall* 2–0–4
A series of lectures, with student participation, on some aspects of the nervous system. A foundation for work on the structure and function of the nervous system.

7.50 *Physical Chemistry of Proteins* (A)
7.05 *D. F. Waugh* 2–0–4
Corpuscular proteins including fractionation, physical-chemical characterization, internal structure, surface structure, and modification by physical and chemical agents. Protein interactions such as the corpuscle, fibril transformation and antigen-antibody interactions.

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7.68 *Intermediary Metabolism* (A)
7.05 *Buchanan, Hartman* 2–0–4
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. The mechanisms of biochemical reactions.

7.69 *Seminar in Biochemistry* (A)
7.05 *Hartman, Buchanan* 2–0–4
Reading and reporting of reviews and recent publications in biochemistry. Designed to be taken simultaneously with 7.68.

7.77, 7.78 *Biophysics Seminar* (A)
7.06 *Levinthal* 1–0–2
Presentation and discussion of reports on current literature in biophysics by participating graduate students.

7.81 *Enzymology* (A)
7.05 *Sizer* 2–0–4
Quantitative study of enzymes emphasizing their general properties; kinetics of reactions catalyzed by them; conditions which control their activity.

7.811 *Enzymology Laboratory* (A)
7.81 Hartman 0–4–2
Methods of purification of enzymes, determination of their catalytic activity and chemical properties, as well as effects of environmental factors on enzymes.

7.82 *Advanced Biochemistry* (A)
7.05 *Gould* 2–4–4
Lectures and laboratory exercises emphasizing current trends in biochemical investigation and illustrating special problems, techniques and approaches of biochemical research; training in the planning and solution of biochemical problems and presentation of results.

7.831 *Biochemistry of Microorganisms*
7.05 *Gould* 3–4–4
General survey covering the biology, chemistry, and physiology of the yeasts, molds, and bacteria. Modern developments in the field, especially as they contribute to an understanding of general processes in plant and animal life. Historical, taxonomic, and morphologic considerations of microbiology given as a background. Laboratory work on various general techniques of microbiology as well as quantitative aspects of the metabolic activities of microorganisms.

7.832 *Biochemistry of Microorganisms* (A)
7.831 *Gould* 0–6–0
Quantitative aspects of the metabolic activities of microorganisms. Investigation of problems in the general biochemistry of yeasts, molds, and bacteria by analytical and research methods now in use in various laboratories. Isolation and identification of various metabolic products, metabolic balance sheets, and respiration studies.

7.85 *Methods in Biophysics I* (A)
7.06, 8.04 *Hall* 2–2–4
Physical and physico-chemical methodology useful for study of biological systems. General principles of instrumentation; electrical methods; absorption and emission spectroscopy; microscopy, including use of phase, interference, ultraviolet, polarization and electron microscopes; X-ray diffraction.

7.86 *Molecular Genetics* (A)
7.06, 8.04 *Levinthal* 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.

7.882 *Biophysics Laboratory* (A)
7.06, 8.04 *D. F. Waugh* 0–4–0
Laboratory coordinated with the topics of 7.86.

7.90 *Seminar in Enzymology* (A)
7.81 *Sizer* 2–0–4
Discussion of recent advances in the field of enzymology, with emphasis on enzymes concerned with respiration, phosphorylation, and intermediary metabolism.

7.911 *Instrumentation and Research Methods* (A)
8.04 *Lion* 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.

7.912 *Instrumentation and Research Methods Laboratory* (A)
8.04 *Lion* 0–4–0
Laboratory subject, complementary to 7.911.

7.92 *Electrical Instrumentation in Biology* (A)
7.911, 7.912 *Lion* 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, including amplifiers, oscillographs, photoelectric cells, X-ray tubes, and dosimeters.

7.93 *Selected Topics in Biology* (A)
7.05 Staff *
Class work in various fields of biology not covered by the regular subjects of instruction.

7.941, 7.942 *Research Problems* (A)
—— *Staff* *
Directed research in a field of biological science, but not contributory to graduate thesis.

7.95 *Electron Microscopy* (A)
7.85 or 8.04 *Hall* 2–0–4
Principles of electron optics, the electron microscope, interaction of electrons with matter, methods in electron microscopy, applications of electron microscopy.

7.96 *Electron Microscopy Laboratory* (A)
7.95 *Hall* 0–2–1
Properties of electron lenses, use of the electron microscope, preparation of specimens, techniques in electron microscopy, selected experiments.

7.97, 7.98 *Biophysical and Biochemical Cytology Seminar* (A)
7.06 *Schmitt, Hodge* 2–0–4
7.97 *Schmitt, Hodge* 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.

7.99 ***Molecular Configuration in Biological Systems*** **(A)**
7.06 *Rich* 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.

8. *Physics*

8.01 ***Physics (Mechanics)***
—— *Ingard* 4–1–6
Fundamental laws of mechanics of particles and rigid bodies. Principles of conservation of mass, energy, momentum, and angular momentum. Free use of elementary calculus during second half of subject.

8.02 ***Physics (Mechanics: Heat and Kinetic Theory)***
8.01 *Ingard* 4–1–6
Oscillations and waves; hydrodynamics; the equations of state of gases, liquids, and solids; elementary kinetic theory.

8.03 ***Physics (Electricity and Magnetism)***
8.02, M12 *Mueller* 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.

8.03S ***Physics***
—— —— 4–0–6
Specially arranged for Course XIII-A.

8.031 ***Physics (Electromagnetism)***
8.02, M12 *Rossi* 4–1–5
Fundamental laws of electricity and magnetism presented from the standpoint of field theory. Electrostatics, steady currents and their magnetic fields, and time-varying electric and magnetic fields. Primarily for students intending to pursue further work in electromagnetism and modern physics. Free use of calculus throughout.

8.04 ***Physics (Optics and Atomic Physics)***
8.03 *Mueller* 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.

8.041 ***Physics (Electromagnetism and Electromagnetic Theory of Light)***
8.031 *Rossi* 4–1–5
Continuation of 8.031. Electromagnetic waves, electric and magnetic properties of matter. Electromagnetic theory of light and radiation. Continuation of the quantitative character of 8.031 with free use of calculus.

8.05 ***Physics of Atoms, Molecules and Nuclei I***
8.04 or 8.041 *F. L. Friedman* 4–0–6
Survey of the experimental foundation of quantum physics with examples largely from atomic phenomena: optical, X-ray, radiofrequency, and infrared spectra; scattering of particles and radiation. Limitations of classical physics; photons, matter waves. Internal structure of atoms, and quantization; vector model, Pauli exclusion principle, and the periodic table of elements.

8.051 ***Atomic and Nuclear Physics I***
8.04 or 8.041 *Buechner* 4–0–5
Atomic and nuclear phenomena and interpretation of experimental facts in terms of quantum physics.

8.052 ***Atomic and Nuclear Physics II***
8.05 or 8.051 *Slater* 4–0–5
Continuation of 8.051, with applications to various topics in modern physics, including the theory of solids. Topics may vary from year to year.

8.053 ***Introduction to Nuclear Physics***
8.05 or 8.051 *Enge* 4–0–5
Discussion of various topics of nuclear physics with description of experiments and correlation of the results with current theories, such as two-nucleon systems, alpha and beta decay, gamma radiation, nuclear reactions, nuclear structure, and fission.

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8.06 *Physics of Atoms, Molecules and Nuclei II*
8.05 *F. L. Friedman* 4–0–6
Continuation of 8.05. Elementary applications of quantum mechanics to atomic, molecular, and nuclear phenomena. Static properties of nuclei, radioactivity, nuclear reactions. Problems of nuclear forces and nuclear models.

8.07 *Statistical Mechanics and Thermodynamics*
8.05 or 8.051 *Frisch* 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.

8.08 *Electronics*
8.04 or 8.041 *Harvey* 4–0–6
Electron ballistics, mass spectroscopy, introduction to theory of special relativity, principles of high-energy accelerators; space charge theory, elements of low-pressure gaseous discharges; Fermi-Dirac statistics, thermionic emission, Schottky effect, high field and secondary emission, photoelectric effect in metals, elementary properties of semiconductors.

8.09 *Experimental Atomic Physics I*
8.04 or 8.041 *Pless* 0–6–3
Laboratory experiments on the foundations of modern physics: atomicity of matter and electricity, and special relativity. Typical experiments on Brownian motion, the Millikan oil drop method, charge-to-mass ratio of high-speed electrons, and Rutherford scattering. Opportunity for detailed technical training in use of machine tools, vacuum practice, glass blowing, and measurements of magnetic fields.

8.10 *Experimental Atomic Physics II*
8.05, 8.08, 8.09 *Kraushaar* 0–4–2
Continuation of 8.09: discreteness of atomic and molecular structure, and wave-corpuscle dualism. Typical experiments on studies of ammonia inversion line, absorption spectrum of sodium, X-ray emission spectra, diffraction of light, photoelectric effect, Zeeman effect, and cosmic ray telescope. Opportunity for detailed training in microwave electronics and pulse counting.

8.11 *Experimental Physics and Thesis*
8.10 *Frisch* 2–10–4
Introduction to experimental research techniques by (1) assigned laboratory exercises which include setting up and carrying through experiments concerned with fundamental principles in optics, nuclear, atomic, and molecular physics, or (2) participation in active research programs which may serve as part of the senior thesis. Presentation of research projects by each student to the whole group. Designed to bridge the gap between elementary laboratory and research in modern physics.

8.12 *Special Problems in Undergraduate Physics*
—— *Staff* *
Opportunity for undergraduates to engage in experimental or theoretical research under the supervision of a staff member.

ACOUSTICS

8.135 *Special Problems in Acoustics* (A)
8.71 *Staff* *
Advanced problems in acoustics or vibrations with assigned reading and consultation.

8.14 *Sound Propagation in Moving Media* (A)
8.71 *Ingard* 3–0–6
General discussion of waves in moving inhomogeneous media; geometric vs. wave analysis; elements of the theory of turbulence; generation of sound by turbulent flow; interaction of sound with turbulence; large-amplitude waves and shocks, and interaction of sound with shocks; selected nonlinear wave problems. (*Alternate years. Not offered 1958–59.*)

OPTICS AND PHOTOGRAPHY

8.15 *Photography*
—— *A. C. Hardy* 2–0–1
Elementary subject primarily an elective for students not in Course VIII.

8.16 *Optics*
8.04 or 8.041 *A. C. Hardy* 3–0–6
Fundamental principles of geometrical, physical and physiological optics. Refraction at spherical surfaces, thick lenses, limitation of rays by apertures, lens aberrations, resolving power of optical instruments, diffraction, interference, polarization, radiation, light sources, the eye, photometry, color, photoelectricity, design and construction of optical instruments, stereoscopy, and description of the performance of well-known optical systems such as telescopes, microscopes, photographic objectives, and projection systems.

8.17 *Color Measurements*
8.04 or 8.041 *A. C. Hardy* 0–3–2
Measurement and specification of color in the objective and subjective sense and the application of such methods to industrial problems. Experiments illustrating photometric and chromatic properties of the human eye and giving experience in the technique of spectrophotometry and colorimetry.

8.18 *Special Problems in Optics* (A)
8.16 *Staff* *
Experimental work in the optics laboratory with assigned reading and consultation.

8.191 *Selected Topics in Physical Optics I* (A)
8.72 *Mueller* 2–0–4
The empirical laws of optics; vector-, spinor- and matrix-optics and their relation to wave- and photon-optics.

8.192 *Selected Topics in Physical Optics II* (A)
8.191 *Mueller* 2–0–4
Selected topics, changing from year to year, in the field of polarization optics dealing with problems of light scattering, diffraction by ultra- and hypersonics, electro-, magneto- and elasto-optical effects.

ELECTRONICS

8.21 *Physical Electronics* (A)
8.08 *Nottingham* 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.

8.212 *Physical Electronics Laboratory* (A)
8.21 *Nottingham* 2–3–3
Lectures and laboratory for the development of techniques useful for research in physical electronics and their application to the experimental investigation of important phenomena of physical electronics.

8.231 ***Electrical Discharges in Gases*** **(A)**
8.05, 8.07 *S. C. Brown* 3–0–6
Fundamental processes of electron emission from cathodes and interaction with gas. Various types of discharges, including ultra-high frequency discharges, the Townsend discharges and breakdown, Geiger-Mueller tubes, the cathode fall, plasma, and anodic parts of glow discharges and arcs.

8.232 ***Theory of Electrical Discharges in Gases*** **(A)**
8.231, *8.72* *Allis* 3–0–6
Development of the Boltzmann transport equation and its application to the velocity distribution of electrons in various types of discharges. Calculation of the Townsend coefficients and of breakdown potentials. (*Alternate years.*)

8.25 ***Special Problems in Electronics*** **(A)**
8.08, *8.21* *Staff* *
Advanced problem in electronics, with assigned reading and consultation.

X-RAYS AND CRYSTAL STRUCTURE

8.27 ***X-rays and Crystal Physics***
8.05, M352 *Warren* 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.

8.28 ***X-ray Diffraction*** **(A)**
8.27 *Warren* 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. Extinction effects in perfect crystals.

8.30 ***Special Problems in Crystal Physics*** **(A)**
8.27 *Staff* *
Advanced problem in X-ray diffraction or crystal physics with assigned reading and consultation.

SPECTROSCOPY

8.31 ***High Resolution Spectroscopy*** **(A)**
8.06 *Bitter* 3–0–6
Analysis of research problems in high resolution spectroscopy, with emphasis on applications to nuclear structure. Content may change somewhat each year, with varying emphasis on experimental and theoretical problems ranging from an analysis of microwave and optical techniques to the interpretation of results in terms of nuclear shell structure. Students to apply material developed in lectures to design of experiments of current interest.

8.32 ***Theory of Atomic Spectra*** **(A)**
8.06 *Bradley* 3–0–6
Characteristics of atomic spectra and their interpretation in terms of current theories of atomic structure. Detailed consideration of the theory of angular momentum operators. (*Alternate years.*)

8.34 ***Special Problems in Spectroscopy*** **(A)**
8.06 *Staff* *
Advanced problems in the Spectroscopy Laboratory or in the Magnet Laboratory, with assigned reading and consultation.

SOLID STATE AND STRUCTURE OF MATTER

8.361 ***Quantum Theory of Matter I*** **(A)**
M351 *Slater* 3–0–6
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.

8.362 ***Quantum Theory of Matter II*** **(A)**
8.361 *Slater* 3–0–6
Electronic structure of molecules and solids. The molecular orbital self-consistent-field method for molecules. Symmetry properties of molecular wave functions, as treated by the group theory. Configuration interaction in molecules. General discussion of molecular binding. The energy-band theory of solids. Energy bands for metals, semiconductors, ionic crystals, molecular compounds. Relation of energy bands to electrical, optical, and magnetic properties of solids.

8.363 ***Selected Topics in Theory of Solids I*** **(A)**
8.362 *Koster* 2–0–4
Discussion of selected topics, changing from year to year, chosen from the theory of energy bands, the theory of molecular structure, the theory of semiconductors, and other subjects.

8.364 ***Selected Topics in Theory of Solids II*** **(A)**
8.363 *Koster* 2–0–4
Continuation of 8.363. (*Not offered 1958–59.*)

8.37 ***Neutron Diffraction*** **(A)**
3.50 or 8.27 *Shull* 3–0–6
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. (*Alternate years.*)

8.411 ***Statistical Thermodynamics I*** **(A)**
8.731 *Tisza* 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 1958–59.*)

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

8.412 *Statistical Thermodynamics II* (A)
8.411 *Tisza* 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 1958–59.*)

8.43 *Microwave Physics* (A)
8.361 or 8.731 *Strandberg* 3–0–6
Theory and measurement of atomic, molecular, and crystal energy level differences corresponding to short-wave radio frequencies; rotational energy levels, vibration-rotation interactions, nuclear multipole structure, rotation-induced electronic angular momentum, Stark and Zeeman effect, dia- and para-magnetism, time-dependent perturbations including induced absorption and thermal relaxation processes; properties of angular momentum, tensor interactions and the Racah formalism, and the approximation of perturbations; the interpretation of particular experimental data in terms of the geometry and mass of nuclei, internal fields and charge multipoles; introduction to the experimental parameters defining the limits of experimentation; practical sensitivities and resolution. (*Alternate years.*)

8.45 *Special Problems in Solid State Physics* (A)
8.362 or 8.412 *Staff* *
Advanced problems in the physics of the solid state, with assigned reading and consultation.

NUCLEAR PHYSICS

8.511 *Nuclear Physics I* (A)
8.06, *8.77* *M. Deutsch* 3–0–6
Advanced experimental nuclear physics, including description of the properties of nuclei and nuclear transformations, observational methods and instruments and correlation of experimental results with current theory. Charge, mass, radius, nuclear moments, statistics, parity, and selection rules for nuclear transitions. Interaction between particles, binding energy, nuclear models. Radioactive transformations, theory of statistics and fluctuations.

8.512 *Nuclear Physics II* (A)
8.511 *M. Deutsch* 3–0–6
Continuation of 8.511. Ionization, scattering, and radiative losses for swift-charged particles. Properties of neutrons. Origin of gamma rays and their interaction with matter. Transmutation; fission; reactions induced by charged particles, gamma rays, and neutrons; excitation functions. Artificial radioactivity, nuclear spectroscopy.

8.513 *Nuclear Physics Laboratory* (A)
8.511 *M. Deutsch* 1–3–3
Study of the properties of particles from natural, artificial, and fission disintegrations and the corresponding measuring instruments. Use of counters, coincidence amplifiers, ionization chambers, and the cyclotron.

8.52 *Advanced Applied Nuclear Physics* (A)
8.512 or 8.532 *R. D. Evans* 3–0–6
Physical problems involved in the use of radioactive and stable isotopic tracers. Industrial and engineering applications. Units, standards, instrumentation, and techniques. Radiation hazard evaluation. Shielding. Safe handling and disposal of radioactive materials.

8.531 *Nuclear Physics for Engineers I* (A)
8.051 or 8.06 *R. D. Evans* 3–0–6
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.

8.532 *Nuclear Physics for Engineers II* (A)
8.531 *R. D. Evans* 3–0–6
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.

8.541 *Advanced Topics in Nuclear Physics* (A)
8.06 *Schluter* 2–0–4
Intensive study of selected subjects of contemporary interest in nuclear and high-energy physics, with subject matter related to research in progress at the Institute and treated from the point of view of the experimentalist. Stress on the relation of experiment to the development of current theories.

8.551 *Theory of Nuclear Structure I* (A)
8.732 *Weisskopf* 3–0–9
Review of the current theories of the structure of atomic nuclei. Nature of internuclear forces as determined by two-body phenomena. Three- and four-body problems. Nuclear spectroscopy. (*Alternate years.*)

8.552 *Theory of Nuclear Structure II* (A)
8.551 *Weisskopf* 3–0–9
Continuation of 8.551. Interaction of nuclei with light. Beta decay. Shell structure. Theory of nuclear reactions. Alpha decay. (*Alternate years.*)

8.56 *Cosmic Physics* (A)
8.71, 8.72 *Rossi* 3–0–6
Introductory study of the physical phenomena occurring in interplanetary, interstellar and intergalactic space, with discussion of such topics as the elements of magneto-hydrodynamics, survey of radioastronomical data and some aspects of the cosmic ray problem. (*Alternate years.*)

8.58 *Meson Physics* (A)
8.06, 8.732 *Feld* 3–0–6
Production, properties, interactions of π-mesons. Selection rules and phenomenological description of interactions with nucleons and nuclei, and associated high-energy phenomena. Connections with meson field theories. (*Alternate years. Not offered 1958–59.*)

8.59 *Statistical Fluctuations in Physical Processes* (A)
8.052 or 8.06 *R. D. Evans* 2–0–4
Application of statistical theory of fluctuations and errors to experimental physics. Theoretical frequency distributions: binomial, normal, Poisson, interval, and composite distributions. Statistical characterization of data, and tests of significance. Applications of Poisson statistics to the response of nuclear detection instruments, including scaling circuits and counting rate meters. Appraisal of random processes by inefficient statistics using non-parametric tests.

8.60 *Special Problems in Nuclear Physics* (A)
8.511 or 8.531 *Staff* *
Experimental work on radioactivity, nuclear bombardment, and general nuclear research, with assigned reading and consultation.

THEORETICAL PHYSICS

8.71 *Introduction to Theoretical Physics I (Mechanics)* (A)
M351 *M. H. Friedman* 4–0–8
Mechanics of particles, planetary motion, rigid bodies, vibrating particles, vibrating strings and membranes, elasticity and hydrodynamics. Use of Lagrange's equations and generalized coordinates, ordinary and partial differential equations, Fourier series, and vector analysis.

[1] Not a graduate subject for students in Course VIII.

8.72 *Introduction to Theoretical Physics II (Electromagnetic Theory)* (A)
M351 *M. H. Friedman* 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.

8.731 *Introduction to Quantum Theory I* (A)
8.71, 8.72 *Haber-Schaim* 3–0–9
Qualitative discussion of quantum phenomena, relation to classical mechanics, Schrödinger formulation. Motion of free particles, one dimensional problems, transmission through potential barriers, binding, virtual levels using both exact and approximate methods. Central force fields, Zeeman and Stark effects, scattering. Many-body problems, complex atoms, molecules, valence. Interaction with radiation.

8.732 *Introduction to Quantum Theory II* (A)
8.731 *Haber-Schaim* 3–0–9
Operator formulation of quantum theory. Matrix mechanics. Symmetry and integrals of motion. Generalized angular momenta. Pauli spin theory, composition of angular momenta. Perturbation theory, variational methods, etc. Many-body problems. Applications to nuclear physics including the two- and three-body problems, binding energy of light nuclei, scattering of particles by nuclei, alpha decay.

8.74 *Applications of Group Theory to Theoretical Physics* (A)
8.361 or 8.731 *Koster* 3–0–9
Theory of groups and their matrix representations. Application to physical problems drawn from quantum and classical mechanics. Permutation groups and the Dirac Vector Model. Rotation and double groups. Space groups. (*Alternate years.*)

8.791 *Methods of Theoretical Physics I* (A)
8.71, 8.72 *Feshbach* 3–0–9
Solution of physical problems systematized by grouping them according to the partial differential equation they satisfy. Boundary conditions and methods of solution peculiar to each equation, including separation of variables, eigenfunctions, Green's function, integral equations, variational and perturbation procedures, integral representations, conformal transformations. Applications to problems in electrostatics, hydrodynamics, acoustics, quantum mechanics, etc. (*Alternate years. Not offered 1958–59.*)

8.792 *Methods of Theoretical Physics II* (A)
8.791 *Feshbach* 3–0–9
Continuation of 8.791, with emphasis on solutions for vector fields, electromagnetic fields, elasticity, etc. Special emphasis given, in alternate years, to either: (1) electromagnetic wave theory, including wave guide theory, radiation scattering and propagation of microwaves, etc.; or (2) relativity, including special relativity, relativistic dynamics with application to particle accelerators, selected topics in general relativity. (*Alternate years. Not offered 1958–59.*)

8.80 *Advanced Mechanics* (A)
8.71, 8.72 *Harvey* 3–0–9
Generalized equations of motion: d'Alembert, Lagrange, Hamilton; transformation theory and the Hamilton-Jacobi equation; perturbation theory; theory of orbits. (*Alternate years.*)

8.861 *Relativistic Quantum Mechanics I* (A)
8.732 Villars 3–0–9
Relativistic dynamics. The Klein-Gordon equation. π-mesic atom and Coulomb scattering of π-mesons. Relativistic Green's functions. The Dirac equation. The hydrogen-atom and scattering of electrons. Quantization of scalar, electromagnetic and spinor fields. (*Alternate years. Not offered 1958–59.*)

8.862 *Relativistic Quantum Mechanics II* (A)
8.861 *Villars* 3–0–9
Spin and statistics. Theory of the scattering matrix. Feynman graphs. Compton effect, Møller scattering, and pair creation. Mass and charge renormalization, vacuum polarization. Radiative corrections to scattering and Lamb shift. Renormalization in Heisenberg representation. (*Alternate years. Not offered 1958–59.*)

8.90 *Special Problems in Theoretical Physics* (A)
8.791 *Staff* *
Reading, consultation, and original investigation on a problem in theoretical physics.

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10.
Chemical Engineering

10.11 *Chemical Engineering*
5.02 *Fairbanks* 2–0–3
Introductory subject to acquaint the student with the engineering method as applied to chemical problems, by the use of the project and case system.

10.15 *Thesis Reports*
—— *Baddour* 0–3–0
Work done in conjunction with the S.B. thesis. Written and oral reports on literature survey and experimental work.

10.17 *Industrial Chemistry*
5.02 *Baddour* 3–0–4
Techniques of industrial chemical calculation and their application to the chemistry of fuels and combustion.

10.18 *Industrial Chemistry*
5.61, 10.17 *Baddour* 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.

10.21 *Industrial Chemistry*
5.42, 5.62 *Satterfield* 3–0–6
Development of concepts based on the properties and behavior of molecules, directed toward effective study of amorphous, polymeric, and colloidal materials. Subject matter similar in content to 10.63, but presented at a level commensurate with the background of seniors majoring in chemical engineering.

10.25 *Industrial Chemistry* (A)
5.42, 5.62 *Meissner* 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.

10.26 *Industrial Chemistry Laboratory*
10.17 *Merrill* 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.

10.27 *Chemical Engineering Laboratory*
10.17 *Gilliland* 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.

10.28 *Chemical Engineering Thermodynamics*
10.17 *Sherwood* 4–0–6
Thermodynamic properties of matter and the energy relationships underlying mechanical and chemical processes. Applications of the first law of thermodynamics to both batch and flow processes, including compression, combustion, pumping, and chemical reactions. Development of the second law and its elementary application.

10.29 *Chemical Engineering*
10.28 *Sherwood* 4–0–6
Engineering applications of the second law, including free energy and homogeneous and heterogeneous chemical and phase equilibria. Final weeks on elementary fluid mechanics, friction in conduits, and fluid meters.

10.31, 10.32 *Chemical Engineering*
2.41, 10.17; or *3.20;* or 10.17, 10.28
Gilliland 4–0–6
10.29 *Vivian* 4–0–6
Basic principles underlying the unit operations of the chemical industry; material and energy balance, rate laws, and equilibrium considerations. The primary unit operations of heat transmission, evaporation, condensation, filtration, mass transfer, and distillation, with emphasis on the analogies between heat, mass, and momentum transfer, are covered by problems, lectures, and discussions in 10.31. Further study in 10.32 of mass transfer as illustrated by absorption, extraction, air conditioning, and drying, followed by comprehensive process design problems integrating all unit operations.

10.33 *Analytical Treatment of Chemical Engineering Processes* (A)
5.62, M22 *Mickley* 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.

10.36 *Process Design*
10.31 *Sherwood* 3–0–5
Presentation and discussion of a real process and design problem, the class selecting the best process and specification of optimum equipment sizes and operating conditions. Cost estimates and economic evaluation. Entire term ordinarily devoted to a single process design.

10.37 *Chemical Kinetics*
5.62, 10.17, 10.29 *G. C. Williams* 3–0–6
Emphasis on 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.

ENGINEERING OPERATIONS

10.40 *Chemical Engineering Thermodynamics* (A)
5.62, 10.29 *Meissner* 4–0–8
Properties of homogeneous and heterogeneous systems, physical and chemical equilibria and energy effects, and mechanical manipulation and control of industrial processes. Behavior of complex mixtures, correlation of data, and methods of approximation.

10.41 *Distillation* (A)
10.32 *Gilliland* 3–0–6
Basic principles of distillation as applied to binary and multi-component mixtures. Problems on vapor-liquid equilibria of ideal and non-ideal solutions, batch and continuous simple distillations, steam distillations, vacuum and pressure distillation, and rectification. The distillation of systems of limited miscibility, azeotropic distillation, extractive distillation, and adsorption distillation.

10.43 *Separation Processes* (A)
5.62 *Sherwood* 3–0–6
Principles of separation processes of importance in chemical and petroleum industries. Molecular and turbulent diffusion, transfer between phases, countercurrent operations, use of reflux, types of equilibria. Applications to absorption, extraction, distillation, thermal and barrier diffusion, ion exchange, and crystallization.

10.45 *Distillation and Absorption* (A)
10.32 *Vivian* 4–0–8
Distillation, including rectification of binary and complex mixtures. Diffusional processes, with attention to design computations for gas absorption equipment. A combination and condensation of subjects 10.41 and 10.46.

10.46 *Absorption and Extraction* (A)
10.32 *Sherwood* 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.

10.47 *Ion Exchange* (A)
5.62, 10.32 *Baddour* 2–0–4
The 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.

10.50 *Heat Transmission* (A)
10.31 *McAdams* 2–0–4
Application of fundamentals of conduction, radiation, and convection of heat to industrial problems. Numerical methods for complex problems in transient and steady conduction. Analogies between transfer of heat and momentum. Design problems, including economic balance between cost of heat-transfer surface and power.

10.52 *Chemical Engineering II* (A)
10.32 *Mickley* 3–0–6
Basic theories in flow of fluids and mass transfer. Application to problems of advanced character and attention to recent developments.

10.53 *Chemical Engineering Design* (A)
10.31, *10.32* *G. C. Williams* 3–0–6
Design of a complete plant. Plant size, location, and process used based on market analysis and technical and economic evaluation of alternative processes and of sources of raw materials.

10.55 *Economic Balance in Chemical Industry* (A)
10.32 *G. C. Williams* 3–0–6
Development of original power in the solution of problems in chemical industry covering a wide range of topics, with quantitative analysis of various factors under the control of the designer to determine optimum design from the viewpoint of cost and economic return. Economic balance applied to unit operations and processes.

APPLIED CHEMISTRY

10.62 *Advanced Thermodynamics* (A)
10.40 *Meissner* 3–0–6
Further study of physical and chemical equilibria, particularly in heterogeneous systems. Special emphasis on prediction of thermodynamic properties by theoretical and empirical techniques. Consideration of the effects of surface and force field energies.

10.63 *Molecular Forces and Properties of Matter* (A)
5.42, 5.62 *Michaels* 3–0–6
Review of atomic and molecular interactions and their importance in determining physical and chemical properties of matter. Gas-law deviations; viscosity of fluids; volatility, surface tension, and miscibility of liquids. Crystalline and amorphous solids; mechanical and thermal properties of crystalline solids; rheologic and elastic phenomena in amorphous solids with emphasis on synthetic and natural polymeric substances. Role of molecular architecture in determining non-Newtonian flow behavior, rubberlike elasticity, stress-induced orientation, and microcrystallinity in polymers. Techniques for characterizing molecular structure and for predicting properties of solid, liquids, and gases.

10.65 *Applied Chemical Kinetics* (A)
5.62, 10.29 *Satterfield* 3–0–6
Analysis of problems involved in carrying out chemical reactions in the plant, including study of theories of reaction kinetics and catalysis.

10.66T *Colloid Chemistry* (A)
5.42, 5.62 *Michaels* 3–0–6
The colloidal state of matter and the characteristics and behavior of colloids; natural colloids and different methods of producing matter in the colloidal state; methods applied in the study of substances in the colloidal state.

10.67 *Applied Surface Chemistry* (A)
10.21 or 10.63 or 10.66T *Michaels* 3–0–6
Structure and properties of interfaces; functions and uses of surfactants; emulsification, foaming, detergency. Dispersion and flocculation mechanisms and their effects on sedimentation, filtration, suspension-rheology. Flow through porous media. Thermodynamics and kinetics of nucleation and crystal growth. Adhesion and adhesives. Application of surface phenomena to chemical process technology.

10.69 *High Polymer Technology* (A)
5.42, 5.62 *Michaels* 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.

10.70 *Principles of Combustion* (A)
—— *Hottel* 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.

10.72 *Selected Combustion Problems* (A)
—— *G. C. Williams* 2–0–4
Seminar on advanced problems in combustion. Flame stabilization, simultaneous mass and heat transfer at phase interfaces where combustion occurs, flame propagation, mixing and mixedness, compressible flow, ignition, and combustion models. Sessions led by various staff members and research students.

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

10.74 ***Principles of Furnace Design*** **(A)**
10.31 *Hottel* 3–0–6
Radiant heat transmission in application to engineering equipment operating at high temperature. Radiation geometry; mathematics of interchange in enclosures; 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, retorts, or still settings.

SCHOOL OF CHEMICAL ENGINEERING PRACTICE

(See also 22.01–22.03 Engineering Practice School at Oak Ridge)

10.81T ***School of Chemical Engineering Practice — Bayway Station*** **(A)**
10.32 *Reid* 0–24–0
Conducted in the refinery area of Esso Standard Oil Company, Linden, New Jersey: large scale production of gasoline, heating oils, tars, petrochemicals, and other petroleum products. Operations in all phases of petroleum refining and purification, including the manufacture of many petrochemicals. Opportunity to study problems in all phases of mass and heat transfer, kinetics, instrumentation, and other engineering operations.

10.82T ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
10.32 *Reid* 0–24–0
Conducted in the main plant of the Organic Chemicals Division of American Cyanamid Company at Bound Brook, New Jersey. Highly diversified operations, including process development and production of dyes, synthetic pharmaceuticals, organic pigments, rubber chemicals, intermediates, textile chemicals, plastics, resins, and related products.

10.83T ***School of Chemical Engineering Practice — Bayway Station***
10.32 *Reid* 0–18–0
Similar to 10.81T. For seniors during the second period of the academic year.

10.84T ***School of Chemical Engineering Practice — Bound Brook Station***
10.32 *Reid* 0–18–0
Similar to 10.82T. For seniors during the second period of the academic year.

GENERAL

10.90 ***Experimental Research Problem*** **(A)**
—— *G. C. Williams* *
For special and graduate students who wish to carry out some minor investigation in a particular field. Subject and hours arranged to fit individual requirements.

10.991, 10.992 ***Seminar in Chemical Engineering*** **(A)**
10.32 *Mickley* 2–0–4
For graduate students engaged on doctorate theses.

12.
Geology and Geophysics

12.00 ***Earth Science (Geology, Geophysics, Geochemistry)***
—— *Pinson* 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 various features of bed rocks and glaciation.

12.001 ***Astronomy***
—— *Pinson* 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.

12.003, 12.004 ***Physical Oceanography I and II***
M22 *Staff* 3–0–6
Different aspects of the ocean and its relations to the atmosphere and the solid earth. Lectures varying from year to year and, in general, given by staff from Woods Hole Oceanographic Institution.

12.011 ***Mineralogy I***
5.02 *Dennen* 3–4–3
Study of the more common minerals, their crystal structure and crystal chemical relationships. Introduction to common rock types. Hurlbut, *Dana's Manual of Mineralogy.*

12.012 ***Mineralogy II***
12.011 *Dennen* 3–4–3
Intensive study of minerals with emphasis on determinative methods. Use and occurrence of minerals. Identification and classification of rocks. Huribut, *Dana's Manual of Mineralogy.*

12.05 *Mineralogical Seminar* (A)
12.202 *Buerger* 2–0–4
Presentation and discussion of literature bearing on certain phases of theoretical mineralogy.

12.14 *Petrology*
12.011, 12.301 *Fairbairn* 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.*

12.15 *Petrology Laboratory*
12.231 *Fairbairn* 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.*

12.161, 12.162 *Mineral Deposits and Petrology Seminar* (A)
12.14, 12.40 *Hurley, Fairbairn*
2–0–4
Discussion of igneous and metamorphic rocks, mineral deposits, and problems bearing on their genesis. (*Alternate years. Not offered 1958–59.*)

12.17 *Advanced Petrology Laboratory* (A)
12.15 *Fairbairn* 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.

12.201 *Crystallography*
—— *Buerger* 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; and equipoints. Buerger, *Elementary Crystallography.*

12.202 *Crystallography*
12.201 *Buerger* 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.

12.231 *Optical Crystallography*
12.011 or 12.201 *Fairbairn* 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.*

12.232 *Advanced Optical Crystallography* (A)
12.231 *Fairbairn* 0–3–1
Determination of the optical properties of crystals using Universal stage, minimum-deviation, and variable temperature-wavelength methods. Opportunity to undertake optical research problems.

12.27 *Crystallographic Research* (A)
12.201 *Buerger* *
Supervised research on some crystallographic problem.

12.301 *Physical Geology*
—— *Dennen* 3–4–4
Objective study of the earth including geological agents and processes. Structural relations of rock masses. Laboratory and field exercises.

12.302 *Historical Geology*
12.301 *Boucot* 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.

12.303 *Geological Surveying*
12.301 *Parks* 0–7–0
At Nova Scotia Centre for Geological Sciences. Training in surveying methods and in handling instruments commonly used by geologists in the field.

12.304 *Field Investigations and Reports*
12.301 *Staff* 0–17–0
At Nova Scotia Centre for Geological Sciences. Geological examination of areas selected for either scientific or economic interest. Specific areas assigned to each group of students for survey and preparation of geological sections, maps, and reports.

12.308T *Sedimentation and Stratigraphy*
12.302 *Mencher* 3–4–5
Principles and data on which geologic column is based. Regional study of geologic formations and structure. Advanced historical geology.

12.321 *Engineering Geology*
—— *Brace* 2–2–2
Geology adapted to the needs of engineers.

12.322 *Engineering Geology*
12.321 *Brace* 2–0–4
Relations of geology to engineering problems, with reviews of actual cases.

12.40 *Mineral Deposits*
12.011, 12.301 *Hurley* 3–0–5
Occurrence and origin of ore deposits. Lindgren, *Mineral Deposits*, Fourth Edition.

12.41 *Mineral Deposits Laboratory*
12.301 *Hurley* 0–4–0
Determination of ore minerals by microchemical analysis and by use of the metallographic microscope on polished sections; study of mineral relationships for the interpretation of processes of deposition. Short, *Microscopic Determination of the Ore Minerals* (U.S.G.S. Bull. 914).

12.432 *Advanced Mineral Deposits Laboratory* (A)
12.40 *Hurley* 0–4–1
Study of specimens or suites of specimens from mineral deposits; metallographic or petrographic work.

12.44 *Petroleum Geology*
12.308T, 12.702 *Mencher* 3–0–5
Nature and origin of petroleum and natural gas. Factors responsible for accumulation of oil and gas, illustrated by a study of typical oil fields. Application of geologic principles to location and evaluation of new fields.

12.45 *Petroleum Geology Laboratory*
12.44 *Mencher* 0–4–2
Methods of illustration and interpretation of oil field data, in conjunction with principles discussed in 12.44.

(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.

12.461T, 12.462T *Petroleum Geology Seminar* (A)
12.44 *Mencher* 2–0–6
12.461T *Mencher* 2–0–6
Discussion of stratigraphy and structure of principal oil-bearing areas of the world, with reference to the tectonic setting. (*Alternate years. Not offered 1958–59.*)

12.51T *Paleontology*
12.302 *Boucot* 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.*

12.52T *Advanced Topics in Paleontology* (A)
12.51T *Boucot* 2–0–6
Advanced topics in paleontology, including problems of evolution, paleontology, and animal geography.

12.58 *Sedimentary Petrography*
12.15 *Boucot* 2–6–2
Petrography of sediments and sedimentary rocks, with emphasis on their chemical and mineralogical composition. Although not required, 12.308 recommended.

12.581T *Sedimentology*
12.308T *Shrock* 2–0–6
Survey of the chief types of sediments and sedimentary rocks, with some consideration of the environmental conditions under which sediments are formed and deposited. Shrock, *Sequence in Layered Rocks.*

12.582 *Advanced Sedimentology* (A)
12.581T *Boucot, Mencher* *
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. Arranged to suit preparation and requirements of individual students.

12.583T *Sedimentology Seminar* (A)
12.308T *Shrock, Mencher, Boucot* 2–0–6
Discussion of latest literature on the origin, deposition, classification and significance of sediments and sedimentary rocks. (*Alternate years.*)

12.65 *Special Problems*
—— *Staff* *
For seniors desiring special laboratory or field work on geologic problems.

12.66 *Special Problems* (A)
—— *Staff* *
For graduate students desiring special investigation of some geological subject or special laboratory or field work on geological problems.

12.702 *Structural Geology*
12.301 *Brace* 3–2–6
Elementary survey of rock structures and mechanics of rock deformation. Development of elementary concepts of plastic flow and fracture of materials. Within this framework, discussion of observed strains in all classes of rocks in relation to mineral deposits, intrusion and metamorphism. Laboratory work stressing map and rock interpretation and developing skill in three dimensional visualization. At least five days of field work near Boston mapping various structures. Billings, *Structural Geology*, and Jaeger, *Elasticity, Fracture and Flow.*

12.721 *Special Topics in Tectonics* (A)
12.73T *Staff* *
Topics varying from year to year. Seminar discussion of such subjects as plasticity, gravity tectonics, theories of mountain building and associated metamorphism. Open only to properly qualified graduate students.

12.722 *Tectonics Seminar* (A)
12.15, 12.702 *Fairbairn* 2–0–4
Introduction to microtectonics and experimental rock deformation, with discussion of regional structures to which petrofabric methods have been applied. Assigned reading and reports. (*Alternates with 12.162.*)

12.73T *Advanced Structural Geology*
12.702 *Brace* 3–2–6
Further application of mechanics to a number of structural problems. Laboratory work on regional problems, and field trips to various parts of the Appalachian Mountain system

12.801, 12.802 *Theoretical Geology I and II*
M351 *Hughes* 3–0–9
12.801 *Hughes* 3–0–9
Application of the physics of solids to geological problems, including estimation of changes of elastic constants with depth, magnetism in rocks, phase transitions, optical absorption and radiative heat transfer, and excitation of solids giving rise to diffusion and electrical conduction in the earth. (*Alternate years;* 12.802 *not offered in 1958–59.*)

12.803 *The Earth's Interior* (A)
12.831 *Hughes* 3–0–9
Interpretation of the seismic velocity depth curve and geomagnetic data to infer the constitution and temperature of the Earth's interior. The degree of uncertainty in the conventional earth model will be specially considered so that the plausibility of current hypotheses in this field may be assessed. (*Alternates with* 12.804. *Not offered 1958–59.*)

12.804 *The Earth's Crust* (A)
12.831 *Hughes* 3–0–9
Discussion of the physics of the crust and its deformation. Poldervaart, *The Crust of the Earth.* (*Alternates with 12.803.*)

12.811, 12.812 *Geochemistry I and II*
5.61 *Winchester* 3–0–6
5.62, 12.811 *Winchester* 3–0–6
Discussion of principles of physical chemistry with application to geology; selected descriptive inorganic chemistry stressing the periodic table, organic and inorganic complexes and analytical applications; geochemical behavior of the elements; abundances of elements, nuclear reactions, and theories of the origin of the elements.

12.82 *Spectrochemical Analysis* (A)
12.811 *Dennen* 2–2–3
Elementary theory of spectroscopy. Excitation sources, particularly the D-C arc discharge. Qualitative and quantitative analysis with particular emphasis on the analysis of minerals, rocks and soils with the D-C arc. Ahrens, *Spectrochemical Analysis.*

12.831, 12.832 *Elements of Geophysics I, II*
8.041, M22 *Doell* 3–0–9
12.831 *Doell* 3–0–9
Gravity and its relation to the earth's shape, constitution and surface features; the earth's magnetism, including the effects of surface irregularities and magnetic properties of materials; seismology, elastic wave propagation, and seismic interpretation of earth structures; electrical characteristics. Emphasis on fundamentals and earth problems, with some applications to exploration geophysics.

12.833 *Geophysical Laboratory*
12.831 *Doell* 2-4-2
Theory, description and study of geophysical field measuring apparatus, extension of basic geophysical concepts to exploration applications, and data interpretation. Field work covering gravity, magnetic, electrical, and seismic surveys over local geologic structures.

12.851, 12.852 *Geophysical Analysis and Computation* (A)
12.874, M352 *S. M. Simpson* 2-1-6
12.851 *S. M. Simpson* 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.

12.86 *Elements of Seismology*
M22 *Doell* 2-0-4
Brief review of seismic elements; special elastic wave propagation problems of current interest; methods of treating random or quasi-random seismic data and propagation problems.

12.873, 12.874 *Advanced Geophysics* (A)
M352 *Staff* 3-0-6
12.873 *Staff* 3-0-6
Mathematical and physical basis of the phenomena studied in earth physics and exploration geophysics, with emphasis on the theory of quantitative interpretation of geophysical data. Potential theory as applied to gravity, magnetism, electricity and heat flow. Elasticity and seismic wave propagation; electromagnetic induction and wave propagation.

12.88 *Geophysics Seminar* (A)
12.874 *S. M. Simpson* 2-0-4
Topics selected from problems of current geophysical interest; subject matter varying from term to term.

12.89 *Isotope Geology* (A)
8.04, 12.301 *Hurley* 2-0-4
Measurement and uses of the relative abundance of isotopes in geological materials; methods of measuring geological time, radioactive production of heat, and the quantity of radioactive elements in rocks and minerals, with demonstrations.

12.91 *Elements of Mining*
—— *Parks* 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 operating properties.

12.92 *Mining Methods and Practice*
12.91 *Parks* 3-0-6
Mining systems, costs, engineering and administration. Adaptability and operation of representative methods of mining as applied to either open-pit or underground mining of metals and non-metallics. Opportunity for mine inspection trips.

12.94 *Mineral Economics*
—— *Parks* 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.

12.95 *Valuation of Mineral Property* (A)
12.92 *Parks* 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.*

12.96 *Mineral Economics Seminar* (A)
12.94 *Parks* *
Detailed study or report on a particular mineral, area, or condition developing in the mineral field.

12.97 *Mineral Valuation Seminar* (A)
12.95 *Parks* *
Optional study; engineering report on valuation of a mineral or oil property, or detailed investigation of some phase of the problem, e.g., taxation.

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13.

Naval Architecture and Marine Engineering

13.01T *Naval Architecture I*
8.01, M21 *Allmendinger* 2–2–5
Hydrostatics applied to naval architecture: buoyancy and stability of ships in intact, damaged and partially waterborne conditions; freeboard and subdivision; problems in the launching of ships.

13.012 *Naval Architecture*
2.25, 13.01 *Abkowitz* 3–1–5
Combination of material in 13.01 and 13.02, including laboratory exercises. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*)

13.02 *Naval Architecture II*
2.25, 13.01 *Abkowitz* 3–1–5
Dynamics of naval architecture: resistance, propulsion, oscillation and steering of ships and design of propellers and rudders. Laboratory work consisting of towing tests of ship models in the towing tank and tests of propeller models in the cavitation tunnel.

13.03T *Principles of Ship Design* (A)
13.46 *Mandel* 2–4–5
Principles and procedures involved in the preparation of the preliminary design of ships.

13.031 *Preliminary Design of Ships* (A)
13.03 *J. H. Evans, Powell* *
Preparation of the preliminary design of a ship selected by the student; emphasis on hull or engineering aspects to suit interests of the student. Fulfills the Department's requirement of a comprehensive design problem for the Engineer degree.

13.04 *Advanced Ship Design* (A)
13.03 *Arentzen* 2–0–8
Seminars dealing with problems in naval architecture and ship design more advanced than those given in the undergraduate Course. Historical development, basic design of various types, structural design, stability in the damaged condition, subdivision, powering, analysis of performance, economics of design, general arrangement, cargo handling, launching, heating, ventilation, air conditioning, hull piping systems, etc. Discussion of naval and merchant vessels.

13.05 *Advanced Hydromechanics of Ship Design* (A)
13.02 *Abkowitz* 3–0–5
Advanced work in the fields of ship resistance, propulsion, seakeeping, excited oscillations, directional stability, automatic control, and allied topics. Discussion of model research techniques and recent research and progress in ship hydrodynamics.

13.06 *Special Problems in Naval Architecture and Marine Engineering* (A)
—— *Troost* *
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.*

13.12 *Warship General Arrangements* (R)
13.20 *Arentzen* 3–0–5
Principles involved in the general arrangements of warships 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.*)

13.13 *Warship Structure Theory I* (RA)
2.046, 2.081 *J. H. Evans* 3–0–6
Stresses in a warship and the design of the hull structure. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.14 *Warship Structure Theory II* (RA)
13.13 *J. H. Evans* 3–0–6
Continuation of 13.13, including problems peculiar to submarines. Lectures and seminars. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.15T *Warship Basic Design I* (RA)
13.012, 13.12, 13.13 *Mandel* 2–4–5
Principles and procedures to be followed in the preparation of the preliminary design of warships. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.16 *Warship Basic Design II* (RA)
13.12, 13.22 *Arentzen* 3–0–6
Fundamental considerations involved in the selection and provision of the military features of warships. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.17 *History of Warships* (R)
—— *Arentzen* 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.*)

13.20 *Elementary Warship Design* (R)
—— *Arentzen* 1–7–2
Indoctrination lectures on elementary principles of warship design and statics of naval architecture. Work in the drawing room on fairing of warship lines, calculations for and drawing of displacement and other curves, cross curves of stability, curves of statical stability and floodable length curves for a warship from preliminary design data. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.22 *Warship General Design* (R)
13.012, 13.12, 13.20 *Mandel* 0–5–0
Analyses of general arrangement problems and the preparation of general arrangement plans. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.24 *Warship Structure Design I* (RA)
13.13 *Mandel* 0–5–0
Determination of requirements for longitudinal strength of a warship, the preparation of a structural design for a midship section and arrangement of shell and deck plating and framing. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.241 *Warship Structure Design I* (RA)
13.13 *Mandel* 0–3–0
Abridgement of 13.24, including only the preparation of a structural design for a midship section. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.25 *Warship Structure Design II* (RA)
13.14, 13.24 *J. H. Evans* 0–5–0
Continuation of 13.24, including the preparation of structural designs for a transverse bulkhead, stem and bow framing, stern framing with stern post and propeller struts and a transverse strength analysis. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.26 *Preliminary Design of Warships* (RA)
13.15, 13.16 *Arentzen* 0–9–0
Work in the drawing room, including the preparation of the necessary plans and calculations for the preliminary design of a warship. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.43 *Ship Structural Drawing*
13.45 *J. H. Evans* 0–3–0
Design of a ship's structure in compliance with the requirements of the American Bureau of Shipping Rules, checking the adequacy of the structure by the balancing of the ship on a wave to determine the bending moment, and calculating the moment of inertia of the mid-section of the ship to establish the maximum stress in compression and tension.

13.45 *Ship Structures*
2.002, *13.02* *J. H. Evans* 3–0–6
General and local stresses in ships, both longitudinal and transverse, including some consideration of dynamic loads. Shipbuilding materials, structural sections, continuous beam and elastic stability theories with application to ship structure. Lectures on riveting and welding, culminating in the factors involved in the design of the midship section longitudinally continuous material; examination of bulkheads and framing from the theoretical aspects in conjunction with American Bureau of Shipping Rules requirements.

13.46 *Ship Design*
13.02, 13.43, 13.53 *Allmendinger* 1–8–2
Lectures on the basic principles of ship design and the methods of preparing the preliminary design of a ship. Drawing room work consisting of the preliminary design of a merchant ship, including the determination of principal dimensions and external form, internal arrangements to satisfy subdivision, cargo stowage and accommodation requirements, the design of the salient structural features, and the machinery and shafting arrangement.

13.52T *Marine Engineering I*
2.403, *13.02* *Powell* 2–0–4
Basic considerations, common calculations and performance of boilers, steam turbines, surface condensers, evaporators; steam conditions and cycles. Diesel engines, cycles, supercharging, scavenging, auxiliary plant. Effect of direct drive of propeller on Diesel. Gas turbine and reactor plants. Electric drive.

13.53 *Marine Engineering II*
1.611, 2.42, 6.18, 13.52 *Powell* 3–0–5
Heat balance, steam cycles, auxiliary requirements. Characteristics of pumps and centrifugal fans; multistage steam turbine steam path, its efficiency and performance; reduction gears. Steam piping system. Properties of machinery for ship propulsion and auxiliary machinery. Electrical equipment, particularly electric motors, generators, and distributing systems; ventilation equipment and pumps.

13.54 *Marine Engineering Dynamics*
2.002 *F. M. Lewis* 2–0–4
Dynamic problems of marine engineering. Elementary vibration theory, the balance of rotating and reciprocating machinery. Torsional vibration of reciprocating machinery, vibration of turbines, vibration of ships.

13.56 *Marine Engineering Economics* (A)
6.18, 13.02, 13.53 *Powell* 3–0–9
Economic aspects of marine engineering; comparison of fuels, and the various types of steam and Diesel propelling machinery for different types of ships and trade routes; the economical operation of propelling machinery and auxiliaries at sea and in port; heat balances; boilers, main engines, auxiliaries and auxiliary systems; turboelectric and Diesel-electric drives; gas turbine developments. Nuclear plants. (*Alternate years. Not offered 1958–59.*)

13.61 *Marine Engineering Design III*
2.002 *Powell* 1–4–0
Design projects including dynamic forces and stresses on selected marine machinery parts and provisional design of same.

13.62 *Marine Engineering Design IV*
13.53, 13.61 *Burtner* 1–4–0
Heat transfer principles, application to marine heat transfer equipment: condensers, lubricating oil cooler, boiler equipment. Special design projects, propeller-blade-hub construction.

13.711 *Ship Machinery Design I* (A)
13.53, 13.54 *Powell* 2–0–4
Lectures and seminars on the design of important components of ship propulsion plants. Students to attend selected lectures in 13.76 and prepare one or more seminar papers based on outside reading in an area of interest. Background in marine engineering is required; registration is accepted only after consultation with the instructor in charge.

13.721 *Ship Machinery Design II* (A)
13.53, 13.54 *Powell* 2–0–4
Lectures and seminars on the design of important components of ship propulsion plants. Students to attend selected lectures in 13.76 and prepare one or more seminar papers based on outside reading in an area of interest. Background in marine engineering is required; registration is accepted only after consultation with the instructor in charge.

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13.73 ***Mechanical Vibration*** **(A)**
2.002 or 2.046 *F. M. Lewis* 3–0–6
The 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; the balance of rotating machinery and reciprocating engines; the elements of torsional vibration problems in reciprocating engines.

13.74 ***Mechanical Vibration*** **(A)**
13.73 *F. M. Lewis* 4–0–8
Advanced theory of the torsional vibration of reciprocating engines, including uniform distributions, forced vibration, calculation of amplitude, branched systems, etc. The transverse vibration of uniform and irregular beams and the application to the vibration of turbines and other rotating machinery; Rayleigh's, Stodola's and other methods; separation of normal modes of vibration; vibration isolation; Lagrange's theorem; nonlinear systems; self-sustained oscillation. Transient response of linear systems; dynamics and stability of control systems.

13.75 ***Warship Propulsion I*** **(RA)**
2.402, 2.501 *Thornbury* 3–2–6
Critical interpretation leading to useful application of the formal and theoretical content of naval engineering to foster discrimination in practice. Selection of machinery units supported by related design studies and calculations. Lectures, outside reading, critiques. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.76 ***Warship Propulsion II*** **(RA)**
13.75 *Thornbury* 2–4–4
Continuation of 13.75 with emphasis on the propulsion plant as a whole and its arrangement. Supported by studies and calculations. Selection and arrangement of machinery with emphasis on student exploration. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.791 ***Marine Propellers*** **(A)**
1.612 or 2.25; *13.012* or 13.02 *Troost, Powell* 3–0–6
Theories of propeller action. Propeller testing procedure. Methods of presenting propeller test data. Application of theories and test data to propeller selection. Maneuvering and towing performance. Cavitation criteria. Theoretical and mathematical basis of modern airfoil theory and its application to design. Strength of propeller blades.

13.90 ***Warship Electrical Engineering*** **(RA)**
6.18, 6.19 *Thornbury* 3–0–4
Review of basic electrical engineering, including single-phase and polyphase electric circuits, magnetic circuits and transformers, and electric machines. Critical examination of these electrical engineering principles as applied to the generation and distribution of electric energy in warships; system design; selection of machinery and equipment; the application of new developments in electrical engineering practice to warship electrical systems. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

13.91T ***Advanced Warship Electrical Engineering*** **(RA)**
6.10, 6.213 *Thornbury* 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.*)

13.92 ***Problems in Shipyard Management*** **(A)**
14.61 or 15.30 *Thornbury* 3–0–6
Application of industrial management technique to problems of shipyard management at both policy and operating levels, with emphasis on (though not restricted to) naval shipyards. Work at an advanced level to suit the needs of students with prior experience in shipyard management. (Experience to be evaluated by instructor in charge, prior to acceptance of enrollment.) Broad coverage of all facets of shipyard management with specific coverage of such topics as comptrollership, production planning and control, and labor-management relations in private industry and government. Many guest lecturers from management in private industry and government.

14.
Economics and Social Science

GENERAL ECONOMICS AND THEORY

14.01 ***Economic Principles I***
21.02 *E. C. Brown* 3–0–5
Introduction to fundamental economic concepts, such as production, money, banking, labor, business organization, government fiscal policy, with emphasis upon the level and fluctuations in national income and employment. Current economic problems.

14.02 ***Economic Principles II***
14.01 *Adelman* 3–0–5
Continuation of 14.01. The composition and pricing of output of particular industries, supply and demand analysis, competition and monopoly, and international trade. Current economic problems.

14.03 *Prices and Production*
14.02 *Bishop* 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 the distribution of income; introduction to the concept of general equilibrium.

14.04 *Industrial Organization and Public Policy*
14.02 *Adelman* 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.

14.09 *Economic Problems Seminar*
14.02 *Kindleberger* 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.*)

14.101 *Mathematics for Economists*
—— *H. A. Freeman* 3–0–6
Introduction to mathematical methods, with emphasis on topics useful in economics, analytic geometry, differential calculus, problems in maxima and minima, functions of several variables. Allen, *Mathematical Analysis for Economists.*

14.102 *Mathematics for Economists*
14.101 *Ando* 3–0–6
Continuation of 14.101. Functions of several variables, integral calculus, Taylor series, elementary determinants and matrices. Allen, *Mathematical Analysis for Economists.*

14.114 *Economics and Finance: Principles and Policies I*
—— *E. C. Brown* 4–0–9
Introductory discussion of the determination of national income and its fluctuations; the composition and pricing of output; financial institutions and the functioning of money and capital markets; fiscal and other stabilization policies; industrial economics, price policy and the relations of government and business; and international economics. (*Restricted to Sloan Fellows.*)

14.115 *Economics and Finance: Principles and Policies II*
14.114 *R. E. Freeman* 3–0–6
Continuation of 14.114. (*Restricted to Sloan Fellows.*)

14.116 *Economics and Finance: Principles and Policies III* (A)
14.115 *Kindleberger* 3–0–6
Continuation of 14.115. (*Restricted to Sloan Fellows.*)

14.117 *Economics and Industrial Management*
—— *Solow, E. C. Brown* 3–0–6
Introduction to measurement and determination; interpretation of national income and national product; economic fluctuations and effectiveness of stabilization policies, especially monetary and fiscal. (*Restricted to graduate students in Course* XV.)

14.121, 14.122 *Economic Analysis* (A)
14.03 *Bishop* 3–0–6
14.121 *Samuelson* 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.

14.132 *Schools of Economic Thought* (A)
14.121 *Bishop* 3–0–6
Economic ideas developed by different groups of economists in recent times.

14.151 *Mathematical Approach to Economics* (A)
14.122 *Samuelson* 3–0–6
Use of mathematical methods in all fields of economics.

14.161 *Economic History* (A)
14.121 Letwin 3–0–6
Analysis of development of world economy and major national economies in terms of theory of economic growth, 1750–1873.

14.162 *Economic History* (A)
14.121 Letwin 3–0–6
Analysis of development of world economy and major national economies in terms of theory of economic growth, 1873 to present.

14.171 *Theory of Economic Growth* (A)
14.122, 14.451 *Rosenstein-Rodan* 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.

14.172 *Research Seminar in Economic Development* (A)
14.171 *Millikan* 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.

14.174 *Non-Economic Factors in Economic Growth* (A)
14.171 *Hagen* 3–0–6
Psychological, social, and political factors as causal in economic growth. The interrelations among personality characteristics, systems of belief, and social structure in economic growth, with emphasis on society as a system, and on empirical materials. Motivations, values, "world view"; traditionalism, religion, nationalism; kinship structure, class structure, legal systems, political structure; communication patterns; etc.

14.182 *Capitalism, Socialism and Growth* (A)
14.121, 14.451 *Domar* 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.

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14.191, 14.192 *Economics Seminar* (A)
14.121 —— 3–0–6
Special social problems or economic problems of particular industries. (*Open to graduate students only.*)

14.195, 14.196 *Reading Seminar in Economics* (A)
14.121 —— *
Reading and discussion of special topics in economics. Open to advanced graduate students by arrangement with individual members of the staff.

—— ——

INDUSTRIAL ECONOMICS

14.21 *Economics of Invention*
14.01 *Maclaurin* 3–0–5
Discussion of the process of research, invention and innovation in relation to economic development in the United States and other countries.

14.271 *Problems in Industrial Economics* (A)
14.03 *Adelman* 3–0–6
Small and large enterprises in the American economy; market structures; degrees of monopoly and competition; requisites of public policy.

14.272 *Government Regulation of Industry* (A)
14.271 *Adelman* 3–0–6
Follows 14.271. Development of anti-trust policy, generally and in specific cases. "Public utility" price fixing, government ownership as alternative.

14.281 *Entrepreneurship, Innovation and Economic Development* (A)
14.03 *Maclaurin* 3–0–6
The theory of innovation and its relation to capital formation; innovation and growth models; the impact of scientific research and technology; the clustering of innovations in relation to business cycles; measurement of innovation; classification of different types of industries; the role of the innovative and imitative entrepreneur in the economic development; difference in entrepreneurial types; contrasts and comparisons with entrepreneurship in selected countries in Europe and Asia.

14.282 *Economics of Innovation Seminar* (A)
14.281 *Maclaurin* 3–0–6
The theory and practice of industrial innovation; resistance to change; formulas for the measurement of resistance; methods of introducing innovations; classification of innovative types; sampling limitations; case studies of innovation in this country and abroad; innovative problems. Entrepreneurs in selected American industries will be invited to discuss the solutions offered.

14.291, 14.292 *Industrial Economics Seminar* (A)
14.271 —— 3–0–6
Readings, discussions, reports on such topics as industrial price policies, government regulation of industry, competitive practices and other phases of industrial economics.

STATISTICS

14.31 *Elementary Statistics*
M12 *Ando* 3–0–5
Introduction to statistical methods. Frequency distributions, moments, elements of probability, probability distributions, elements of sampling, confidence limits, regression and correlation of two variables. (Similar to 15.02 and 14.381.)

14.32 *Statistical Quality Control*
14.31 *H. A. Freeman* 3–0–6
Application of statistical methods to industrial problems including sampling inspection, quality control, and engineering tolerances. Duncan, *Quality Control and Industrial Statistics*.

14.371 *Statistical Theory*
M21 *H. A. Freeman* 3–0–6
Elementary but mathematical viewpoint. Random variables, elements of probability, mathematical expectation, generating functions, probability distributions, sampling theory, correlation and regression, elements of the theories of estimation and testing hypotheses.

14.372 *Statistical Theory*
14.371 *H. A. Freeman* 3–0–6
Maximum likelihood, Markoff estimates, stochastic processes, sequential analysis, introduction to game and decision theory.

14.374 *Design and Analysis of Scientific Experiments G* (A)
14.31 or 14.371 or M32 *H. A. Freeman* 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.

14.381 *Statistical Method*
—— *Ando, Durand* 3–0–6
Elements of probability, sampling, statistical inference, and the design and analysis of experiments, with emphasis on industrial applications and their interpretation, rather than on manipulation. (Similar to 15.02 and 14.31.)

14.382 *Economic Statistics* (A)
14.371 *Solow* 3–0–6
Study of selected statistical techniques which have been found useful in recent economic work, especially the regression analsis of economicy time series.

14.391 *Research Seminar in Economics* (A)
14.122, 14.371 *Solow* 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 each year.

NATIONAL INCOME AND FINANCE

14.40 *Money and Income*
14.02 *R. E. Freeman* 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.

14.43 *Public Finance*
14.02 *E. C. Brown* 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.

14.451 *National Income* (A)
14.40 *Millikan* 3–0–6
The principles of social accounting with special reference to the national income accounts of the United States; the uses of national income accounts; the theory of aggregate spending and of equilibrium levels of national income and employment.

14.461 *Monetary and Banking Problems* (A)
14.40 *Bator* 3–0–6
Commercial and central banking in relation to price levels and employment. Analysis of such problems as bank asset management, Federal Reserve organization and policy, interest rates, money markets, the Treasury and the banking system, proposals for monetary reform with some historical background.

14.472 *Fiscal Policy* (A)
14.451 *E. C. Brown* 3–0–6
Analysis of alternative tax, expenditure, and debt policies with particular reference to the federal government; relation of various fiscal policies and procedures to economic stability and progress; relation of fiscal to monetary policy.

14.481 *Business Cycles* (A)
14.451 *Solow* 3–0–6
Statistical, historical, and theoretical examination of determinants of income, production and employment. Modern methods of analysis, forecasting, and control.

INTERNATIONAL ECONOMICS AND RELATIONS

14.51 *International Relations*
21.04 *Padelford* 3–0–5
Basic factors in world politics: the influence of geography, demography, economic resources, nationalism upon national power and foreign relations. Power politics and the balance of power system. The formation and conduct of foreign policy. The United Nations and regional arrangements. The search for national and collective security.

14.52 *Principles and Problems of American Diplomacy*
14.51 *Pye* 3–0–5
The underlying assumptions, basic principles and major objectives of American foreign policy. Some of the leading issues confronting American diplomacy today, including changing patterns of alignment, programs of economic and technical assistance, and domestic problems of policy making.

14.521 *Strategic and Political Geography*
—— —— 3–0–6
Geography as a basis of national economy. Geography of natural resources, including raw materials and sources of energy; their bearing on economic development and national security. Theories of utilization of land, sea, and air space. Global patterns and critical areas in politics and strategy. (*Not offered 1958–59.*)

14.523 *National Security and Military Technology* (A)
14.52 or 14.521 *Eastman, J. McCormack* 3–0–6
Analysis of major changes in science and technology affecting military capabilities, strategy and national security. Political implications of military technology; functional relationship between technology, military doctrine and foreign policy; problems posed for national security by the advent of nuclear energy.

14.524 *Politics and National Defense Policy* (A)
14.523 —— 3–0–6
Formulation and execution of national defense policy; the process which relates science, industry, the public, Congress and the Executive to the military in making decisions on national defense problems, including budgeting of national resources and use of manpower in war and peace.

14.526 *Research and Development for Military Purposes*
14.52 or 14.523 *Eastman* 3–0–6
Management of military research and development in the U. S., including national policy and organization; the problem of ascertaining those relations among scientists, politicians, the military services, and industry that will best facilitate the generation of new ideas and the further development of military technology; case studies.

14.53 *Seminar in International Politics*
14.52 —— 3–0–5
Selected problems designed to complete a three-term sequence in international relations. Problems varying from year to year with special emphasis on the nations of Asia and the Pacific area.

14.531 *Asian Politics and United States Foreign Policy* (A)
14.121 or 14.52 *Pye* 3–0–6
Processes of social change and problems of political stability in modern Asia, and an examination of American policy interests in the area. Factors influencing political behavior in changing societies.

14.533 *Social Science and U. S. Foreign Policy* (A)
14.117 *Millikan* 3–0–6
The contributions which modern research in the social sciences can make to the solution of problems faced by the United States in the modern world. Problems on which the Center for International Studies is currently conducting active research in the fields of international communications, economic and political development, and United States-Communist Bloc Relations.

14.534 *National Interest and Principles of International Cooperation* (A)
14.52 or 14.533 *Bloomfield* 3–0–6
The relationship of national foreign policy objectives to programs of the United Nations and related international organizations. Implications for U. S. foreign policy of participation in the U. N. and of current trends. Concepts of national interest and common interest, and of instrumentalism versus institutionalism. Illustrative problems of policy making.

14.54 *International Trade*
14.01; 14.02 or 14.51 *Kindleberger* 3–0–5
Theory of international trade and finance, and application to current problems, such as exchange restrictions, economic development, and foreign aid.

14.55 *Basic Ideas of Western Politics and Ethics 500 B.C.–1500 A.D.*
21.04 *Bursey* 3–0–5
Survey of development of fundamental ideas and institutions of Western Civilization. Discovery of generalized thinking — science — in the search for truth, ideas of predictability and fitness — law and justice — in the search for political stability, ideas of personality and soul in search for a meaningful life. Rise and collapse of scientific progress and political power in the Roman era, new start by early Christians with new attitude toward persons, work, and the universe, rise of communities and experimentation in new social order in Middle Ages, and such resulting western traditions as division of political and spiritual power and legacy of continuing technological and social changes in a self-transforming civilization.

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14.56 *The Rise of Modern Political and Social Science, 1500–1914*
14.55 or 21.51 or 21.52 *Bursey* 2–0–5
Continuation of approach of 14.55. Background of ideas represented by the Renaissance, Reformation, and Age of Reason, with the resulting new patterns of scientific and social thought. Conceptions of mechanism, organism, and society and their application to political and social problems. Attempts to apply reason to society, as illustrated by ideas of Machiavelli, Hobbes, Locke, Hume, Adam Smith, Madison, Robespierre and Kant. Changes in conservative position as shown by Burke, Hegel, Nietzsche, Cecil Rhodes, Spengler, and Pareto. Evolution of liberalism in Bentham, J. S. Mill, Herbert Spencer, and Lloyd George.

14.57 *Contemporary Ideas on Political and Economic Development*
Any two 14 or 21 subjects above 21.04 — 3–0–5
Evaluation of major political ideas from the 1890's to the present, with special attention to the problems that arise in their application to economic and political practice. Study of political ideas with regard to the actual performance by which they have been followed. The effects of ideas of liberalism on the actual extent of personal freedom. The effects of ideologies stressing economic growth on the course of economic development. The practices and institutions which conservative governments have been able to conserve in practice; and the extent to which the specific content of their conservatism has changed. Examination of the following political theories against a background of data from comparative politics and economic growth: the pragmatism and liberalism of John Dewey, William James, and J. M. Keynes; the pessimistic theories of Pareto and Spengler; Soviet Communism and "Titoism"; western economic planning and the welfare state; democratic socialism; Protestant and Catholic views of social reform; and current perspectives and trends in political and economic development. (*Not offered 1958–59.*)

14.58 *Nationalism and National Development*
Any two 14 or 21 subjects above 21.04 — 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. (*Not offered 1958–59.*)

14.571 *Major Problems in United States Foreign Policy*
—— *Padelford* 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, colonialism issues, the United Nations. (*Restricted to Sloan Fellows.*)

14.581, 14.582 *International Economics* (A)
14.40 *Kindleberger* 3–0–6
14.581 *Kindleberger* 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.

INDUSTRIAL RELATIONS

14.61 *Industrial Relations*
15.30 *D. V. Brown* 3–0–6
Structure and functioning of management and unions in the handling of industrial relations. Union policies and problems to which they may give rise. Reconciliation of union and management policies. Intended for students who do not plan to take 14.63 and 14.64.

14.63 *Labor Relations*
21.04 *Siegel* 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.

14.64 *Labor Economics and Public Policy*
14.01 or 14.73; 14.63 *Myers* 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.

14.662 *Human Relations and Labor Relations*
—— *Myers* 4–0–8
(1) The basic principles of human relations; (2) the place and functions of personnel administration, with emphasis on actual case situations; (3) the development of the American labor movement, significant union policies and practices, and basic issues raised by the present strength of unions. (*Restricted to Sloan Fellows.*)

14.671 *Problems in Labor Economics* (A)
14.61 *Myers* 3–0–6
Development of the labor movement, and detailed analysis of collective bargaining and union policies on wages, hours of work, entrance to the trade, hiring, layoffs and transfers, make-work and restriction of output, technological change, union-management cooperation, and industry-wide agreements. The economic aspects and effects of these policies. (*Not offered 1958–59.*)

14.672 *Public Policy on Labor Relations* (A)
14.61 *Myers* 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.

14.673 *Labor-Management Relations and Public Policy* (A)
14.672 *D. V. Brown, Siegel* 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, and selected problems in public policy. (*Restricted to Sloan Fellows.*)

14.674 *The Labor Movement: Theories and Histories* (A)
14.61 or 14.63 *Siegel* 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.

14.681, 14.682 *Seminar in Personnel Administration* (A)
14.61 *Pigors* 3–0–6
14.681 *Pigors* 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.

14.69 *Labor Problems Seminar*
14.64 *Siegel* 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.*)

14.691 *Research Seminar in Industrial Relations* (A)
14.671 or 14.672 *Myers* 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.

14.692 *Research Seminar in Industrial Relations* (A)
14.691 *Myers* 3–0–6
Continuation of 14.691.

14.693 *Collective Bargaining and Union-Management Cooperation* (A)
14.61 *Lesieur* 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.

14.694 *Seminar in Union-Management Cooperation* (A)
14.693 *Lesieur* 3–0–6
Seminar involving active participation in the work being done at a number of firms which are beginning or have developed union-management cooperation programs.

PSYCHOLOGY AND SOCIOLOGY

14.70 *Introductory Psychology*
21.02 *Howes, Swets* 3–0–5
Facts, principles, and theories of development, motivation, learning, memory, thinking, emotion, personality, communication, intelligence, and social processes.

14.71 *Personality and Social Structure*
14.70 —— 3–0–5
Socialization of the individual: the way in which the individual's personality develops in society. Communication, both from the point of view of interchange of information between individuals and the flow of information in social systems. Analysis of behavior in formal social systems. There will be a social psychological analysis of a factory system and of a modern industrial society. (*Not offered 1958–59.*)

14.73 *Organization and Communication in Groups*
21.02 *Gleicher* 3–0–5
This subject will deal with the problems in organization and communication in groups which have specific tasks to perform. Two-person situations, small informal groups, and larger organizations such as businesses, industrial firms, military units, etc., will be studied. The approach will be made from the point of view of social psychology.

14.75 *Experimental Psychology*
14.70 —— 3–0–5
Problems of method and procedure in the scientific study of living organisms. Analysis of and participation in psychological research. (*Not offered 1958–59.*)

14.77 *Psychology of Language and Communication*
14.70 *Howes* 3–0–5
Statistical and experimental studies of the psychology of language. The effects of verbal habits on perception, learning and communication.

14.771 *Interpersonal Relations Seminar*
—— —— 3–0–6
To improve the student's understanding in working with other people. Leadership and communication in a small group, interpersonal cooperation and competition, group creativity and productivity. Investigation through lectures demonstrations and exercises, but primarily by analysis of the changes that take place in the seminar group. (*Not offered 1958–59.*)

14.772 *Industrial Sociology Seminar* (A)
14.771 —— 3–0–6
Topical approach to problems of industrial and social organization including such topics as authority and power in organizations, cultural and social obstacles to and consequences of industrialization, morale and productivity in organizations, sociology of occupations and professions, social aspects of science and technology, role and personality in organizations.

14.774 *Social Psychology Seminar* (A)
—— *R. W. Brown* 3–0–6
Selected problems in social psychology; their origins and theoretical development; the methods and findings associated with them.

14.79 *Learning*
14.70 —— 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.

14.791, 14.792 *Reading Seminar in Social Science* (A)
—— —— *
Reading and discussion of special topics in the fields of social science. Open to advanced graduate students by arrangement with individual members of the staff.

14.81 *Psychology of Perception*
14.70 *Swets* 3–0–5
The basic sensory phenomena, with emphasis on vision and audition. Principles of perceptual organization. Classical and modern psychophysical methods and various theoretical analyses.

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14.82 *Psychology of Motivation*
14.70 —— 3–0–5
Processes responsible for the activation of behavior patterns. Instinctive response patterns and their specific sensory releasers. Primary drives and related phenomena. Modern conceptualizations of motivation. Problems of maturation and species specificity in the analysis of these phenomena.

14.84 *Theories of Personality*
14.70 *R. W. Brown* 3–0–5
Survey of major theories of personality — especially the writings of Freud, Adler, Jung, Allport, Eysenck, and Murray — and of empirical research designed to test these theories.

14.85 *Social Psychology*
14.70 *R. W. Brown* 3–0–5
Problems of social behavior; e.g., prejudices, rumor, riot, propaganda. Analysis in terms of basic principles of perception, learning, and motivation.

14.86 *Behavior in Groups*
14.70 *M. E. Shaw* 3–0–5
Psychological study of the behavior of individuals in group situations. Field studies and laboratory research, with emphasis on the latter.

14.87 *Mass Communication*
14.70 *R. W. Brown* 3–0–5
Crowd behavior, social movements, effects of the mass media, and prediction of voting.

14.88 *Advanced Psychology Seminar*
14.70 and any two subjects in Psychology
Staff 3–0–5
Critical survey and discussion of contemporary problems in experimental psychology. Restricted enrollment.

POLITICAL SCIENCE
(see also international economics)

14.901 *Concept Formation and Research Technique in Political Behavior*
—— *Lerner* 3–0–6
Requirements for testable concepts and innovations in research technique relating to attitudes, institutions, and decision-making. Case studies on key problems of national, international, and comparative processes.

14.902 *Theory of Political Processes*
14.901 —— 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.

14.91 *The American Political Process*
21.02 *Tillman* 3–0–5
The functioning of the American political system under the impact of contemporary economic, social and technological conditions. Executive-legislative relationships; problems of coordination and direction of national policy; Federal-State issues; the interrelationship of political parties, public opinion and the pursuit of individual interests.

14.92 *Comparative Political and Economic Systems*
21.04 *Totten* 3–0–5
Comparative study of the organization and use of political power in contemporary foreign political systems, British and European parliamentary governments, the Soviet structure, and selected Asian institutions; political parties and the changing role of government in economic affairs.

14.93 *Seminar: Issues in Contemporary American Politics*
14.91 or 14.92 *Bursey* 3–0–5
Selected problems connected with political parties, elections, and pressure politics, public policy in such fields as federalism (federal centralization, regional development, states rights), government and education, impact of national security problems on the Constitution and governmental institutions.

14.94 *Government, Politics and Technology*
14.91 or 14.92 *R. C. Wood* 3–0–5
Fundamental political conceptions and ways in which modern political thinking and social science are attempting to meet issues of technological change. Case problems involving political leadership, the politics of electrical and atomic energy power development and the industrialization of underdeveloped countries.

14.941 *Government and Public Administration*
—— *R. C. Wood* 3–0–6
Organization, powers and duties of state and local administrations; general survey of public administration — national, state and local — including the relationship of administrative agencies to the legislative and judicial branches; budget and personnel systems; how administrators handle their problems.

14.942 *Metropolitanism, Federalism and Technological Change* (A)
14.93 or 14.941 *R. C. Wood* 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.

14.95 *Politics, Society, and Policy Making*
14.01 or 14.51 or 14.91 or 21.41 or 21.42
Pool 3–0–5
Case material drawn largely from studies of decision-making conducted in the Center for International Studies 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.

14.951 *Behavioral Factors in International Politics* (A)
14.58 or 14.95 —— 3–0–6
Analysis of the psychological, cultural, and personal factors affecting policy determination, leadership procedures, and action patterns in national and international politics. (*Not offered 1958–59.*)

14.953 ***Mass Media and Communication Systems***
—— *Lerner* 3–0–6
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.

14.954 ***Methods of Communication Research*** **(A)**
14.953 *Lerner* 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.

14.956 ***Public Opinion and Propaganda***
14.77 *Pool* 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.

14.957, 14.958 ***Research Seminar in International Communications*** **(A)**
—— *Pool* 2–0–4
—— —— 2–0–4
Cooperative examination of key problems in this field. (*14.958 not offered 1958–59.*)

14.96 ***Influences on Policy Decisions***
14.95 —— 3–0–5
Review of factors shaping such decisions as those examined in 14.95. Systematic analysis of communication flows, the values, motivations and personality traits of political activists, and the structure of power among them. Uses of game theory, operational codes, and elite analysis. (*Not offered 1958–59.*)

14.961 ***Personality, Society, and Politics***
14.774 *Erikson* 3–0–6
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.

14.962 ***Identity and Ideology***
14.961 *Erikson* 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.

14.97, 14.98 ***Political Science Seminar***
14.53 or 14.57 or 14.93 or 14.96 — 3–0–5
14.97 *Padelford* 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.

15.

Industrial Management

15.01 ***Industrial Management I***
14.01 Alexander 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.

15.02 ***Industrial Management II***
M12 *Durand* 3–0–6
Introduction to statistical methods with application to engineering and administrative problems. Frequency distributions, moments, elements of sampling, confidence limits, regression, and correlation of two variables. (Similar to 14.31 and 14.381, but designed primarily for School of Industrial Management students. Completion of M221 is desirable.)

15.032 ***Sampling of Human Populations*** **(A)**
14.381 and consent of instructor
Durand 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.

15.11 ***Introduction to Industrial Management***
14.01 *Moore* 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.

15.17 ***Historical Studies in Innovation*** **(A)**
15.201 *Morison* 3–0–6
The process of innovation in industry. The nature of environment in which innovation takes place, personality of innovator, areas of resistance and means of accommodation to new ideas or new instruments. Influence of innovations upon technological development, administrative policy, and social arrangements. Case histories such as introduction of continuous-aim firing in the U. S. Navy and introduction of Bessemer converter.

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15.18 *Accounting and Production*
—— *T. M. Hill, Goetz* 5–0–10
A basic study of two important aspects of business management activity planned for students who have had substantial experience in industry: (1) basic methods and problems in maintaining financial and cost control records within a business and in the use of recorded data for policy determination and review of performance; (2) organization of manufacturing processes, with emphasis directed toward distinguishing fundamental principles from current practice. (*Restricted to Sloan Fellows.*)

15.183 *Structure of American Law and Business Environment* (A)
15.18 *Krebs, Morison* 3–0–6
First half: study of fundamental legal principles as an element of the environment within which management of industrial enterprises is carried out. Second half: examination of major historical ideas affecting American industrial philosophies and processes. (*Restricted to Sloan Fellows.*)

15.185 *Management Problems* (A)
15.18 *Tallman, Goetz* 3–0–6
Study of problems in two areas: (1) quantitative approaches to business problems and (2) marketing policy. Work at an advanced level to serve the needs of students who have had a substantial amount of general business experience. (*Restricted to Sloan Fellows.*)

15.201 *Problems in American Political Economy*
—— *Letwin* 3–0–6
Examination of economic, political and social problems attending development of federal regulation of American economy. Emphasis on function of politics and law in reconciling conflicting demands of various social groups. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*)

15.30 *Personnel Administration*
14.01 Pigors 3–0–6
Personnel administration as a staff function to assist line executives. Discussion on basis of case material, of fundamental requirements for personnel work with regard to principles that build and problems that test constructive personnel policies. Selection, placement, and follow-up of employees; basic problem of worker's attitude toward authority; the plant as a social system; man-power problems; recruitment, training and upgrading; management-union relationships; establishment and maintenance of satisfactory working conditions; job analysis and grading; employee evaluation; interviewing as a tool of management; wage administration; employee counseling.

15.312 *Labor-Management Relations*
—— *D. V. Brown* 3–0–6
Similar to 14.61. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*)

15.322 *Problems in Labor Relations and Personnel Administration* (A)
15.312 *Johnson* 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 of company personnel programs in terms of criteria.

15.362 *Seminar in Group Behavior* (A)
—— *M. E. Shaw* 3–0–6
Reading and discussion of selected topics in the field of group interaction. Emphasis on empirical investigations. (*Restricted to graduate students who have had a course in social psychology.*)

15.371 *Social Psychology*
—— *Schein* 3–0–6
Opportunity for the student to become familiar with the methods, subject matter, and findings of social psychology, with opportunity to look into literature in the field and to raise questions about his reading. Detailed examination of a few subjects within social psychology which are particularly relevant to the problems of industrial management, with class discussions and reading on such subjects as motivation, learning and behavior change, leadership. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*)

15.372 *Laboratory in Industrial Behavior* (A)
14.662 *McGregor* 3–0–6
General demonstration, discussion, and analysis of learning, social perception, problem solving, and organized group activities. Student participation and assistance in demonstrations and in the analysis of the data. Readings and reports. (*Restricted to Sloan Fellows.*)

15.373 *Managerial Behavior in Industrial Organizations* (A)
15.371 *McGregor* 2–0–7
Critical examination of managerial policy and practice from the point of view of social psychology. Preliminary consideration of the nature of the managerial task, followed by intensive study of a topic selected by the student and presentation of a paper on this topic for discussion by the seminar. (Admission by permission of the instructor to students who have sufficient background for independent study in this field.)

15.41 *Financial Management*
15.50 *Kuh* 3–0–6
Principles of financial organization and management; directed primarily toward analysis of demand for funds, their costs to the firm, and problems of internal financial control. Types of corporate securities, financial institutions, and tax aspects.

15.412 *Financial Management*
15.501 *Kuh* 3–0–6
Similar to 15.41. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*)

15.42 *Investments*
15.41 —— 3–0–6
Investment objectives; nature of alternative means to attain these objectives; estate planning; portfolio planning; industry and security analysis; security and commodity markets; state and federal laws bearing on taxes and security transactions.

15.452 *Taxation and Business Management* (A)
15.412 *E. Shapiro* 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. Inventory and depreciation accounting, depletion allowances, deferred compensation and fringe benefits, the taxation of capital gains, the "double" taxation of distributed earnings, and 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 the methods used to finance it, as well as the effect of government tax and expenditure operations on the economic environment in which business is undertaken.

15.46 *Financial Administration of Industry* (A)
15.412 *E. Shapiro* 3–0–6
Practical problems of internal financial management. Analysis of specific problems confronting business managers in manufacturing, mercantile, and public utility fields. Use of case method, with other readings also required. Emphasis on current financial operations; financial problems relating to taxation, consumer purchasing power and availability of investment funds. Oral and written reports.

15.50 *Accounting*
14.01 *T. M. Hill* 3–2–4
Introduction to the use of accounting as a tool of applied economics with emphasis on its employment by management. Concepts and methods pertinent to the accumulation, organization, and interpretation of data useful in evaluating and controlling the performance of the individual business enterprise.

15.501 *Managerial Accounting*
—— *T. M. Hill* 4–0–8
Consolidation of 15.50 and 15.51. *(Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.)*

15.51 *Industrial Accounting*
15.50 or 15.52 *Shillinglaw* 3–0–6
Analysis of information requirements of cost accounting systems. Study of cost and profit behavior within the firm. Problems of measuring costs and profits of individual products and activities of the firm. Methods of using accounting data in evaluating alternative courses of action, future planning, control of current operations. Case material from a variety of industrial situations supplemented by accounting exercises and selected readings.

15.511 *Economics of the Firm*
—— *Alexander* 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.)*

15.52 *Business and National Income Accounting*
14.01 *Gordon* 3–0–5
Fundamentals of the methods and principles of business accounting and of the development of national income statistics from private accounting data. The problems of asset valuation and income determination, contrast between private and social concepts of income, familiarity with the structure and interrelation among national income accounts, and analysis of data for the solution of problems in business and economics. Designed for majors in economics.

15.531 *Problems in Accounting Control* (A)
15.501, 15.511 *Gordon* 3–0–6
Design and use of semi-variable overhead expense budgets and standard cost systems for income measurement, determination of product costs for pricing, and planning and control of costs. Survey of other selected topics such as operations budgets, capital budgeting, break-even analysis, distribution cost analysis, LIFO, and responsibilities of controller to stockholders. Exercises, case material, and reports to develop facility in organizing and interpreting data.

15.542 *Management Information Systems* (A)
15.501 or 15.52 *Gregory* 3–0–6
Study of the structure and related techniques of an information system required for managing an enterprise. Nature and development of information systems and formulation of improved system. Emphasis on development and use of both digital computers and less sophisticated techniques, and relationship to firm management. Lectures, library research, problem formulation and solution, computer facility visits, and case studies of existing information systems.

15.581 *Dynamic Models of the Firm* (A)
15.712, M22 *Yance* 3–0–6
Models describing behavior of firm and industry in terms of major aggregative variables — expectations, production and inventory behavior, employment, pricing, investment, cash flows, and financial policy. Study of the dynamic behavior of models and evaluation of alternative policies through solution of difference equations and simulation on computer.

15.591, 15.592 *Advanced Treatment of Techniques in Scientific Management* (A)
14.381 —— 3–0–6
Detailed study of selected topics in scientific management from a mathematical and rigorous point of view, such as inventory control, mathematical programming, waiting-line theory, Monte Carlo techniques, statistical decision theory, and theory of games. Either or both terms may be elected. Admission by consent of instructor in charge.

15.61 *Business Law*
14.01 Macmillan 3–0–6
Elementary study of some legal problems involved in the operation of a business enterprise; formation, performance and discharge of contracts, and remedies for breach, the Statute of Frauds; agency and employment relationships and liability of principal and agent in contract and tort; provisions of the Uniform Negotiable Instruments Act; use of checks, notes and other negotiable instruments; rights and duties of parties in various banking transactions; organization of corporations, duties and responsibilities of management, rights and remedies of stockholders and creditors; consideration of some legal aspects of corporate finance.

15.65 *Labor Law*
14.01 Jacks 3–0–6
Fundamental legal principles underlying formation and operation of labor unions, limitations upon right to strike and right of boycott, and control of union and employer activities through administrative governmental agencies.

15.66 *Fundamental Legal Principles* (A)
15.312, 15.412, 15.712, 15.812T *Krebs* 3–0–6
Survey of the fundamental principles of American law. Development of insights into capabilities and limitations of legal system, considered as an element of the environment within which management of industrial enterprises is carried out. The way in which the system works and changes, the underlying ethical and political ideas which give it direction, and the major policy issues exemplified in it. Seminar discussion of legal cases and selected essays. *(Admission limited to School of Industrial Management graduate students; others admitted only by permission of the instructor.)*

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15.71 *Production Management*
15.02 *Bowman, Goetz* 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.

15.712 *Production Management*
14.381, 15.511 *Bowman* 3–0–6
Similar to 15.71. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*)

15.72 *Industrial Standardization*
14.01 *Moore* 3–0–6
Historical and theoretical background of standardization movement in industry. Present practices and techniques exemplified by actual industrial situations. Problems of initiation, organization, and development of company programs, including managerial evaluation and support. Responsibility, authority, and opportunity of standards engineer in operating organization. Evaluation of present and potential worth of standardization as tool of management. Development of underlying philosophy as aid to improvement in industrial management.

15.73 *Management Laboratory*
14.01 *Goodwin* 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 through personal involvement in an actual company project situation.

15.74 *Advanced Management Laboratory*
15.73 *Goodwin* 3–3–3
Organization and implementation of industrial improvement. Advanced treatment of work simplification. Managerial procedures employed in introducing and demonstrating a company improvement program to 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.

15.741 *Advanced Management Laboratory* (A)
15.712 *Goodwin* 3–3–3
Industrial improvement as a management philosophy. Critical analysis and appraisal of various improvement techniques as currently applied in industry. Re-evaluation of these techniques in the light of specific management situations originating at the moment as a result of the participation of a team of local industrial executives who meet regularly with the group.

15.75 *Manufacturing Analysis*
15.71 *Goetz* 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.

15.751 *Manufacturing Analysis* (A)
15.712 *Goetz* 3–0–6
The subject matter of 15.75 at advanced graduate level.

15.781 *Studies in Manufacturing Analysis* (A)
15.712 *Bowman* 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.

15.782T *Manufacturing Decisions Seminar* (A)
15.712 *Bowman* 3–0–6
Seminar based on literature of decision making and one manufacturing problem area, such as inventory, scheduling, quality, or equipment, combined with field study in a local firm to observe, describe, and predict the decision-making behavior of individuals concerning that manufacturing problem.

15.81 *Marketing*
15.01 *Tallman* 3–0–6
Introduction to managerial problems in marketing operations, emphasizing study of underlying determinants and dynamics of consumer and industrial demand behavior and of wholesale and retail institutional structures. 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. Application of theoretical concepts and quantitative techniques in study of marketing phenomena.

15.812T *Marketing*
—— *P. S. King* 4–0–5
Intensive coverage of the subject matter of 15.81, with some flexibility to allow for special interests of the group. Instruction on a seminar basis. Oral reports and analyses by individual class members. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*)

15.82 *Marketing Management*
15.81 *P. S. King* 3–0–6
Intensive study of managerial strategies and policies employed in marketing of industrial and consumer products. Planning the product and product line based on knowledge of market potentials, customer buying habits and competition. Determining marketing strategies and programs utilizing the optimum mix of advertising, sales force, dealer cooperation and other promotional tools. Management problems in implementing, controlling and evaluating marketing operations.

15.821 *Marketing Policy and Administration* (A)
15.812T *Cunningham* 3–0–6
Intensive treatment of subject matter of 15.82; group projects developing detailed marketing programs for specific new or existing products. Instruction on seminar basis with oral reports and case analyses by students.

15.83 *Marketing Research*
15.81 *Cunningham* 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 of data, analysis of results and reporting of problem solution.

15.832T ***Demand Analysis and Marketing Research*** **(A)**
14.381, 15.812T *Chow, Cunningham* 3–0–6
Presentation of various theoretical approaches and case studies in demand analysis, and evaluation of their applications to marketing problems. Statistical design in the measurement of demand relationships. (*Normally restricted to second-year graduate students in the School of Industrial Management.*)

15.86 ***Product Planning and Development*** **(A)**
15.812T *Tallman* 3–0–6
The product mix as a major element in marketing strategy. Diversification policy. Sources of ideas for new or improved products and methods for screening such ideas in light of potential market demand, costs, prices, and suitability to company's production and marketing facilities; organizational relationships and methods used to insure coordination between production, research, marketing, financial and other company departments affected by production planning and development. Problems on transferring new products from development stage to regular production, package design, testing market acceptability, and planning introductory sales campaigns.

15.90 ***Organization***
15.30, 15.41, 15.71, 15.81
Haberstroh, Rubenstein 3–0–6
Examination of basis for useful theories of organizational behavior. Requirements for successful design and control of industrial organizations and their components. Study of selected problem areas: decision-making, communication, measurement of organizational effectiveness, etc.

15.91 ***Administrative Policy***
15.30, 15.41, 15.71, 15.81 *Hudgins* 3–0–6
Principles of policy making. Business problems as viewed by top management. How policy decisions are made and results evaluated. Role of corporate objectives, impact of decisions on corporate continuity, study of long-term versus short-term considerations, and study of selected current problems as they affect decisions in specific cases.

15.92 ***Organization*** **(A)**
15.312, 15.412, 15.712, 15.812T
Rubenstein 3–0–6
The subject matter of 15.90 at advanced graduate level.

15.93 ***Administrative Policy*** **(A)**
15.312, 15.412, 15.712, 15.812T *Hudgins* 3–0–6
The subject matter of 15.91 at advanced graduate level.

15.942 ***Administrative Policy Seminar*** **(A)**
15.18 *Hudgins* 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 critical decisions of selected companies illustrating the principles discussed. (*Restricted to Sloan Fellows.*)

15.951, 15.952 ***Special Studies in Management*** **(A)**
—— *T. M. Hill* *
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.

15.96 ***Administrative Theory and Practice*** **(A)**
15.312, 15.412, 15.712, 15.812T *Schell* 3–0–6
Especially designed for graduate students who look forward to ultimate responsibilities in the top management of industry. Initial problems confronting the new business administrator. Formulating methods of approach to administrative problems. Techniques of negotiation, mediation and group deliberation. Relationships of top management to subordinates, investors, vendors, customers, associates, community, government, and the public. Underlying principles leading to long-term continuity and tenure. Evening conferences with business administrators and industrialists.

15.971T ***Seminar in Research Management***
—— *Rubenstein* 2–0–7
Graduate seminar dealing with several aspects of managing research laboratories: organization, economics, human relations. Case discussions, guest speakers, readings and reports. Participation by research supervisors from local laboratories. Generally restricted to graduate students who have been employed in research or development laboratories. Permission of instructor required.

15.972 ***Management of Research and Development***
—— *Rubenstein* 3–0–6
Organizational and economic aspects of managing research laboratories. Lectures, readings, discussions, field studies, reports. For graduate students with little or no previous experience in research management.

15.98, 15.99 ***Seminar in Administration*** **(A)**
15.18 *Johnson* 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.*)

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16.
Aeronautical Engineering

16.00 *Aeromechanics*
2.001, M21 *Halfman* 3–1–5
Dynamics, with applications to aeronautical problems. Kinematics of a point and of plane motion of a rigid body. Relative motion as seen by accelerating and rotating observers. Dynamics of particles, groups of particles, and rigid bodies in planar motion. Work and energy, impulse and momentum in relative motion. Particles of variable mass.

16.01 *Aeromechanics*
16.00, *M22* *Halfman* 4–1–5
Dimensional analysis. Kinematics of a rigid body in general motion. Mass properties of rigid bodies, ellipsoid of inertia, geometric and mass symmetries. Dynamics in general motion of a group of particles, a rigid body, a body of variable mass. Euler's dynamical equations, gyroscope equations, rocket equations with application to airplanes, missiles and their components. Linear systems, free and forced oscillations, multiple degrees of freedom, classical and operational methods of analysis. System performance and stability. Examples of nonlinear systems.

16.02 *Aerodynamics*
2.40, 16.01 *Ashley* 4–2–6
Applications of principles of particle dynamics and thermodynamics to study of real and perfect fluids, with particular reference to aeronautical problems. One-dimensional flow of perfect gases; fundamental equations of three-dimensional fluid motion; applications of incompressible-flow theory to airfoils and wings, including complex variable techniques; effects of viscosity.

16.03 *Principles of Aerodynamics*
16.02 *Ashley, Bicknell, Trilling* 4–0–5
Navier-Stokes equations, laminar boundary layer equations, transition, turbulent boundary layers, effect of compressibility. Two-dimensional airfoils in incompressible flow. Lifting line and surface theories for straight and swept wings. Influence of compressibility on subsonic flight. One-dimensional compressible flow, shock, combustion, and condensation waves. Slender bodies in compressible flow, Ackeret theory for supersonic airfoils.

16.04 *Aerodynamics — Viscous Fluids* (A)
16.02 *Bicknell* 3–0–6
Equations of motion and energy equation for laminar flows. Application to laminar boundary layers, incompressible and compressible. Transition. Mechanics of turbulent boundary layers.

16.051 *Aerodynamics of Compressible Fluids I* (A)
16.02, *M351* *Baron* 3–0–9
Thermodynamics and one-dimensional aerodynamics of compressible flows. DeLaval nozzles. Shock waves. Equations of motion of a compressible fluid. The Prandtl-Glauert approximation; subsonic and supersonic airfoil theory. Method of characteristics. Transonic and hypersonic similarity laws. Experimental techniques.

16.052 *Aerodynamics of Compressible Fluids II* (A)
16.051 *Baron* 3–0–9
General solutions of the Prandtl-Glauert equation. Nonlifting and lifting flow past bodies of revolution and very low aspect ratio configurations. Supersonic wing theory. Source superposition method and conical flow method. Boundary layer concept and some properties of compressible boundary layers.

16.061, 16.062 *Steady and Unsteady Potential Flows* (A)
16.051 *Ashley, Trilling*
3–0–9
Part of a series of advanced topics in aerodynamics. Equations of motion of an inviscid fluid. Range of application of various approximate equations. Steady and oscillating airfoils and wings in subsonic flows. Transonic flow past two-dimensional airfoils and past fixed and oscillating slender configurations. Supersonic wing theories. Reverse flow theorems.

16.063 *Viscous Flows* (A)
16.052 *Finston* 3–0–9
One of a series of advanced topics in aerodynamics. Some special solutions of the Navier-Stokes equations and their behavior as viscosity vanishes. One-dimensional and linearized models of boundary-layer-like behavior. Plane and three-dimensional boundary layer problems. Unsteady flows. Survey of experimental results and comparison with theory. Discussion of recent work on transition and turbulent flow. Demonstration of various flow phenomena, when possible. (*Not offered 1958–59.*)

16.064 *Thermal Effects* (A)
16.04 or 16.052 or 16.063 *Finston* 3–0–9
One of a series of advanced topics in aerodynamics. Brief discussion of modes of heat transfer and physical properties of fluids. Origin of aerodynamic heating. Heat transfer through laminar and turbulent boundary layers at supersonic and hypersonic flow. Discussion of various surface protection or cooling schemes. Interaction of stream and body. Application to hypersonic aircraft and re-entry bodies including real gas effects and radiation. Laboratory demonstrations, when possible.

16.065 *Physics of High Speed Gas Flows* (A)
16.051 *Trilling* 3–0–9
One of a series of advanced topics in aerodynamics. Kinetic theory of gases; physical phenomena of high-speed flows: vibrational excitation, dissociation, ionization, radiation, relaxation effects. Free molecule and slip flows. Introduction to magnetohydrodynamics.

16.066 *Hypersonic Flow* (A)
16.051 *Trilling* 3–0–9
One of a series of advanced topics in aerodynamics. General hypersonic similarity laws. Flows past pointed and blunt bodies. Explosion waves. Boundary layers at very high speeds and temperatures.

16.07 *Aerodynamics and Dynamics of Missiles* (A)
16.02, 16.13 *Ashley* 3–0–6
Introduction to aerodynamic techniques useful for predicting performance and dynamic stability of missiles and rockets. Review of needs of missile designer. Flow of compressible fluid past wings, bodies and wing-body combinations. Validity and limitations of slender-body theory. Estimation of forces and moments at subsonic, transonic and supersonic speeds, including nonlinear effects. Similarity laws and area rules. Examples of nonlinear dynamic problems, such as the influence of high rate of roll, peculiar to missiles.

16.10 *Applied Aerodynamics*
16.01, 16.82 *Ober* 4–0–8
Application of aerodynamic theory to airplane design and aircraft propellers. (*Not offered 1958–59.*)

16.11 *Aircraft Performance and Stability*
16.01, 16.82 *Ober* 4–0–8
Application of aerodynamic theory to aircraft performance and stability. General theory of aircraft stability.

16.105 *Applied Aerodynamics* (A)
16.02, 16.10 *Ober* 3–0–6
Further studies of airplane performance, including the effects of variations of propeller, type of power plant, and Mach number at trans- and supersonic velocities.

16.13 *Airplane Stability and Control*
16.01, 16.10 *Bicknell* 3–0–6
General theory of longitudinal and lateral stability, controllability and maneuverability of airplanes.

16.15 *Advanced Stability and Control of Aircraft* (A)
16.11 or 16.13 *Larrabee* 3–0–6
Various features of stability and control of aircraft, including airplane motion with free controls; rotary derivatives; airplane frequency response to control motion; controls and control forces.

16.20 *Structures*
2.37 *Bisplinghoff, Sandorff* 4–0–6
Fundamental theory and methods for static strength analysis and design of airplane components. Elasticity relations and practical two-dimensional plasticity. Properties and failure modes of ductile materials, including combined stresses, fatigue, and elevated temperature effects. Solid sections, simple shells, and stiffened-skin structures under shear, bending, torsion, and compression; both elastic and plastic effects.

16.21 *Structural Analysis*
16.20 *Dugundji* 4–0–6
Introduction to the energy theorems in structural analysis. Influence coefficients and statically indeterminate structures. Aircraft and missile shell structures; load distribution in multi-cell and tapered stiffened shells, analysis of ribs and fuselage rings, general stability problems. Introduction to digital computing techniques.

16.22 *Shell Structures* (A)
16.21 *Bisplinghoff* 3–0–6
Advanced topics in aircraft structural theory. Theory of elasticity applied to the stress and stability analyses of plates and shells including variational methods. Approximate solutions including finite difference techniques and relaxation methods. Plastic effects in stress and stability analyses. Thermal effects.

16.23 *Aircraft Structural Design*
16.20 *Sandorff* 3–0–5
Structural features of various methods of fabrication and application to design of airplane components. Extrusions, castings, forgings, integrally stiffened designs, sandwich structures, brittle materials. Methods of optimum design for selection of materials and structural types. (*Not offered 1958–59.*)

16.25 *Advanced Structures* (A)
16.21 *Pian* 3–0–6
Varying content from year to year as new methods for analysis of all-metal aircraft become available for examination. Investigation and development of methods involving stability criteria or applications of elastic theory and of probable effects on structural analysis methods to be expected from new trends in design.

16.30 *Principles of Automatic Control*
16.01 *McKay* 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 first and second order differential equations with applications to more involved automatic control loops.

16.302 *Aeronautical Systems*
16.30 *McKay* 3–0–6
Application and extension of the basic techniques for control system analysis such as root locus, frequency response, and computer utilization to feedback control systems in the aircraft and missiles field. Case studies of power boost and control systems, radar and fire control systems, guidance systems, etc.

16.31 *Principles of Instrumentation and Control* (A)
2.003 or 2.07 or 6.02 or 16.01 *Li* 3–0–9
Generalized concepts and methods for the quantitative description of static and dynamic performance of physical systems having multiple inputs and outputs. Principles of signal generating systems. Minimization of interference effects by isolation, compensation, and rejection schemes. Generalized stability criteria for feedback systems. Modification principles for overcoming load disturbances and for improving dynamic response. Open loop and closed loop dynamic measuring systems. Application to stabilization of moving vehicles and to self-excited systems.

16.32 *Principles of Instrumentation and Control* (A)
16.31 *Li* 3–0–9
Analysis and design of coupled and multi-looped linear systems with attention to stability criteria. Dynamic performance testing methods of linear systems. Study and exploitation of nonlinear systems. Use of analog computer to solve linear and nonlinear systems. Generalized criteria for selection and design of power amplifiers and output drive systems. Principles of programmed control systems and of optimalizing systems.

16.33 *Instrumentation and Control Laboratory* (A)
16.31 *Li* 2–2–6
To be taken simultaneously with 16.31. Laboratory exercises on instruments and control systems designed to provide experimental familiarity with the principles set forth in 16.31. Static and dynamic performance tests on various instruments followed by exercises involving control systems.

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16.35 *Special Problems in Instrumentation and Control* (A)
16.32 *McKay* *

Problems of interest to qualified individual students in consultation with the instructor.

16.36 *Dynamic Measurements* (A)
2.003 or 2.07 or 8.13 or 13.73 or 16.31 *Li*
2–2–6

Measurement of the physical quantities encountered in engineering practice with emphasis on rapidly varying quantities. General principles of dynamic measurement, supplemented by detailed studies of systems used for measuring mechanical vibrations, pressure, strain, temperature, and flow.

16.37 *Random Processes in Automatic Control* (A)
16.30, M351 *Vander Velde* 3–0–9

Foundations of the analysis and synthesis of feedback control systems in which random inputs are significant. Extensive treatment of stationary random processes in linear, time invariant systems. Brief treatment of nonstationary random processes, time varying systems, and nonlinear systems. Introduction to sample theory.

16.38 *Control Systems Components* (A)
6.18 *R. K. Mueller* 3–0–6

Physical components utilized in instrumentation and control systems from the point of view of the effect of their separate performance characteristics on the control system problem. Specification of components to meet particular control system requirements. Consideration of electrical, mechanical, pneumatic, and hydraulic components with emphasis on nonideal effects.

16.39 *Vector Kinematics and Gyroscopic Instrument Theory* (A)
2.07 or 8.71 or 16.01 *Wrigley* 3–0–6

Generalized theory of accelerations and velocities of bodies in spaces which are moving with respect to inertial space. Specialized application of this general theory and of Newtonian mechanics to the theory of gyroscopic instruments. Development of the treatment from the standpoint of the engineer, using both the methods of vector analysis and those of conventional coordinate components. Application to the analysis of gyroscopic devices in airborne and marine craft.

16.392 *Inertial Guidance* (A)
16.39 *Wrigley* 3–0–6

Fundamentals of self-contained guidance systems that operate without radiation; effect of the figure of the Earth. Accelerometers and measurement of inertial mass forces. Gyroscopes and determination of inertial space reference frames. Combinations of accelerometers, gyroscopes, and attendant equipment to form inertial guidance systems. Measurement of the vertical from moving bases, Schuler tuning. Damping of vertical indicators. Effect of component uncertainties on system performance. Inertial control of vehicles to programmed paths. Dynamic aids to inertial systems.

16.40 *Automatic Control of Aircraft and Missiles* (A)
16.13, 16.30, 16.39 *Whitaker* 3–0–6

Theory of design of automatic control systems for manned aircraft and missiles. Errors, uncertainties, and dynamic response of components included in automatic control equipment. Analysis and synthesis of orientational control, navigation control, blind landing systems, and fire control systems for aircraft including the effects of random inputs and cross-coupling of airplane degrees of freedom. Typical engineering problems associated with design of aircraft control equipment.

16.411 *Introduction to Weapons Systems* (RA)
16.39 *Markey* 4–0–8

Condensation, for students with adequate preparation, of subject matter of 16.412 and 16.422. (*Restricted to selected officers of the U. S. Air Force, Army and Navy.*)

16.412, 16.422 *Introduction to Weapons Systems* (RA)
16.39 *Markey* 4–0–8
16.412 *Markey* 4–0–8

Static and dynamic behavior of weapons system components and subsystems from the standpoint of functional performance, in terms of harmonic analysis and elementary classical physics. Development of a coherent pattern for associating solutions in terms of nondimensional variables with typical weapons system engineering problems. Numerical and graphical methods for determining the transient stability of feedback systems. Limitations imposed by uncertainties and interferences on the performance of physical equipment. Introduction to the theoretical statement of the fire control problem and to inertial navigation. (*Restricted to selected officers of the U. S. Air Force, Army and Navy.*)

16.421 *Weapons Systems* (RA)
16.411 *Wrigley, Markey* 4–0–8

Generalized treatment of the fire control problem and methods available for its solution by physical concepts and vector operations. Interference isolation, tracking, and computing in weapons systems. Application of gyroscopic and other equipment used in weapons systems. Fundamentals of inertial guidance and its application to aircraft, ships, and missiles. Examples taken from service systems. (*Restricted to selected officers of the U. S. Air Force, Army and Navy.*)

16.43, 16.44 *Weapons Systems Laboratory* (RA)
16.45 *R. K. Mueller* 1–3–5
16.421 *R. K. Mueller* 1–3–5

Demonstration of the principles treated in either 16.45 or 16.421. 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 the static and dynamic performance characteristics of typical airborne and antiaircraft equipment. Problems of solution time, smoothing, and tracking. (*Restricted to selected officers of the U. S. Air Force, Army and Navy.*)

16.45 *Weapons Systems* (RA)
16.422 *Wrigley* 3–0–9

Subject material similar to that in 16.421, but with further emphasis on airborne systems. (*Restricted to selected officers of the U. S. Air Force, Army and Navy.*)

16.46 *Advanced Weapons Systems* (RA)
16.45 *Wrigley* 3–0–6

Continuation of 16.45 with problems of current interest and study of projected developments in weapons systems. (*Restricted to selected officers of the U. S. Air Force, Army and Navy.*)

16.47 *Rocket Propelled Missiles* (A)
16.11 or 16.13 *Stever, Trilling* 3–0–6

Review of one-dimensional gas dynamics and rocket propulsion; exterior ballistics of rockets; interceptor missile trajectories; ballistic missile trajectories; multiple step ballistic missiles; terminal ballistics; design considerations for guided missile and rockets.

16.48 *Structural Problems in Weapons* (RA)
2.001, 16.422 *Dugundji* 3–0–9

Principles of static and dynamic stress analysis of aircraft structures. Theory of shock loading. Effect of structural response on the fire control system. Fundamentals of gun and gun mounting structural analysis. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*)

16.49 *Special Problems in Weapons Systems* (RA)
16.421 or 16.422 *Wrigley* *
Problems of interest to qualified students in consultation with the instructor. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*)

16.50 *Vertical Take-Off Aircraft* (A)
16.10 and 16.13; or 16.11 *Miller* 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.

16.51 *Advanced Vertical Take-Off Aircraft* (A)
16.50 *Miller* 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.

16.53 *Aircraft Propulsion*
2.25 or *16.02;* 2.40 *E. S. Taylor* 3–0–6
Review of mechanics of compressible fluids. Applications to analysis and design of gas turbines, rockets, and ram jets. Limits on performance imposed by thermodynamics, fluid mechanics, and strength.

16.56T *Rocket Engines* (A)
2.213; or 2.252 and 16.53; or 2.48T *E. S. Taylor* 3–0–9
Application of fundamental principles of fluid mechanics and thermodynamics to the analysis and design of rocket engines. Discussion of propellants, thrust chambers, regenerative cooling, and turbopump systems. Development of theory by application to a preliminary design study of a rocket engine for a missile or satellite.

16.60 *Advanced Aeronautical Problems* (A)
16.13 or 16.20 *Staff* *
Individual advanced work by properly qualified graduate students. Problems selected in consultation with the instructor.

16.605 *Aeronautical Problems*
—— *Staff* *
Individual or group work by properly qualified students. Problems selected in consultation with the instructor.

16.61 *Aeronautics Seminar* (A)
—— —— 2–0–2
Weekly two-hour seminar given by the staff and the graduate students to discuss current aeronautical problems.

16.65 *Aeronautical Engineering Laboratory*
16.13, 16.20, *16.30* *Ober* 3–3–6
Lectures and experiments to illustrate the principles and practices of experimental aeronautics in the fields of aerodynamics, structures, and automatic control systems.

16.70 *Aircraft Detail Design*
—— *Bentley* 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.

16.71, 16.71T, 16.72 *Aeronautical Engineering*
16.13, 16.20, 16.70 *Koppen* 0–10–0
16.11, 16.20, 16.70 *Koppen* 2–10–0
16.30, 16.71T *Koppen* 0–9–3
Design of an airplane including layout, weight, balance, and performance estimates, structural design and preliminary stress analysis, stability and control analysis including the design of a simple automatic control system. Emphasis on individual initiative and independent application of fundamental principles of design and on the presentation of a final report. A selected group is permitted to substitute a similar missile problem. (*16.71T not offered 1958–59.*)

16.74 *Advanced Design* (A)
16.105, 16.72 *Miller* 2–6–4
Application of current design and operations analysis methods to the determination of the optimum vehicle capable of satisfying a given mission. Weight estimation from preliminary structural design and aeroelastic considerations, performance substantiation, evaluation of functional suitability, control system analysis and determination of optimum propulsive device. Considerable latitude in the choice of mission; use of the vehicle primarily as a means of illustrating methods used during the preliminary design stages in the development of aircraft and missiles.

16.76 *Orbital Vehicles*
M22 *Sandorff* 3–0–6
Introductory engineering considerations in the design of rocket-propelled vehicles. Mechanics of long-range trajectories and sateilite orbits, environmental conditions in the upper atmosphere and beyond, aeroelastic, aerodynamic, propulsive, structural guidance, and control aspects.

16.81 *General Aeronautics*
M21 *Markham* 3–0–6
Characteristics of aircraft, engines, and propellers for non-aeronautical students.

16.82 *Introductory Aeronautical Engineering*
M21 *Markham* 3–0–3
Introduction to aircraft, their components and general principles of flight.

16.851, 16.852 *Industrial Practice*
—— *Markham* 40 h.p.w.
Six 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.

16.91 *Aeroelasticity* (A)
16.02 *Mollö-Christensen* 3–0–6
Dynamics of elastic structures; air forces under unsteady conditions; flutter.

16.92 *Advanced Aeroelasticity* (A)
16.91 *Ashley* 3–0–9
Advanced aspects of aeroelasticity: corrections for finite span and compressibility in flutter calculations; study of wing divergence and aileron reversal.

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16.93 ***Aeroelasticity Laboratory*** **(A)**
16.91 *Halfman* 2-2-2
Experimental study of problems in structural dynamics and aeroelasticity.

16.94 ***Dynamics of Structures*** **(A)**
16.21 *Pian* 3-0-9
Fundamental variational principles in dynamics; Lagrange's equation and Hamilton's principle. Vibration characteristics of unrestrained elastic systems. Dynamic stresses produced during transient response of aircraft and missile structures to rapidly applied forces. Response of structures to continuous random disturbances. Current structural dynamics problems.

17.
Building Engineering and Construction

17.401 ***Advanced Job Management*** **(A)**
1.922 *McCreery* 3-0-6
Development of the organization of large projects with reference to the initial economic survey, time schedules, job organization, and integration of construction procedures. The character of contract instruments, legal requirements for job insurance and the expedition of materials to accomplish speed and quality.

17.402 ***Construction Management Seminar*** **(A)**
1.921, 1.922 *McCreery* 3-0-6
Continuation of 17.401 in seminar form. Diagnosis of failures and their causes; integration of the electrical, mechanical and sanitary services into building construction; analysis of architectural concepts in the light of existing construction procedures; study of professional relations in the conduct of contracting as a profession. Extensive contributions by the students. Field trips to illustrate difficult situations. Participation of contractors, architects and engineers from a variety of projects. Field surveys, library research papers and a term paper.

17.41 ***Building Management*** **(A)**
—— *McCreery* 3-0-6
Especially designed to train graduate students in the field of property management. Elements of first cost, expansion, maintenance, rentals, repairs and modernization as applied to commercial and industrial buildings. Lectures, field surveys, assigned readings and reports.

17.44 ***Specifications*** **(A)**
1.43, 1.921 *McCreery, Heger* 3-0-6
Development of theory and practice of writing specifications for large buildings. Utilization of principles of structural design, construction, construction management and materials in specifications. Simplification of technical requirements for greater efficiency and clarity. Discussion of all major trade subdivisions and choice of materials for proper coordination and performance in the completed structure. Development of engineering judgment in technical choice and in anticipation of difficulties.

17.531 ***Advanced Reinforced Concrete Design*** **(A)**
1.42 *H. Simpson* 3-0-6
Analysis and design of retaining walls, continuous footings, flat slabs with irregular spans, beams subject to torsion, rigid frame bents and hipped plate roofs. Calculation of elastic and plastic deformations.

17.532 ***Advanced Reinforced Concrete Design*** **(A)**
17.531 *H. Simpson* 3-0-6
Stresses due to shrinkage and creep, ultimate strength theories, design of prestressed members, design of shells.

17.542 ***Advanced Structural Steel Design*** **(A)**
1.42, 1.44 *H. Simpson, Heger* 3-0-6
Design of rigid and semi-rigid riveted and welded connections; design of members subject to torsion. Limit design; design of members with variable moment of inertia; design of rigid frame bents.

17.73 ***Materials — Wood, Plastics, Fabrics***
8.02 *Dietz* 3-0-3
Mechanical and physical properties of wood in relation to growth, structure and other characteristics which influence its use in construction and engineering. Strength, moisture content, preservative treatment, wood products, identification, and selection of species for various uses. Fundamental properties and uses of plastics, and basic characteristics of coatings and fabrics used in construction. *Wood Handbook;* Dietz, *Construction Materials;* A.S.T.M., *Selected Standards for Students in Engineering.*

17.74 ***Materials — Masonry and Metals***
8.03 *J. A. Murray, McGarry* 3-2-4
Primarily for architectural students with emphasis on masonry materials, concrete, and metals. Factors affecting the durability of masonry structures. Principles

underlying metals, alloys, corrosion and welding of metals. About two-thirds of subject on masonry materials, and the balance on metals. Laboratory work testing brick and mortar; concrete and concrete beams; ferrous and non-ferrous metals; wood, plastics, and laminates; and thermal conductivity of walls. Murray, *Masonry Materials; Laboratory Manual;* Williams & Homerberg, *Principles of Metallography.*

17.741 *Engineering Properties of Plastics*
1.41, 2.002 *Dietz* 2–0–4
Engineering attributes of plastics studied, with principal emphasis upon mechanical and structural properties. Introductory review of the chemistry of plastics to familiarize the student with the various types; the various strength properties; other properties important from an engineering standpoint such as dimensional stability and durability; and methods of manufacture and fabrication, insofar as these modify and influence the engineering properties.

17.742 *Engineering Laminates* (A)
1.41, 2.002 *Dietz, McGarry* 3–0–6
Consideration of the general theory of composite materials, followed by discussion of specific laminates such as plastics reinforced with paper, textiles, glass fibers, and various types of mats; sandwiches of soft cores and hard faces; plywood and laminated timber; laminated glass, rubber duplex metals, and cements and adhesives employed in making up composite materials. Dietz, *Engineering Laminates.*

17.76 *Research in Organic Structural Materials* (A)
17.741 *McGarry* *
Opportunity for laboratory investigation amplifying the work done in subjects 17.741 and 17.742.

17.771 *Cementitious Materials*
1.42, 17.74 *J. A. Murray* 2–0–4
Advanced study of cementitious materials. Critical studies of the composition of cements, effect of composition on the use of the cement and upon the durability of the products. Composition and physical properties of mortars, stuccoes and plasters, and effect of these properties on masonry construction. Murray, *Masonry Materials; Concrete Manual.*

17.772 *Concrete* (A)
17.771 *J. A. Murray* 3–0–6
Advanced study of Portland cement concrete with attention to the effect of type and composition of cement, type and size of aggregate on such properties as soundness, volume stability, and durability. Advanced study of selected topics as concrete mix design, air entrainment, admixes, bleeding, and creep. No required text but frequent assignments from current literature on concrete.

17.78 *Research in Cementitious Materials* (A)
17.772 *J. A. Murray* *
Opportunity for laboratory investigation amplifying the work done in subjects 17.771 and 17.772.

19.
Meteorology

19.003 *Elementary Meteorology I*
—— *Wurtele* 3–0–3
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.

19.01 *Descriptive Meteorology I*
—— *Willett* 3–0–6
Simplified treatment, with a minimum of mathematics, of composition and structure of the atmosphere; elementary thermodynamics and the heat balance of the atmosphere; the circulation principle (geostrophic, gradient, and frictional wind); formation and characteristic forms of atmospheric condensation phenomena. Willett, *Descriptive Meteorology.*

19.02 *Descriptive Meteorology II*
19.01 *Willett* 3–0–6
Continuation of 19.01, covering 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, *Descriptive Meteorology.*

19.14 *Long-Range Weather Forecasting* (A)
19.44 *Willett* 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.

19.21 *Meteorological Observations*
8.02 *Keily* 1–3–2
Introduction to the instruments and techniques for observing, recording and coding the basic weather elements for synoptic and climatological use. Open to undergraduate and graduate students.

19.22 *Meteorological Instruments* (A)
19.02 *Keily* 2–4–6
Laboratory study of the design and response characteristics of current surface and upper air instruments, with reference to the requirements of the meteorologist.

19.23 *Micrometeorological Instrumentation* (A)
19.21 *Keily* 2–2–4
Design and evaluation of measuring systems for use in the lowest levels of the atmosphere. For graduate students specializing in micrometeorology.

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19.30 *General Climatology*
—— *J. M. Austin* 2–0–4
Distribution of radiation, temperature, pressure and wind, hydrometeors and air masses and fronts at the surface of the earth and aloft and of the physical factors determining this distribution. Climatic zones and types. Description of the climate of each continent and of the oceans in terms of dynamics of the atmosphere, of air mass types and frontal activity. Haurwitz and Austin, *Climatology.*

19.32 *Microclimatology*
8.02, M12 *J. M. Austin* 2–0–4
Study of physical properties which determine the structure of the lowest layer of the atmosphere.

19.33 *Applied Climatology* (A)
19.30 *J. M. Austin* 3–0–6
Study of modern climatological methods applied to problems of business, industry, agriculture, aviation, the military, and public health. Extensive use of principles and techniques of synoptic and dynamic meteorology, physical climatology and statistics in the development of the climatological method. Lectures on techniques and case method of demonstration. Opportunity to select weather problems for solution and presentation for class discussion and criticism.

19.44 *Synoptic Meteorology I*
19.51, 19.601 *Sanders* 3–0–6
Meteorological elements and their conservatism; practical rules and formulae for extrapolating the movement and development of surface and upper air pressure systems; hydrometeors, clouds and precipitation; stability and instability and their relation to weather phenomena. Structure of pressure systems and their synoptic application. Petterssen, *Weather Analysis and Forecasting.*

19.45 *Synoptic Meteorology II* (A)
19.44 *J. M. Austin* 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 and their application to the forecast problem.

19.46 *Numerical Weather Prediction* (A)
M351 *Phillips* 3–0–6
History of the problem and early attempts at its solution; analysis of the hydrodynamical equations; finite difference methods with error control; application to barotropic and baroclinic models of atmospheric flow.

19.51 *Synoptic Laboratory I*
19.02 *Sanders* 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.

19.52 *Synoptic Laboratory II*
19.51 *Sanders* 0–15–0
Continuation of 19.51 for the student specializing in synoptic meteorology, with particular reference to aviation and local forecasting and prediction of severe convective phenomena.

19.53 *Synoptic Laboratory III* (A)
19.44, 19.51 *Wurtele* 0–15–0
Theory and practice of modern weather prediction and development of quantitative prognostic procedures.

19.601 *Introduction to Theoretical Meteorology*
8.02, M12 *Lorenz* 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.

19.62 *Dynamic Meteorology I*
19.601 *Lorenz* 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.

19.64 *Dynamic Meteorology II* (A)
19.62 *Starr* 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.

19.67 *Planetary Fluid Dynamics* (A)
M421 *Charney* 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.

19.70 *Elementary Physics of the Atmosphere*
8.03, M12 *Keily* 2–0–4
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.

19.71 *Radar Meteorology* (A)
8.03, 19.02 *P. M. Austin* 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. Discussion of the potentialities of radar for the examination and measurement of precipitation processes. Lectures and laboratory work with operating radar systems.

19.72 *Physical Meteorology* (A)
8.04, M21 *Houghton* 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.

19.83 *Oceanography*
8.02, M21 *Houghton* 2–0–4
Principles and methods of physical and dynamic oceanography, and the current systems of the oceans with special emphasis on their meteorological significance. Sverdrup, *Oceanography for Meteorologists.*

19.91 ***Meteorological Seminar I*** **(A)**
19.44, 19.62 *Houghton* 2–0–4
Weekly reviews and discussions by staff members and students of recent meteorological contributions published in current periodicals and of original research.

19.911, 19.912 ***Meteorological Seminar I, II*** **(A)**
19.44, 19.62 *Houghton* 1–0–2
19.911 *Houghton* 1–0–2
Same as 19.91.

19.94 ***Special Problems in Meteorology***
19.02 *Staff* *
Reading, consultation, and original investigation on meteorological problems.

19.95 ***Special Problems in Meteorology*** **(A)**
19.44, 19.62 *Staff* *
Reading, consultation and original investigation on meteorological problems of more advanced nature than those in 19.94.

20.
Food Technology

20.00 ***Man's Food***
—— *Staff* 3–0–3
Survey of the natural and cultivated sources of food for mankind from the viewpoint of production, transportation, processing, packaging and consumption. History of the foods of mankind through the ages; natural food resources; nutritional requirements of man; effects of geography on dietary patterns; food habits and fads; environment, soils and agriculture; plant and animal breeding; harvest, storage and distribution of food; international movement of food; food economics; agricultural economics; federal regulation of agriculture; food industry of the U. S.; food laws and regulations; science and engineering in food technology; population and the world food problem.

20.01, 20.01T, 20.02 ***Chemistry and Technology of Food Supplies I, II***
5.41 *Charm* 3–4–3
5.41 *Charm* 3–4–2
20.01 *Charm* 3–4–3
Chemical composition, production, consumption, statistics, and methods of treatment of food materials. General commercial methods of production and handling of raw foods, such as milk, eggs, meats, cereals and other vegetable food supplies, and their preparation for commercial distribution or for later manufacturing processes. Fundamental principles involved in physical processes such as refrigeration, dehydration, and salting, and the microbiology and chemistry of the processes. Laboratory work including numerous exercises involving the chemical analysis of various foods and food products.

20.11 ***Technology of Food Products***
20.02 *Nickerson* 2–4–4
The various methods of preserving foods by heat, refrigeration, and freezing. Storage changes occurring in processed food products. Production of vegetable and fruit juice concentrates.

20.12 ***Technology of Food Products***
20.11 *Nickerson* 2–4–4
Continuation of 20.11 with particular reference to the preservation of foods by dehydration, technological processes of the meat packing and fisheries industries. Use of pectin in the manufacture of food products. Storage changes in fats and oils.

20.13, 20.13T, 20.14 ***Chemical Engineering Food Applications***
5.61 *Charm* 4–0–6
5.61 *Charm* 4–3–6
20.13 *Charm* 4–2–4
Fundamental principles of chemical engineering operations, with emphasis upon application in the food industry. Flow of heat and flow of fluids, extraction, evaporation, distillation, drying, filtration, etc. Laboratory work on various food engineering problems by groups of students. General discussions, supplemented by extensive problem work. (*20.13T not offered 1958–59.*)

20.15 ***Food Engineering***
2.602, 20.14 *Charm, Fuld* 1–4–2
Viscometry, flow, unsteady-state heat transfer, mixing, evaporation, filtration extraction, distillation, and drying as applied to food materials. Laboratory problems related to design, operation, and economic considerations.

20.21 ***Flavor Evaluation*** **(A)**
20.12, 20.32 *Proctor* 2–2–4
The senses of taste and smell and their interrelationship with other senses. The concept of flavor and its estimation by the senses. Natural and synthetic flavors, their preparation, composition and use in food products. Flavor changes in food products. Introduction to organoleptic techniques.

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20.22 *Food Acceptance* (A)
20.12, 20.33 *Proctor* 2–2–4
Factors influencing the acceptance of foods by individuals and by large groups. Consumer acceptance testing. Sensory difference testing. Development and maintenance of specifications and standards for food acceptance. Analysis of variables and attributes for the control of food products.

20.32 *Chemistry of Nutrition*
5.41, *7.05* *R. S. Harris* 2–2–2
The needs of man and animals for calories, carbohydrates, fats, proteins, amino acids, minerals, and vitamins, and discussion of their metabolic interrelationships.

20.32T *Chemistry of Nutrition*
5.41, *7.05* *R. S. Harris* 3–4–3
The needs of man and animals for calories, carbohydrates, fats, proteins, minerals, and vitamins, and their biochemical and physiological interrelationships in digestion and metabolism. Introduction to modern chemical and biological procedures in the analysis and assay of foods for specific nutrients. (*Not offered 1958–59.*)

20.322 *Chemistry of Nutrition Laboratory*
5.41, 7.05 *R. S. Harris* 1–4–0
Analysis for nutrients of representative foods by chemical, colorimetric, fluorometric, and microbiological techniques.

20.34 *Applied Nutrition* (A)
20.32 *R. S. Harris* 2–2–4
Nutrient requirements of man and animals; laboratory and clinical methods for determining requirements and nutritional status; techniques for measuring adequacy of dietaries; genetic and environmental factors influencing nutrient content of foods; food habits; population feeding programs; school lunches; communal feeding, etc.; international nutrition problems.

20.36 *Advanced Nutrition* (A)
20.32 *R. S. Harris* 3–3–2
Digestion of food and metabolism of nutrients, including: occurrence of nutrients in plant and animal products; stability of essential nutrients during plant growth, harvesting, storage, manufacture, and preparation for serving; influence of diet on intestinal synthesis of vitamins; synergistic action of nutrients; absorbability of nutrients from alimentary tract; endocrines and nutrition; dynamics of body constituents; isotopic and radioactive techniques; measurement of food proteins; amino acid analysis; methods of research with animals.

20.38 *Nutritional Evaluation of Food Processes* (A)
20.12, 20.32 *R. S. Harris* 3–0–3
Losses or gains in nutritional values of foods and food products during transit, treatment and storage. Discussion of the effects of the following operations: harvesting, transportation, refrigeration, freezing, concentrating, dehydration, bleaching, refining, blanching, canning, pickling, salting, brewing, fermenting, baking, steaming, boiling, frying, roasting, and toasting. Procedures for minimizing these losses in vitamins, minerals, amino acids and other nutrients.

20.41 *Bacteriology I*
7.01 *Dunn* 3–4–3
Basic relationships of microorganisms in life science. Biochemistry and physiology of bacteria. Pure culture studies, identification of unknown bacteria. Effects of physical and chemical agents, including detergents and sanitizers, on bacteria. Food preservatives, intoxication, infection, and bacteriology. Aspects of pathogenic bacteriology. Analysis of water supplies and milk supplies. Technics for the cultivation of anaerobic bacteria.

20.42 *Industrial Microbiology*
20.41 *Dunn* 2–4–4
Fundamental studies concerning industrially important fermentations, yeasts, bacteria and molds. Cultural and production methods, biochemistry. Ethanol, malt beverages, organic acids, butanol, yeast, vinegar, cheeses, sauerkraut, antibiotics. Field trips.

20.43, 20.44 *Advanced Industrial Microbiology* (A)
20.42 *Dunn* 2–4–4
20.43 *Dunn* 2–4–4
Selected topics in the uses of yeasts, bacteria and molds for the production of substances of industrial or potential value. Emphasis on the study of the most recent cultural and production methods and the biochemistry of the fermentations or the changes concerned. Biochemical activities of the acetic acid bacteria. Preparation of citric, ketogluconic, kojic gibberellic and other organic acids and food yeast. Study of antibiotics, sterols, dextran, lysine, riboflavin, vitamin B_{12}, pickles, alcoholic beverages, lipids, enzymes, butanediol and other substances. Saccharification of complex polysaccharides.

20.45 *Bacteriology II*
20.41 *Dunn* 2–4–2
Study of the application of basic microbiological principles of foods and drugs. Quantitative analytical microbiological procedures for the identification and evaluation of mesophilic, thermophilic, thermoduric, and halophilic organisms in various foods. Sterility testing procedures and their applications to foods and drugs. Membrane filter technic, antibiotics, their composition and function in food preservation. (*Not offered 1958–59.*)

20.46 *Bacteriology of Foods* (A)
7.05, 20.42 *Nickerson* 2–4–2
For advanced students in food bacteriology. Microbiological spoilage and the methods of preventing spoilage of fresh and processed meat, fish, and dairy products. Bacteriology of canned, heat processed foods and of the ingredients used in canning. Methods of calculating thermal processing times for canned, heat processed foods. Use of antibiotics in food products. Control of shellfish foods subject to pollution.

20.47 *Biochemical Engineering*
20.42 *Fuld* 2–6–2
Applications of biochemical engineering to the modern fermentation and to the antibiotics industry. Design and construction principles of pilot plant and full-scale plant fermentation equipment. Elementary heat transfer applications and study of mixing in agitated tanks. Unit operations in fermentation. Study of instrumentation as applied to fermentation control. Laboratory study of operational principles of pilot plant fermentor; and use of ion exchange and chromatography techniques for amino acid separation with new analytical techniques.

20.48 *Biochemical Engineering*
20.47 *Fuld* 2–6–2
Continuation of 20.47. Production of antibiotics. Basic principles of absorption and extraction with emphasis on oxygen absorption in agitated vessels. Scale-up procedures. Laboratory work on use of pilot-plant fermentor for production of submerged mushrooms, bakers' yeast and streptomycin. Techniques for recovery of fermentation end products by filtration, freeze-drying, and vacuum concentration. Oxygen absorption by sulfite oxidation and polarographic techniques.

20.51, 20.52 *Advanced Food Technology* (A)
20.12 *Proctor* 2–6–4
20.51 *Proctor* 2–4–4
Technical problems in special food industries, involving the use of dehydration, sterilization, homogenization equipment, and special applications of physics, chemistry, and biology in food technology.

20.53 *Food Applications of Ionizing Radiations* (A)
8.04 *Proctor, Goldblith* 2–0–4
Introduction to theory and application of ionizing radiations to the sterilization of foods and pharmaceuticals. Effects of radiations on bacteria, molds, insects, enzymes, foods and their constituents. Dosimetry of intense beams of high-energy radiations.

20.531 *Food Applications of Ionizing Radiations Laboratory* (A)
20.53 *Goldblith* 1–3–2
Laboratory exercises and problems on the fundamental as well as applied aspects of the utilization of ionizing radiations for the sterilization of food and pharmaceuticals by ionizing radiations.

20.56 *New Food Product Evaluation*
20.12 *Proctor, Goldblith* 2–4–3
Lecture and laboratory subject on the factors to be considered in the development, production, and marketing of new food products. Problems associated with such developments as nutrition, flavor, consumer acceptability, storage characteristics, and product protection.

20.61, 20.62 *Food Technology Seminar* (A)
20.12 *Proctor* 2–0–2
20.61 *Proctor* 2–0–2
Presentation of recent advances in food technology and research and analysis of the fundamental principles involved.

20.63 *Food Technology Seminar* (A)
20.62 *Proctor* 2–0–2
Presentation of recent advances in food technology and research and analysis of the fundamental principles involved.

20.64 *Food Technology Seminar* (A)
20.63 *Proctor* 2–0–2
Continuation of 20.63. Student presentation of results of their own research, illustrated by conventional, visual aids.

20.71, 20.72 *Research Problems* (A)
—— *Staff* *
Special research techniques in food technology.

20.83, 20.84 *Selected Topics in Food Technology* (A)
—— *Staff* *
Surveys and investigations arranged by individual conference.

20.85, 20.86 *Research Management in the Food and Drug Industries* (A)
—— *C. N. Frey* 2–0–2
Lectures devoted to laboratory management problems peculiar to the food and drug industries and to technological problems encountered in the production of specific foods and food by-products. Governmental regulatory agencies and their relationship to modern food and drug industries. Coordination of research personnel and facilities with the production and sales departments in connection with the development of specific food products.

20.91, 20.92 *Food Industry Seminar* (A)
—— *Proctor* 2–0–2
Seminar, with guest speakers, on industrial aspects of food technology and related professional topics.

20.93, 20.94 *Food Industry Seminar* (A)
20.92 *Proctor* 2–0–2
Continuation of 20.91, 20.92. Seminar, with guest speakers, on industrial aspects of food technology and related professional topics.

21.

Humanities

21.001 *Philosophy and Scientific Methodology*
—— *Stahlman* 2–0–4
The nature of science and scientific inquiry; the nature of philosophy and its problems. The language problem in science and philosophy; the subject matter of logic; the nature and role of induction and deduction, "facts," hypotheses, laws; experimental methods, prediction, and operational definition. Science as a description of experience; scientific law as explanation; critical evaluation of scientific results. Discussion of various key concepts from the physical and biological sciences from the points of view of their role in science and the light they shed on philosophical problems.

21.002 *English Composition*
—— *Urbach* 2–0–4
Principles of effective written communication. Logical organization of papers and precise and coherent expression of facts and opinions. Numerous papers required.

21.003 *Composition Workshop*
—— *Rathbone* *
Workshop for any undergraduate having difficulty with written expression in either a humanities or a professional subject. Instruction by individual conferences, insofar as time permits. Criticism of samples of the student's writing for organization and style, as well as for errors in composition. Application, through practice and revision, of the principles of good writing to specific assignments in the student's field. Formal enrollment unnecessary, since no credit given.

(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.

21.005 *Public Speaking*
—— —— 3–0–3
Principles of effective oral communication. Instruction in the delivery, content and logical development of subject matter. Attention to the informative speech with individual training in the extemporaneous and impromptu speech situation. Practice and individual criticism to assist the engineer in his professional work and give him confidence in his speaking ability.

21.006 *Public Speaking*
21.005 —— 3–0–3
Continuation of 21.005. May be taken separately with permission of instructor. Instruction in content and organization of subject matter with emphasis on delivery. Practice in specific speech situations: group discussions; sales talks; speeches to entertain, introduce, present or receive an award, welcome or response, and the expert witness speech. Duties of the chairman and master of ceremonies.

21.01, 21.02 *Foundations of Western Civilization*
—— *Niehaus* 3–0–5
21.01 *Niehaus* 3–0–5
Man's attempts to work out answers to his perpetual questions about himself, his fellows, his universe and his God. Careful reading of selected classics in history, literature and philosophy. Intensive writing exercises, class discussions. First term: 5th century Athens; medieval Christendom. Second term: Renaissance and Reformation — 16th century crises; 17th century — Science and the Secular State.

21.03, 21.04 *Humanities*
21.02 *Mitchell* 3–0–5
21.03 *Mazlish* 3–0–5
Two options are provided, as follows:
A. The United States: Men and Issues. Problems and forces involved in the formation and perpetuation of the Union with attention to contemporary relevance. Examination of these problems through use of source materials, literature and biography, to illuminate the institutional and intellectual conditions under which they arose and were solved. Second term: problems of industrialism and world politics.
B. Modern Western Ideas and Values. Analysis of selected intellectual, ethical and aesthetic developments since the beginning of the Age of Reason. Readings in literary classics and in great books covering religion, philosophy, science and political economy. Second term: the period since the late nineteenth century.

21.05 *Humanities Seminar*
—— *Stahlman* 3–0–6

21.06 *Humanities Seminar*
—— *Stahlman* 1–0–4

21.07 *Preparation and Presentation of Research Papers*
—— *Rathbone* 1–0–4
Review of the principles of effective communication as applied specifically to the research paper or thesis. Written proposals, outlines, and oral discussion of problems of information gathering, format, style, and composition; editorial conferences on the rough draft.

21.08 *Seminar in Technical Writing*
—— *Rathbone* 2–0–4
Discussion and preparation of various types of business and engineering communications, ranging from informal memoranda and letters to longer, more comprehensive reports and articles for technical journals. Analysis of reader needs at technical and nontechnical reader levels; review of the major pitfalls in organization of material, grammar, word choice, and usage. Selection of topics from the student's professional subjects or experience.

21.11 *Introduction to Literature*
21.04 *W. C. Greene* 3–0–5
Attempt by class discussion of common reading to suggest the possible meanings of pieces of literature, to form some sense of taste, and to formulate criteria for critical judgement. Reading of stories, novels, plays, and poems largely from European and American literature of the last century.

21.12 *Literary Theory*
21.11 *W. C. Greene* 3–0–5
Examination of a few works of literature in various genres and from several periods for their aesthetic, social, and philosophic meanings to show the relation of philosophic attitude and criticism in the arts.

21.13 *The Epic*
21.11 *W. C. Greene* 3–0–5
Reading of such epics as the *Iliad*, the *Aeneid*, the *Mahabharata*, the *Volsungasaga*, *Beowulf*, the *Song of Roland*, *The Morte Darthur*, and *John Brown's Body*; discussion of their mythological and ritual backgrounds, their shaping and decoration, their meanings as documents and as examples of art.

21.15 *Comedy in the Theatre*
21.11 *Everingham* 3–0–5
Close reading study of comedies from Aristophanes to the present day. Historical background and theatre history. Plays by Plautus, Shakespeare, Jonson, Congreve, Sheridan, Goldsmith, Wilde, Shaw, Coward, Dylan Thomas, and others. Approved practical projects in theatrical techniques accepted in lieu of term papers.

21.16 *Tragedy and Modern Drama*
21.11 *Everingham* 3–0–5
Close reading study of non-comic drama from Sophocles to the present day. Historical background and theatre history. Plays by Aeschylus, Marlowe, Shakespeare, Ibsen, Shaw, O'Neill, Wilder, Hellman, Williams, Miller, and others. Approved practical projects in theatrical techniques accepted in lieu of term papers.

21.17 *Shakespeare*
21.11 *Holland* 3–0–5
Reading and discussion of Shakespeare's major plays.

21.18 *Non-Western Literature*
21.11 *W. C. Greene* 3–0–5
Seminar presentation and discussion of some forty or fifty examples of the literature of India, China, Japan, and the Near East: early songs and hymns; religious and philosophic writing; epic; "classic" drama; early and recent novels; and poetry of the past and present. Attitudes of the several nations as seen in their visual arts.

21.19 *Major British and Continental Writers of the 19th and Early 20th Centuries*
21.11 *Lamson* 3–0–5
Analytical and critical study of selected significant works by seven leading writers in England and the Continent in the 19th and early 20th Centuries. Emergent artistic, philosophical, and social ideas in relation to the 19th Century and to their bearing on modern literature and thought. Authors chosen for 1958–1959 are Coleridge, Goethe, Stendahl, Dickens, Browning, Conrad, and Huxley.

21.20 *The Bible*
21.11 *Reiche* 3–0–5
Close reading of seminal texts from Old Testament and New Testament as literary documents illustrating specific kinds of religious experience. Philosophical implications and historical repercussions of such basic problems as faith, creation, perfection, time, etc.

21.21 *Dostoevsky, Tolstoi and Modern Russian Literature*
21.11 *MacMaster* 3–0–5
Major emphasis on Dostoevsky and Tolstoi. Additional readings (varying somewhat from year to year) from such writers as Pushkin, Gogol, Aksakov, Turgenev, Leskov, Chekhov, Bunin, Gorky, Blok, Olyesha, Pasternak. All works in translation. (*Not offered 1958–59.*)

21.22 *The Nature of Poetry*
21.11 *T. Wood* 3–0–5
Aims to stimulate understanding and appreciation of essentials of poetry. Selected works of poets from Chaucer to contemporary Americans discussed in terms of the variety of influences — social, psychological, literary, technical — shaping them. Lectures, readings, and informal discussions by poets in the vicinity.

21.24 *The Comic Sensibility*
21.11 *Holland* 3–0–5
Close reading and discussion of selected comic writings from classical times to the present by such authors as Apuleius, Shakespeare, Jonson, Molière, Swift, Sterne, Chekhov, and Shaw. Emphasis on the special nature of the comic response to events.

21.25 *The Modern Novel*
21.11 *C. Collins* 3–0–5
Discussion of novels by such writers as Joyce, Proust, Kafka, and Camus.

21.26 *Major Writers of the English Renaissance*
21.11 *Lamson* 3–0–5
Study of selected works of Marlowe, Shakespeare (works not read elsewhere in humanities program), Jonson, Bacon, Donne, Browne, and Milton in relation to artistic, philosophical, and scientific ideas in the Renaissance.

21.31 *American Folklore*
21.11 *T. Wood* 3–0–5
American folklore as historical documentation which, in a vital and dramatic way, illustrates the personal beliefs and experiences of our people. An extensive survey of our lore by geographical area and historical era with an examination of diaries and letters, histories like Parkman's *Oregon Trail*, DeVoto's *Across the Wide Missouri*, and fiction like A. B. Guthrie's *The Way West*. Use of folk material in cultivated music, drama, literature, and art.

21.33 *Nineteenth-Century American Literature*
21.11 *C. Collins* 3–0–5
Discussion of works by such authors as Poe, Hawthorne, Emerson, Thoreau, Melville, Whitman, Twain, Dickinson, Henry James, Stephen Crane, and Dreiser.

21.34 *Twentieth-Century American Literature*
21.11 *C. Collins* 3–0–5
Discussion of fiction by such authors as Sherwood Anderson, Fitzgerald, Caldwell, Wolfe, Faulkner, Steinbeck, Hemingway, and Capote; and works by such poets as T. S. Eliot, Jeffers, Frost, Robinson, MacLeish, Pound, Moore, Wallace Stevens, and Cummings.

21.391 *Special Topics in Literature*
Any two subjects in literature *Staff* 3–0–5
Topics in literature not included in other subjects.

21.392 *Special Topics in Literature*
Any two subjects in literature *Staff* 3–0–5
Continuation of 21.391.

21.41 *History and the Historian*
21.04 *Mitchell* 3–0–5
Study of history and the historical process, the ways in which historians look at their subject, and the role of the historian in his culture. Study of these problems by analysis of accounts and interpretations of a major historical event; application of the lessons derived in this way to comparable events in other societies and at different historical periods. Normally the first subject in any elective sequence in history.

21.42 *Political Process in Industrial America*
21.04 *Lichterman* 3–0–5
Selected topics from the political history of the United States since the Civil War, with emphasis on recent history such as: the southern and rural response to industrialism; the urban response to industrialism in its several facets, including the organization and functioning of urban machines, relationships between the business community and city and political machinery, and characteristics of middle-class alienation from the emerging political patterns.

21.43 *Growth of the American Industrial Economy*
21.04 *Chandler* 3–0–5
Transformation of the American economy from an agrarian to an industrial one with emphasis on recent changes. Interaction of such factors as natural resources, capital, labor, management and technology. Growth of the large corporation and the labor union and the expanding role of government in the economy.

21.44 *The Changing Role of the Industrial Leader*
21.04 *Chandler* 3–0–5
Role of the industrial leader, his social and economic backgrounds, the nature of his tasks, his attitudes and values, his relations with other groups in the economy and his position in the larger society. Industrial leadership in the perspective of historical change.

21.45 *American Foreign Policy in Action*
21.04 *Lichterman* 3–0–5
Study of selected topics in the development of American foreign policy in the pre-industrial period, the period of growth to a major industrial power, emergence as a world power, and, finally, in a bi-polar world.

21.46 *Religious Thought and American Society*
21.04 *I. H. Bartlett* 3–0–5
Interaction of scientific, economic and social change with American religious thought. Close textual analysis of the works of Franklin, Edwards, Emerson, James, Freud, Niebuhr and Tillich, etc. Considerable emphasis on contemporary period.

21.48 *Technology and Economic Growth*
21.04 *Rae* 3–0–5
Growth of technology in the modern world in its relationship to economic and social change. Crafts technology; industrialization — invention, origins of mass production and interchangeable parts, power sources, transportation, mechanization of agriculture; technology and large-scale enterprise, new industries, establishment of engineering as a profession; mass production, effects on business and labor organization, engineers in management, social changes.

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21.51 *Europe — The Expansion of Europe*
21.04 *Mahoney* 3–0–5
Case studies in modern imperialism. The British in India, the French in North Africa, and the South African complex. Readings from relevant literary sources. Emphasis on history; coverage of other appropriate disciplines. Focus of student's independent study on a specific nationalistic brand of imperialism.

21.52 *Modern Europe — War, Society and the State*
21.04 *Lockwood* 3–0–5
Analytical study on the national and international levels of the causes of the two world wars. The effects of such total war on the political, social, and economic experience of Europeans, including the rise to power of Hitler. (*Not offered 1958–59.*)

21.54 *The Russian Revolution and the Soviet Union*
21.04 *MacMaster* 3–0–5
Nature and meaning of the Soviet challenge to America. Use of literary, 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.

21.55 *History of Engineering*
21.04 *Woodbury* 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.

21.56 *History of Engineering*
21.04 *Woodbury* 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, etc. Lantern slides.

21.58 *Art and Industrial Civilization*
21.04 *Bush-Brown* 3–0–5
Introduction to painting, sculpture, and architecture in the period since 1750. Design in the visual arts and the ideas they reflect.

21.591 *Special Topics in History*
Any two subjects in history *Staff* 3–0–5
Topics in history not included in other subjects.

21.592 *Special Topics in History*
Any two subjects in history *Staff* 3–0–5
Continuation of 21.591.

21.61 *Philosophic Problems and Systems*
21.04 *Reiche* 3–0–5
Consideration of major branches, methods, issues, terms, difficulties and answers of philosophy. Discussion of curiosity, question-framing, discovery; fact, meaning, value; meaning and verification; reality and appearance; theory and practice; uniqueness and generality; knowledge, will, and faith; thought-models and reality; freedom and determinism; dogmatism and skepticism. The values of metaphysical language. Critical study, comparison, and contrast of crucial texts (*e.g.*, Heraclitus; Parmenides; Plato, *Republic;* Aristotle, *Ethics*, I, VI, X; Descartes). Accompanied by readings in contemporary works (*e.g.*, Langer, Collingwood).

21.62 *Philosophic Problems and Systems*
21.04 *Reiche* 3–0–5
Same focus as 21.61. Stress on the continuity within the diversity of approaches. Theories of knowledge and the problem of Being (*e.g.*, Kant, *Prolegomena;* Spinoza; Hume; and Husserl). The relation of aesthetics to the problem of organism and mechanism (Kant, *Critique of Judgment*). Reason, world-order, and selfhood (Hegel and Kierkegaard).

21.65 *Classical Philosophy*
21.04 *Reiche* 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.

21.66 *Major Religions of the West*
21.04 *H. Smith* 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.

21.67 *Philosophies and Religions of the East*
21.04 *H. Smith* 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.

21.69 *Problems in Contemporary Philosophy*
21.04 *Chomsky* 3–0–5
Main currents in twentieth-century empiricist philosophy. Rise and growth of the analytic, logical positivist and pragmatist movements and their offshoots. Impact of science, mathematics and symbolic logic; rejection of metaphysics; attempt to construct a scientific philosophy whose tasks are clarification, reconstruction, and logical analysis of ordinary and scientific language. The views of Peirce, Moore, Russell, Wittgenstein, Carnap and the Vienna Circle, and other analytic philosophers concerning problems in the theory of language (meaning, existence, verifiability), the theory of knowledge (a priori and empirical truth, reductionism, causality and induction), ethics and the broader role of technical philosophy. (*Not offered 1958–59.*)

21.71 *Philosophy of History*
Any two 21 subjects above 21.40 *Mazlish* 3–0–5
First part on such problems as what is meant by philosophy of history, how history emerges from myth, what constitutes "proof" in history, what certainty about historical materials can we have, and can the historian

predict future events; second part centering on the actual writing of history and studying such great historians as Ranke, Acton and Burckhardt; third part dealing with some major attempts at philosophy of history, as well as modern multicausal theories, including those of Bayle, Vico, Voltaire, Kant, Hegel, Comte, Marx, Dilthey, Spengler, Ortega y Gasset and Toynbee.

21.72 *Metaphysics*
21.04 *H. Smith* 3–0–5
Nature of the metaphysical quest in the light of recent criticisms thereof, leading into an examination of six classic world views: realism, mechanism, naturalism, Whitehead's philosophy of organism, idealism and mysticism.

21.73 *Nature of Man*
21.04 *H. Smith* 3–0–5
Examination, comparison, and evaluation of leading recent and contemporary views, with special attention to those of Nietzche, Marx, Freud, Mead, Maritain, Buber and the Existentialists.

21.74 *Philosophy in Literature*
21.61 or 21.62 or 21.81 or 21.82 *I. Singer* 3–0–5
Discussion of philosophic ideas in literature.

21.75 *Ethical Theory*
21.04 —— 3–0–5
Inquiry into theories of ethics with special reference to language, human nature, and society.

21.76 *Symbolic Logic*
21.04 *Chomsky* 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. (*Not offered 1958–59.*)

21.81 *Science and Philosophy from Antiquity to Copernicus*
21.04 *de Santillana* 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 the later Greek developments through the medieval view down to its breakup in the Renaissance under the influence of Copernicus and the age of discoveries.

21.82 *Science and Philosophy from Copernicus to the Present*
21.81 *de Santillana* 3–0–5
Continuation of 21.81 to modern times. The period from the Scientific Revolution and the founding of modern scientific thought to the present. The formation of the main scientific ideas, their philosophical implications, and the interactions of science and society.

21.83 *Philosophy of Science*
Any two 21 subjects above 21.40 *de Santillana* 3–0–5
The interconnection between the chief philosophical ideas that still stand up from the past, and the scientific philosophy arising from twentieth-century physics. Kant, Schopenhauer, Hegel, Marx, Darwin, Kierkegaard as the Unscientific Postscriptor, Russell, Bridgman, Einstein, Planck, Bohr, and Carnap.

21.84 *Topics in the History and Philosophy of Science*
Any two 21 subjects above 21.40 *de Santillana* 3–0–5
Topics to be arranged in accordance with the interests of students, and to be given, when possible, in cooperation with members of the School of Science.

21.891 *Special Topics in Philosophy*
Any two subjects in philosophy *Staff* 3–0–5
Topics in philosophy not included in other subjects.

21.892 *Special Topics in Philosophy*
Any two subjects in philosophy *Staff* 3–0–5
Continuation of 21.891.

21.91 *Introduction to Music*
21.04 *Liepmann, G. Tucker, Levy* 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 and readings required.

21.92 *Western Music from the Middle Ages to the Present*
21.91 *Liepmann, G. Tucker* 3–0–5
Study of representative composers in their historic perspective with emphasis on outstanding examples of masterworks of Middle Ages, Renaissance, Baroque and Classic eras. Detailed analysis of compositions by Bach, Haydn, Mozart, Beethoven, and by romantic and contemporary composers. Listening to recordings and readings required.

21.94 *Twentieth-Century Music*
21.92 *G. Tucker* 3–0–5
Study of principal works by masters of twentieth century. Tradition and innovation as exemplified in the music of Schönberg, Stravinsky, Bartok, Hindemith, Copland, Ives, Prokofieff, Honegger, and other composers. The interrelationship of art music, folk music and popular music. Concerts, recordings and group discussion.

21.95 *The Opera*
21.92 *G. Tucker* 3–0–5
Study of the nature and development of the music drama. Illustrations at the piano and from recordings.

21.96 *The String Quartets of Beethoven*
21.92 *Liepmann* 3–0–5
Study of the literature for string quartet in its importance as "absolute music" and as origin of the symphony. Detailed analysis of representative quartets, with emphasis on the quartets of Beethoven. Rudiments of score reading with practice. Concerts, recordings, and group discussion.

21.991 *Seminar in Music*
21.92 *Levy* 3–0–5
Various phases and aspects of music. Topics varying from year to year. Topic in fall of 1958: "Principles and Techniques of Variation."

21.992 *Seminar in Music*
21.92 *Levy* 3–0–5
Various phases and aspects of music. Topics varying from year to year. Topic in spring of 1959: "Beethoven's *Missa Solemnis*."

(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.
Nuclear Engineering

22.01, 22.02, 22.03 ***Engineering Practice School at Oak Ridge*** **(A)**
—— *Reid* 0–16–0
22.01 *Reid* 0–16–0
22.02 *Reid* 0–16–0
Engineering Practice School at Oak Ridge, Tennessee — in the Diffusion Plant, the Electromagnetic Plant, and the Oak Ridge National Laboratory of the Atomic Energy Commission, all operated by Union Carbide Nuclear Company — is available for qualified graduate students in any department who are United States citizens, subject to security clearance by the Atomic Energy Commission. Under the direction of Institute faculty residing at Oak Ridge, the work will emphasize the application of engineering principles to the solution of plant problems and is designed to develop initiative, resourcefulness, and cooperative effort in large-scale industrial operations. These subjects are offered twice during the year — in the fall term, and again in the spring term. Each series carries academic credit for 48 units. Application should be made three to four months in advance to allow ample time for clearance.

22.10 ***Introduction to Nuclear Technology I***
8.04 or 8.041; M22 *Kaplan* 3–0–6
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 22.11. Students planning to take graduate work in nuclear engineering should take 8.051.

22.11 ***Introduction to Nuclear Technology II***
8.053 or 22.10; M22 *E. A. Mason* 3–0–6
Survey of nuclear technology. Diffusion and slowing-down of neutrons; elementary theory of steady state and transient behavior of homogeneous fission reactors; engineering design of nuclear reactors; shielding; special nuclear materials; chemical processing of nuclear fuels; isotope separation. Primarily for students who wish an elementary survey of nuclear engineering and who do not plan to take more advanced subjects in this field.

22.20 ***Biological Effects of Nuclear Radiation*** **(A)**
8.053 or 22.10 *Brownell* 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. Biological and physical bases for safety standards.

22.21 ***Nuclear Reactor Physics I*** **(A)**
8.053 or 22.10; *M352* *Kaplan* 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.

22.22 ***Nuclear Reactor Physics II*** **(A)**
22.21 *Kaplan* 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 application of reactor theory to actual reactor systems.

22.23 ***Nuclear Reactor Engineering*** **(A)**
2.43 or 2.50 or 2.58 or 10.31; 22.21 *E. A. Mason, Benedict* 3–0–9
Engineering problems of nuclear reactors: including the production, transfer, and utilization of heat; thermal stresses; materials employed; change of reactivity with fuel radiation; fuel cycles; shielding; power plant thermodynamics; and optimization of reactor systems. Application of information developed in 22.21 and 22.23 to a design project dealing with the steady state characteristics of a particular nuclear reactor.

22.24 ***Nuclear Plant Dynamics*** **(A)**
6.213 or 6.605 or 6.67; 22.21 *Gyftopoulos* 3–0–6
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. Synthesis of control systems.

22.31 ***Nuclear Chemical Engineering*** **(A)**
10.32 *Benedict* 3–0–6
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.

22.41 ***Nuclear Reactor Physics Laboratory*** **(A)**
22.21 *Thompson, Rasmussen* 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.

22.42 ***Nuclear Reactor Laboratory*** **(A)**
22.41 *Thompson, Rasmussen* 2–6–4
Techniques of nuclear reactor operation, reactivity evaluation, critical mass determination, shielding surveys, reactivity effect measurements, power measurements. Techniques and experiments utilizing the M.I.T.

reactor as a neutron and gamma ray source including selections from experiments on shielding, neutron flux, neutron spectrum, reactor parameters, neutron temperature measurements, gamma ray spectrum, pile neutron temperatures and cross sections. Practice in building and using equipment including shielding test facilities, pile oscillators, a neutron spectrometer, time of flight equipment, and mechanical velocity selector.

22.51 ***Neutral Particle Transport in Reactive Assemblies I*** **(A)**
8.791; or 22.21 and M39; or M382 *M. Clark* 3–0–9
Boltzmann and integral transport equations. Adjoint solutions. Infinite medium problem. Spherical harmonic, S_n, Monte Carlo methods. Kinetics. Perturbation theory. Stability of differencing methods. Use of digital computers. (*Alternate years.*)

22.52 ***Neutral Particle Transport in Reactive Assemblies II*** **(A)**
8.791; or 22.21 and M39; or M382 *M. Clark* 3–0–9
Milne problem. Slowing down theory. Variational and harmonic methods. Thermalization. Special methods of solving Boltzmann and integral transport equations. Fundamental shielding theory. (*Alternate years. Not offered 1958–59.*)

22.61 ***Introduction to Thermonuclear Processes*** **(A)**
8.053 or 8.06 or 22.10 *M. Clark* 3–0–9
Survey of the means of obtaining energy from fusion reactions. Energy resources. Electromagnetic methods of containment. Instabilities. Loss processes. Methods of injecting, ionizing and heating plasmas. Energy balances. Methods of power extraction. Effect of impurities. Discussion of recent experiments. Diagnostic methods.

22.90 ***Special Problems in Nuclear Engineering*** **(A)**
—— *E. A. Mason* *
For special and graduate students who wish to carry out some minor investigation in a particular field. Subject and hours arranged to fit individual requirements.

22.91, 22.92 ***Seminar in Nuclear Engineering*** **(A)**
—— *Benedict* 1–0–2
For graduate students engaged on doctoral theses.

AS
Air Science

AS11, AS12 ***Air Science***
Introduction to A.F.R.O.T.C.; elements and potentials of air power; air vehicles and principles of flight; military instruments of national security; professional opportunities in the U.S.A.F.; leadership laboratory.

AS21, AS22 ***Air Science***
Careers in the U.S.A.F.; moral responsibilities of Air Force leaders; introduction to aerial warfare, targets, weapons, aircraft, bases, and operations; and leadership laboratory.

AS31, AS32 ***Advanced Air Science***
Air Force commander and staff, communicating and instructing in the Air Force, military justice system, air navigation, weather, Air Force base functions, and leadership laboratory.

AS41, AS42 ***Advanced Air Science***
Career guidance, leadership and management seminar, military aviation and evolution of warfare, military aspects of world political geography, briefing for commissioned service, and leadership laboratory.

(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.

D
Graphics

D11 ***Engineering Drawing***
—— *Reswick* 0–4–2
Newly revised subject providing an opportunity for students to use graphical techniques effectively. Solution of real problems in a variety of areas of interest; mechanical, electrical, aeronautical, chemical and civil engineering, and physics, metallurgy, meteorology, geology and architecture. Spatial visualization, experience in creative thinking and the ability to convey ideas, especially by freehand sketches. First three weeks on training in technical sketching, including orthographic projections and isometric and perspective pictorials. Remaining time on five projects representing particular fields of science or engineering.

D111 ***Graphics Laboratory I***
—— *Preusser* 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.

D12 ***Descriptive Geometry***
—— *D. P. Adams* 0–4–2
Analysis of three-dimensional space relations on a two-dimensional surface. Analysis of problems involving points, lines, planes and surfaces into fundamental components and development of methods of attack. Development of capacity to think in space terms.

D121 ***Graphics Laboratory II***
—— *Preusser* 0–3–2
Continuation of practice in representational techniques. Exercises employing graphic devices useful in all types of freehand drawing. Use of charcoal pencil, ink wash and water color as effective means to create the graphic equivalent of what is observed or visualized.

D13 ***Graphical Processes***
—— *Coons* 2–0–4
Methods of graphical solution of physical problems. Graphical arithmetic and algebra. Conic constructions, projective geometry, coordinate systems, graphical calculus, scales, nomograms, empirical curves, and periodic curves. An individual project.

D14 ***Elementary Nomography***
—— *D. P. Adams* 2–0–4
Introduction to graphical solution of equations through alignment diagrams based on plane geometry, including graphical use of central projections and duality of point and line.

D15 ***Basic Machine Drawing***
—— *Howes* 0–4–2
Fundamentals of representation by projection. Sectional views. Auxiliary views. Dimensioning. Fasteners. Shop terms and processes. Reproduction of drawings. Freehand sketching and instrumental drawing used where appropriate. *Not intended for students planning to enter mechanical or aeronautical engineering.*

D31 ***Nomography***
M12 *D. P. Adams* 2–0–4
Nomographic methods for solving equations in three or more variables and their use in scientific data. Plane geometry foundation and advanced determinant theory with adequate algebraic background. Central projection in nomography, interpretation in terms of general projective transformation, corresponding determinant operator and graphical and analytical methods. Errors of Lo-Ho. Classical and modern necessary and sufficient conditions for nomographic form as presented by Duporcq, Gronwall, Kellogg, Thomas, and others. Quasi-alignment diagrams and use of the principle of duality to alignment diagrams based upon empirical data. Project.

D32 ***Advanced Graphics***
D12, M12 *Coons* 2–0–4
Projective geometry, construction of conics, projective transformations. Applications to streamlined shapes such as aircraft. Wrapped surfaces. Duality transformations, with application to network charts and alignment diagrams. Theory of graphs and tables. Transformation of curvilinear network charts into rectilinear networks. Graphical calculus, including general methods for solution of ordinary nonlinear differential equations; harmonic analysis. Graphical techniques applied to empirical data. Opportunity for the student to pursue projects connected with his own field of engineering.

L
Modern Languages

L11, L12 ***Elementary German***
—— *Halle* 3–0–5
L11 *Halle* 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.

L13 ***Intermediate German***
L12, or elementary entrance German *Klugman* 3–0–5
Continuation of practice in spoken and written German. Reading, translation, and discussion of shorter prose works by recent representative German authors. Conducted primarily in German.

L14 ***Intermediate German***
L13 *Klugman* 3–0–5
Reading, translation, and discussion of works of the nineteenth and twentieth centuries. The transition from the classical tradition of German idealism to the modern point of view. Study of German thought and life as seen through German eyes. Conducted in German.

L15 ***German Literature 1919–33***
L14 *Bon* 3–0–5
A thumbnail sketch of German literature from the ushering in of the Weimar Republic to the Burning of the Books. 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. Prerequisite: ability to understand spoken and written German.

L16 ***Literature of Postwar Germany***
L14 *Bon* 3–0–5
The evolution of German opinion and life since 1945 as seen in the current works of German writers with reference to books and periodicals. Conducted in German. Prerequisite: ability to understand spoken and written German.

L17 ***Scientific German***
—— *Klugman* 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.*)

L20 ***Great Books and Authors in German Literature***
L14 *Bon* 3–0–5
Reading and discussion of outstanding works in the drama, poetry and prose fiction of German literature. Period 1750–1900. One play of each of the following: Goethe, Schiller, Grillparzer and Hauptmann. Selections from the poetry of Goethe, Schiller, Heine and Rilke. Selections from the prose of Goethe and Heine. One novel each by Gottfried Keller and Conrad Ferdinand Meyer. Conducted in German. Prerequisite: ability to understand spoken and written German. (*Not offered 1958–59.*)

L21, L22 ***Spoken German***
3 years high school German *Dyck* 3–0–3
L21 *Bon* 3–0–3
Two-term sequence for students with three years of high school German, or the equivalent, but 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 upon development of the basic vocabulary of words and phrases used in everyday conversation. Appropriate for Fulbright candidates.

L31 ***English for Foreign Students***
—— *Applegate* 3–0–3
For students for whom English is a foreign language. Essentials of pronunciation and grammar, with attempt to improve understanding of and expression in American English, particularly the spoken language. A reading knowledge of English is assumed.

L32 ***English for Foreign Students***
L31 *Applegate* 3–0–3
For more advanced students as well as for those who have completed L31. Increased emphasis on advanced syntax and the principles of effective communication. Attention given to English morphology to assist in vocabulary building. Selected readings as basis for discussions and preparation of papers.

L51, L52 ***Elementary French***
—— *Dinneen* 3–0–5
L51 *Dinneen* 3–0–5
Necessary foundation for French language and literature, or for scientific studies. Training in pronunciation, elementary grammar, acquisition of useful vocabulary and reading of varied matter, part of which deals with French institutions and the history of France, practice in hearing and speaking French.

L53 ***Intermediate French***
L52 or elementary entrance French *Bottiglia* 3–0–5
Continuation of pronunciation, opportunity to use spoken French. Reading matter in contemporary and nineteenth century plays, fiction, and poetry.

L54 ***Intermediate French***
L53 *Bottiglia* 3–0–5
Reading, translation, and discussion of representative French works, particularly from the nineteenth and twentieth centuries. Short stories, plays and poetry. Study of typical literary art forms of French and investigation into French modes of life and thought. Some discussion in French.

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L55 ***Contemporary French Literature***
L54 *Bottiglia* 3–0–5
Reading and study of post-war literary works for the light which they throw on French thought and action in present-day society. Conducted in French. Prerequisite: ability to understand spoken and written French.

L56 ***French Literature of the Third Republic***
L54 *Bottiglia* 3–0–5
Reading and study of French literary works from 1870 to 1940. The great figures of this period. Economic, social, and philosophical trends as reflected in literature. Conducted in French. Prerequisite: ability to understand spoken and written French. (*Not offered 1958–59.*)

L57 ***Scientific French***
—— *Klugman* 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.*)

L59 ***Great Books and Authors in French Literature***
L54 *Bottiglia* 3–0–5
Reading and discussion of great works in the drama, poetry, and prose fiction of French literature. One play of each of the following: Corneille, Racine, Molière, Marivaux, Beaumarchais, and Hugo. Selection from the writings of Montesquieu, Voltaire, and Rousseau. Selections from the poetry of Ronsard, Du Bellay, Lamartine, Hugo, de Vigny, de Musset and Gautier. Some discussion in French. Prerequisite: ability to understand spoken and written French.

L61 ***Introduction to Spoken French***
3 years high school French *Hornik* 3–0–3
For students with three years of high school French or the equivalent, but with little or no experience in using the spoken language. Practice in speaking French. Phonetic method for correction of accent. Mechanical devices used for improving intonation and pronunciation. Appropriate for Fulbright candidates.

L62 ***Conversational French***
3 years high school French *Hornik* 3–0–3
Development of the basic vocabulary of words and phrases used in everyday conversation. Attention to individual pronunciation problems. For students with three years of high school French or the equivalent, but with little or no experience in using the spoken language. Appropriate for Fulbright candidates.

L75 ***Language and Society***
—— *Chomsky* 3–0–5
Languages of the world, their distribution, relations, and structural classification; how languages change and develop; basic elements of language and the nature of a linguistic system; speech and writing; development of systems of writing; interrelation of language and culture.

L76 ***Problems of Phonology***
L75 *Halle* 3–0–5
Aims and principles of a scientific description of the structure of a spoken language. The mechanism and the acoustics of speech. The phonemic system of a language. The pair test. Distinctive features as a descriptive framework. The phoneme. The interrelation between phonology and other linguistic levels. Some problems of historical phonology. Practical exercises in preparing a phonemic analysis of a language with the help of a native informant.

L78 ***Linguistic Structure***
L75 *Chomsky* 3–0–5
Problems and methods of the descriptive study of language. *Study of form in language:* definition and determination of linguistic elements; mathematical models for linguistic behavior; construction of an objective and abstract theory of formal linguistic structure; systematic application of this theory to the description of English structure. *Study of meaning in language:* relation of linguistic form and meaning; various approaches to a theory of meaning; contemporary philosophy of language and the influence of symbolic logic; extensional and intensional structure. Comparison of the logic of natural languages with that of special purpose language systems (i.e. mathematics, science).

(See also 6.696 HEARING, SPEECH AND LANGUAGE, offered jointly by members of the Department of Electrical Engineering and the Department of Modern Languages.)

L91, L92 ***Elementary Russian***
—— *Znamensky* 3–0–5
L91 *Znamensky* 3–0–5
Essentials of grammar, practice in hearing, pronunciation, speaking and translation of connected stories. Practice in reading easy scientific Russian articles in second term.

L93, L94 ***Intermediate Russian***
L92 *Znamensky* 3–0–5
L93 *Znamensky* 3–0–5
Continuation of pronunciation and practice in conversation, reading of matter dealing with Russia, some standard modern authors, reading of scientific Russian.

L97 ***Scientific Russian***
—— *Znamensky* 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.*)

M
Mathematics

M100 *Elementary Number Theory*
—— *Franklin* 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.

M101 *Topics in Discrete Mathematics*
—— *H. Rogers* 2–0–4
Elementary topics in: propositional logic; algebra of sets; permutations and combinations; probability; vectors and matrices; mathematical models and axiomatic method. Kemeny, Snell and Thompson, *Introduction to Finite Mathematics.*

M11 *Calculus*
—— *Douglass* 3–0–6
Fundamental ideas of differential and integral calculus. Differentiation and graphical representation of algebraic functions and of the sine and cosine. Integration of simple algebraic and trigonometric functions. Applications to problems in geometry and mechanics: maxima and minima, velocity and acceleration, plane areas, volumes, arc length, areas of surfaces of revolution, center of gravity, moment of inertia. Analytic geometry of the straight line. Thomas, *Calculus and Analytic Geometry.*

M12 *Calculus*
M11 *Douglass* 3–0–6
Analytic geometry of the conic sections. Further study of differentiation and integration: trigonometric, inverse trigonometric, exponential, logarithmic and hyperbolic functions. Polar coordinates and parametric representation. Complex numbers. Elementary vector analysis in the plane. Thomas, *Calculus and Analytic Geometry.*

M21 *Calculus*
M12 *Zeldin* 3–0–6
Vector velocity and acceleration in plane curvilinear motion. Three-dimensional analytic geometry. Partial differentiation. Multiple integration. Infinite series. Thomas, *Calculus and Analytic Geometry.*

M22 *Differential Equations*
M21 Zeldin 3–0–6
Treatment of ordinary differential equations. Introduction to the Laplace transform. Series solutions. Separation of variables for partial differential equations. Fourier series. Probability. Martin and Reissner, *Elementary Differential Equations.*

M221 *Probability and Operations Analysis*
M21 *Wadsworth* 3–0–6
Linear differential equations with constant coefficients, Gamma and Beta functions, probability, distribution theory, and expected values. Mathematical theory and techniques particularly appropriate to the application of the scientific method to the solution of business and industrial problems. Emphasis upon the setting up of simple mathematical models and interpretation of analytical results with reference to the primary purpose of aiding in executive decisions.

M32 *Elementary Statistics*
M21 *Wadsworth* 3–0–6
General survey of the mathematics behind the application of statistical methods to scientific and engineering problems. Probability, discrete and continuous random variables, joint distributions, derived distributions, mathematical expectation, hypothesis testing, estimation and standard tests, and regression and correlation. Illustrations of the practical applications.

M341, M342 *Modern Statistical Theory*
M22, M32 *G. B. Thomas* 3–0–6
M341 *G. B. Thomas* 3–0–6
Rigorous development of mathematical statistics, including such topics as generalized distribution functions, characteristic functions, statistical inference, sampling theory, tests of significance, maximum likelihood statistics, hypothesis testing, theory of estimation, regression theory, introduction to multivariate statistical analysis, and time series analysis. References: S. S. Wilks, *Mathematical Statistics;* H. Cramer, *Mathematical Methods of Statistics;* N. Wiener, *Stationary Time Series.* (*Not offered 1958–59.*)

M351, M352 *Advanced Calculus for Engineers* (A)
M22 or M221 *Hildebrand* 3–0–6
M351 *Hildebrand* 3–0–6
Vector analysis; orthogonal curvilinear coordinates. Functions of a complex variable; calculus of residues; conformal mapping. ordinary differential equations; integration by power series; Bessel and Legendre functions. Characteristic-value problems; expansions in series of orthogonal functions, including Fourier series. Partial differential equations; characteristics; solution of classical equations of mathematical physics.

M371, M372 *Operations Research* (A)
M32; M351 or M831 *Wadsworth* 3–0–6
M371 *Wadsworth* 3–0–6
Development of the concepts of probability and mathematical models in physical, industrial and laboratory situations as the scientific approach to small and large-scale operations. Basic problems involving probability; also inverse probability, geometrical probability, distribution theory and the construction of mathematical models, game theory, linear programming, time series and prediction theory, and stochastic processes.

M381, M382 *Theory of Functions* (A)
M352 or M831 *Ambrose* 3–0–9
M381 *Ambrose* 3–0–9
Complex numbers, analytic functions. Complex integration, Cauchy's theorem, Cauchy's integral formula, evaluation of definite integrals. Taylor series, Laurent series, partial fractions, infinite products. Riemann's mapping theorem. Analytic continuation. Harmonic functions, solution of Dirichlet's problem, Green's function. Methods in conformal mapping. Asymptotic series. Fourier and Laplace transforms. Hadamard factorization theorem. Gamma function, special functions.

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M39 *Methods of Applied Mathematics* (A)
M351 *Hildebrand* 3–0–9
Operations with matrices and determinants; linear vector spaces; characteristic-value problems. Techniques of calculus of variations; Hamilton's principle and Lagrange's equations; variational principles for deformable bodies; direct and semi-direct methods. Formulation and solution of linear difference equations. Formulation and treatment of integral equations; Green's function; analytical and numerical methods of solution. Hildebrand, *Methods of Applied Mathematics.*

M411, M412 *Numerical Analysis* (A)
M351 *Hildebrand* 3–2–7
M411 *Hildebrand* 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, *Numerical Analysis.*

M42 *Introduction to Hydromechanics*
M351, *M352* *Lin* 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. (*Not offered 1958–59.*)

M421 *Theoretical Hydromechanics* (A)
M42 *Lin* 3–0–9
Recapitulation of general theory of perfect fluids. One-dimensional motion. Two-dimensional motion involving subsonic and supersonic speeds; application of the theory of complex variables. Application of the theory of characteristics to hydrodynamical problems. Three-dimensional motion involving subsonic and supersonic speeds; theory of lifting surfaces. Other selected topics.

M422 *Theoretical Hydromechanics* (A)
M42 *Lin* 3–0–9
Recapitulation of the general theory of viscous fluids, fundamental concepts and basic equations, examples of exact solutions. Flow at low Reynolds numbers. Flow at high Reynolds numbers, boundary layer theory. Hydrodynamic stability. Turbulent flows, mixing length theories and statistical theories. Other selected topics of current interest.

M442 *Elementary Differential Geometry*
M832 *Struik* 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. Struik, *Differential Geometry.*

M451, M452 *Fourier Series and Integrals* (A)
M381 or M831 *Wiener* 3–0–9
M451 *Wiener* 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.

M461 *Seminar in Mathematics* (A)
M352 or M381 or M832 *Lin* *
Reading, consultation and discussion of current mathematical research. (*Not offered 1958–59.*)

M47 *Mathematical Theory of Hydromagnetics I* (A)
8.041, M42 *Backus* 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 and organized oscillations.

M481, M482 *Topology* (A)
M62; M381 or M831 *Peterson* 3–0–9
M481 *Peterson* 3–0–9
Elements of point-set topology. Homology and cohomology groups of simplicial complexes. Universal coefficient and Künneth theorems. Singular and Cech homology theories. Fundamental group and covering spaces. Alexander and Poincaré duality.

M483 *Advanced Topology* (A)
M482 *G. W. Whitehead* 3–0–9
Homotopy groups. Obstruction theory. Fibre maps. Spectral sequences. Eilenberg-MacLane spaces. Cohomology operations. 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. (*Not offered 1958–59.*)

M491, M492 *Geometry of Manifolds* (A)
M481, M832 *Ambrose* 3–0–9
M491 *Ambrose* 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 1958–59.*)

M50 *Fundamentals of Mechanics of Continua*
M352 *Lin* 3–0–6
Analysis of strain, small and large deformations; analysis of stress, stress-strain relations. Equation of continuity, equations of motion. Equation of state, equation of energy, and other thermodynamical considerations. Curvilinear coordinates. Invariance of physical laws under transformation of coordinates. Introduction to tensor calculus in the study of mechanics of continua. (*Not offered 1958–59.*)

M521, M522 *Topics in the Theory of Numbers* (A)
M381 *Ankeny* 3–0–9
M521 *Ankeny* 3–0–9
Discussion of the Riemann Zeta function. Proof of the prime number theorem through contour integration, the method of contour integration applied to the divisor problem, the solution of Waring's problem via the circle method of Hardy-Littlewood and Vinogradoff's improvements, other applications of the circle method, the general sieve method of Selberg with application to primes, twin primes, Goldbach's problem. Proofs of certain best possible results of the sieve. Content varying from year to year, so that graduate students may take the subject in successive years. (*Not offered 1958–59.*)

M53 *Locally Compact Groups* (A)
M551 or M651 *Singer* 3–0–9
Haar measure, group algebras, unitary representations, harmonic analysis on compact and abelian groups, Plancherel theorem, duality theorem. (*Not offered 1958–59.*)

M54 *Mathematical Laboratory*
M22 *Douglass* 3–0–6
Practical instruction in numerical, graphical and mechanical calculation and analysis as required in the engineering or applied mathematical sciences, numerical solution of equations; graphical methods; nomography and the construction of graphical charts; curve fitting to empirical data, approximate methods of integration, differentiation and interpolation; use and principles of construction of instruments employed in calculation, and many kindred topics. Lipka, *Graphical and Mechanical Computation.* (*Not offered 1958–59.*)

M551, M552 *Functions of a Real Variable* (A)
M832 *Kunze* 3–0–9
M551 *Kunze* 3–0–9
Elements of the theory of metric spaces, category and Baire theorem. Lebesgue integration, absolute continuity and differentiation of functions of bounded variation. Abstract measure theory, Radon-Nikodym and Fubini theorems, L^p spaces. Independent random variables, Rademacher functions, law of large numbers, and maximal ergodic theorem. Elements of Banach spaces, Hahn-Banach and closed graph theorems. Selected topics on linear transformations on L^p spaces.

M553, M554 *Singular Integrals and Applications* (A)
M381, M552 *Calderon* 3–0–9
M553 *Calderon* 3–0–9
Hilbert transforms, conjugate functions in one variable. The theorems of F. Riesz and Hardy-Littlewood. Real variable approach. Convolution operators on Lebesgue spaces. The Marcinkiewicz multiplier theorem. Extension to several variables. Riesz and Beurling transforms. Convolution operators with variable kernel representation of differential operators and the operator lambda. Singular integral operators on compact manifolds. Applications to analysis and differential equations.

M561, M562 *Functions of Complex Variables* (A)
M382, M481 *Singer* 3–0–9
M561 *Singer* 3–0–9
Classical theory of several complex variables. Sheaves and their application to complex manifolds, topology and algebraic geometry. Content varying from year to year, so that students may take the subject in successive years.

M571, M572 *Differential Equations* (A)
M381; M39 or M62 *Levinson* 3–0–9
M571 *Levinson* 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.

M573 *Dynamical Systems* (A)
M351 *Moser* 3–0–9
Brief derivation of classical Hamilton-Jacobi theory and the transformation theory for Hamiltonian systems with applications to examples of mechanics and optics. Main emphasis on the flow in the phase space in the large — especially near periodic — solutions, existence of integrals, and stability for nonlinear dynamical systems. Discussion of the transformation of surface of section. (*Not offered 1958–59.*)

M574 *Dynamical Systems* (A)
M573 *Moser* 3–0–9
Continuation of M573. Analytic study of the flow generated by Hamiltonian systems in the large, in particular near periodic orbits. Investigation of nonlinear effects, stability theory, existence and non-existence of integrals (Poincaré, Birkhoff). Applications to celestial mechanics and to the stability theory of accelerators. (*Not offered 1958–59.*)

M581, M582 *Continuous Groups* (A)
M481, M551 *Singer* 3–0–9
M581 *Singer* 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. Symmetric spaces. (*Not offered 1958–59.*)

M591, M592 *Partial Differential Equations* (A)
M352 or M381 *Moser* 3–0–9
M591 *Moser* 3–0–9
Geometric approach to first and second order partial differential equations. Characteristics and wave fronts. Stress on second order equations, their classification and physical significance. Boundary value problems, initial value problems. Adjoint equation, variational methods, operational methods. Maximum principle. Applications.

M61 *Mathematical Logic* (A)
M62 *H. Rogers* 3–0–9
Classical systems of logic and their use in the formalization of mathematical argument. Algebraic structure in logical systems. Brief study of effective computability, the Gödel incompleteness theorem and related topics.

M62 *Linear Algebra*
M22 *Crowell* 3–0–6
Vector spaces, euclidean spaces, linear transformations, linear equations, matrices, determinants, quadratic forms, canonical forms of matrices.

M63 *Modern Algebra* (A)
M62 *Mattuck* 3–0–9
Introduction to modern algebra; discussion of basic concepts and demonstration of fundamental theorems. Groups, rings, fields, (normal) subgroups, factor groups, ideals, residue class rings, prime fields, homomorphisms and isomorphisms.

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M631 *Integral Equations* (A)
M22 *Crout* 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 1958–59.*)

M633 *Algebra* (A)
M63 *Iwasawa* 3–0–9
Further study of algebraic structures. Theory of fields and their extensions: algebraic and transcendental extensions, Galois extensions, algebraic closures. Structure of groups and rings.

M634 *Topics in Algebra* (A)
M63 or M633 *Iwasawa* 3–0–9
Study of algebraic number fields, including such topics as factorization of ideals, splitting and ramification of prime ideals, the group of units, quadratic and cyclotomic fields, general ideal theory and valuation theory. Content varying from year to year so that graduate students may take the subject in successive years.

M641 *Tensor Calculus* (A)
M39 or M62 *L. N. Howard* 3–0–9
Tensor algebra and analysis. The geometry of Riemannian space. Applications to mechanics and especially to general relativity.

M651, M652 *Functional Analysis* (A)
M381; M551 or M832 *Calderon* 3–0–9
M651 *Calderon* 3–0–9
Locally convex topological vector spaces, Banach spaces. Completely continuous operators. Banach algebras. Spectral theorem for operators in Hilbert space. Algebras of bounded operators in Hilbert space. Semigroups of operators. (*Not offered 1958–59.*)

M661 *Topics in Foundations of Mathematics* (A)
M62 *H. Rogers* 3–0–9
Topics in mathematical logic, effective computability, and axiomatic set theory, with emphasis on the second of these. Brief study of certain classical systems of mathematical logic with related results.

M671, M672 *Algebraic Functions* (A)
M381, M633 Mattuck 3–0–9
M671 Mattuck 3–0–9
Closed Riemann surfaces and corresponding algebraic function field. Differentials and abelian integrals. Riemann-Roch theorem. Abel's theorem and Jacobi's theorem. Unramified extensions and covering Riemann surfaces. Algebraic correspondences. Elliptic functions. (*Not offered 1958–59.*)

M711 *Theory of Games*
M22 *Nash* 3–0–9
Probabilities in games. Strategies. Mixed strategies. "Optimal" strategies and the minimax theorem for two-person zero-sum games. Information pattern analysis. Applications to statistical decision and programming. Non-cooperative games, behavior strategies, applications to economics, poker. Cooperative games, coalitions, theory of von Neumann and Morgenstern, other theories, the area of unsolved problems. Two-person cooperative games, precise treatment of duopoly situations.

M72 *Automata and Artificial Intelligence* (A)
M39 or *M62* or *M76* *Minsky* 3–0–9
Discussion of the problem of making machines behave intelligently. Theory of automata, neural nets, and other computing structures. Application of such machines to learning, induction, pattern recognition, game playing, theorem proving, and other areas where problems can be solved by heuristic programming.

M73 *Review of Mathematics*
—— *Douglass* 8–0–12
Review of calculus and differential equations. (Primarily for selected officers of the U. S. Army, Air Force, Navy and Coast Guard.) Douglass and Zeldin, *Calculus and Its Applications*. Martin and Reissner, *Elementary Differential Equations*.

M76 *Probability*
M351 *G. B. Thomas* 3–0–6
Elements of combinatorial analysis. Random variables and expectations. Laws of large numbers. The central limit theorem and its applications. Recurrent events and Markov chains. W. Feller, *An Introduction to Mathematical Probability and Its Applications*.

M761, M762 *Theory of Probability* (A)
M551 or M832 *Ray* 3–0–9
M761 *McKean* 3–0–9
Characteristic functions. Sums of independent variables, limit theorems, topics from Martingales and Markov processes.

M78 *Introduction to Elasticity*
M351 Reissner 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. Wave propagation problems. Transition to plasticity.

M791, M792 *Theoretical and Applied Elasticity* (A)
M352, M78 or 2.081 *Reissner* 3–0–9
M791 *Reissner* 3–0–9
Analysis of stress and strain in three dimensions. Stress-strain relations. Variational principles in elasticity, including application to the approximate solution of boundary value problems. Theories of torsion, of flexure and of plane stress and strain. Bending of flat plates, linear and non-linear theory. Bending and stretching of thin shells. Elastic stability theory. Elements of the finite deformation theory of elasticity. (*Not offered 1958–59.*)

M831, M832 *Analysis*
M21, *M62* *G. B. Thomas* 3–0–9
M381 *G. B. Thomas* 3–0–9
Real numbers and euclidean n-space; Bolzano-Weierstrass and Heine-Borel theorems, Cauchy condition. Infinite series of real and complex numbers, tests for convergence, power series. Real valued functions, continuity, uniform continuity, bounded variation. Riemann-Stieltjes integration. Infinite series of functions, uniform convergence, differentiation and integration of series of functions. Taylor's theorem, Weierstrass approximation theorem, Fourier series, completeness of the trigonometric functions, Fejer's theorem. Orthogonal functions, Bessel's inequality, Parseval's equality. Jacobians and inverse function theorem, implicit function theorem, functional dependence. Change of variables in multiple integrals, line and surface integrals. Stokes, theorem, Green's theorem, divergence theorem.

M90 ***Mathematical Reading*** **(A)**
—— *W. T. Martin* *
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.

MS
Military Science

MS11, MS12 ***Military Science***
School of the soldier and exercise of command; military organization; American military history; individual weapons and marksmanship; United States in world affairs.

MS21, MS22 ***Military Science***
Map and aerial photo reading; small unit tactics; crew served weapons and gunnery; elementary communications; school of the soldier and exercise of command.

MS312, MS322 ***Advanced Corps of Engineers***
Leadership; school of the soldier and exercise of command; basic engineer organization; military explosives; mine warfare; construction materials; military structures; engineer computations and layout; fortifications and camouflage construction; military teaching methods.

MS313, MS323 ***Advanced Signal Corps***
School of the soldier and exercise of command; military teaching methods; leadership; communication security; signal orders; field wire communication techniques; field radio communication techniques; applied signal communication (division); message center and communication center procedures.

MS314, MS324 ***Advanced Ordnance Corps***
Leadership; school of the soldier and exercise of command; organization of the Ordnance Corps; automotive materiel; small arms materiel; ammunition materiel; ammunition supply; artillery materiel; fire control materiel; guided missiles and special weapons; Ordnance service in the field; military teaching methods.

MS316, MS326 ***Advanced Chemical Corps***
Leadership; military teaching methods; school of the soldier and exercise of command; origin, development, and mission of Chemical Corps; organization and function of Chemical Corps and of Chemical Corps units; characteristics of and defense against CBR agents; detection of CBR agents and individual protective equipment; Chemical Corps materiel; decontamination; collective protection; field behavior of CBR agents; employment of CBR agents; chemical combat intelligence.

MS318, MS328 ***Advanced Quartermaster Corps***
Leadership; school of the soldier and exercise of command; organization and mission of the Quartermaster Corps; principles of supply; procurement functions; aerial supply and delivery; quartermaster operations in the theater of operations; military teaching methods.

MS412, MS422 ***Advanced Corps of Engineers***
Military administration and military justice; supply of engineer units; movement of personnel and equipment; maintenance of engineer and ordnance equipment; military roads and airfields; buildings and utilities; staff procedures for engineer battalions; operations of engineer units; engineers in the military team; school of the soldier and exercise of command.

MS413, MS423 ***Advanced Signal Corps***
Military administration and military justice; school of the soldier and exercise of command; higher echelon signal communication systems and equipment; career guidance plan for Signal Corps officers; command and staff; military intelligence; wire communication-materiel; radio communication-materiel; Signal Corps photographic activities; laboratory techniques; logistics.

MS414, MS424 ***Advanced Ordnance Corps***
Operations; logistics; military administration and military justice; service orientation; school of the soldier and exercise of command; Ordnance maintenance and supply service.

MS416, MS426 ***Advanced Chemical Corps***
Operations; logistics; military administration and military justice; service orientation; school of the soldier and exercise of command; Chemical Corps supply and field service; duties of staff Chemical officers; responsibilities and duties of Chemical Corps officers; employment of Chemical Corps units, operations and training.

MS418, MS428 ***Advanced Quartermaster Corps***
School of the soldier and exercise of command; military administration and military justice; logistical organization, continental U. S.; training management; command and staff; petroleum supply functions; research and development; quartermaster unit mess and motor activities; officer indoctrination.

(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.

NS
Naval Science

NS11, NS12 *Orientation and Sea Power*
Fundamentals of naval knowledge. Concepts of use of sea power from geographical, geopolitical and national strategical considerations. Historical influence of sea power in shaping world affairs socially, politically and economically. (*Restricted to students selected for N.R.O.T.C.*)

NS21, NS22 *Naval Guided Missiles*
Lecture series on technological fundamentals of present day naval guided missiles. (*Restricted to students selected for N.R.O.T.C.*)

NS31, NS32 *Naval Nuclear Propulsion*
Lecture series on technological fundamentals of applied and planned naval nuclear propulsion plants. (*Restricted to students selected for N.R.O.T.C.*)

NS41, NS42 *Naval Industrial Management and Leadership*
Study of the principles of human relations and their application in naval industrial management; group dynamics; personnel psychology; principles of sound planning, execution and control methods as applied to administrative leadership. (*Restricted to students selected for N.R.O.T.C.; not offered 1958–59.*)

This Section lists in numerical order *all* subjects of instruction given at the Massachusetts Institute of Technology. The information is subject to change. The final list of subjects to be given in each term will be published with detailed class schedules prior to the start of the term.

The prerequisite subjects whose numbers are shown in italics may be taken simultaneously with the subject concerned.

The symbol (A) following the year for which a subject is scheduled indicates a subject given primarily for graduate students. The symbol (R) means that the subject is restricted to special groups because of content; a subject open only to special groups for other reasons is indicated by a dash (—) in the Course numbers column; the groups to which such a subject is open are indicated at the end of the description of the subject, in the "Descriptions of Subjects."

The time distribution is given in units, each unit representing 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.

1.

Civil and Sanitary Engineering

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
1.002	TECHNOLOGY IN OUR CIVILIZATION *Lang*	——	1	2	Elective	2	—	4
1.01	SURVEYING I *C. L. Miller*	M12	2	1	I	2	6	0
1.02	SURVEYING II *C. L. Miller*	1.01	2	2	I	2	6	0
1.04	APPLIED SURVEYING *C. L. Miller*	1.02	4	2	Elective	2	3	4
1.06	PHOTOGRAMMETRIC ENGINEERING *C. L. Miller*	——	4	1 or 2	Elective	2	2	4
1.12	SPECIAL STUDIES IN PHOTOGRAMMETRY *C. L. Miller*	1.06	G(A)	1 or 2	Elective		★	
1.201	TRANSPORTATION PLANNING *Roggeveen*	——	4	1	Elective	3	3	3
1.202	TRANSPORTATION ENGINEERING *Bone*	1.02	4	2	Elective	3	3	3
1.251T	TRAFFIC ENGINEERING *Bone*	1.201 or 1.202	G(A)	1	Elective	3	—	6
1.252T	HIGHWAY LOCATION AND GEOMETRIC DESIGN *Bone*	1.201 or 1.202	G(A)	2	Elective	2	1	4
1.261	AIRPORT PLANNING AND ADMINISTRATION *Bone*	1.201 or 1.202	G(A)	1	Elective	2	—	4
1.262	AIRPORT DESIGN *Roggeveen*	1.201 or 1.202	G(A)	2	Elective	2	4	0
1.27	SPECIAL STUDIES IN TRANSPORTATION ENGINEERING *Roggeveen*	1.201 or 1.202	G(A)	1 or 2	Elective	2	—	4
1.271	TRANSPORTATION SEMINAR *Roggeveen*	1.201 or 1.202	G(A)	1	Elective	1	—	2
1.282T	HIGHWAY AND AIRPORT PAVEMENTS *Bone*	1.201 or 1.202	G(A)	1	Elective	2	2	4
1.29	MANAGEMENT PROBLEMS OF THE TRANSPORTATION INDUSTRY *Roggeveen*	1.201 or 1.202	G(A)	2	Elective	3	—	3
1.30	SOIL MECHANICS *Lambe*	1.41	3	2	I	3	3	6
1.31	SOIL ENGINEERING *Roberts*	1.30	4	1	Elective	3	—	6
1.361	ADVANCED SOIL MECHANICS *R. V. Whitman*	1.30	G(A)	1	Elective	3	—	6
1.362	EARTH STRUCTURES *R. V. Whitman*	1.361	G(A)	2	Elective	3	—	6
1.364	FOUNDATIONS *Roberts*	1.361	G(A)	2	Elective	3	—	6
1.367	SOIL TECHNOLOGY *Lambe*	——	G(A)	1	Elective	2	—	4
1.37	SOIL MECHANICS LABORATORY *Ladd*	*1.361*	G(A)	1	Elective	1	3	4
1.39	SOIL ENGINEERING SEMINAR *Lambe*	1.361, 1.367	G(A)	2	Elective	1	—	2
1.40	STATICS AND DYNAMICS *Biggs*	8.02, M12	2	2	I	3	—	5
1.41	MATERIALS AND MECHANICS *McGarry, Heger*	1.40	3	1	I	4	2	6
1.42	MATERIAL AND MECHANICS *J. A. Murray, McGarry*	1.41	3	2	I	4	2	6
1.43	ADVANCED MATERIALS *Dietz, J. A. Murray*	1.42	4	1	Elective	2	—	4
1.44	ELEMENTARY STRUCTURAL ENGINEERING *Hansen*	1.42	3	2	I	3	3	2
1.441	STRUCTURAL DESIGN *Mirabelli*	1.44, *1.451*	4	1	I	2	4	0
1.442	REINFORCED CONCRETE DESIGN *Holley*	1.44, *1.451*	4	2	I	2	4	0

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
1.443	STRUCTURAL DESIGN *Mirabelli*	*1.44, 1.451*	4	1	Elective	3	4	2
1.444	REINFORCED CONCRETE DESIGN *Holley*	*1.44, 1.451*	4	2	Elective	3	4	2
1.451	STRUCTURAL ANALYSIS *Mirabelli*	1.44	4	1	I	3	—	6
1.452	STRUCTURAL ANALYSIS *Norris*	1.451	4	2	Elective	3	—	6
1.521	STRUCTURAL LABORATORY *Hansen*	1.452	G(A)	1	Elective	2	3	1
1.531	SPECIAL PROBLEMS IN STRUCTURAL ENGINEERING *Norris*	1.571, 1.572	G(A)	1 or 2	Elective		★	
1.541	ADVANCED REINFORCED CONCRETE DESIGN *Holley*	1.44, 1.452	G(A)	1	Elective	2	4	0
1.542	ADVANCED REINFORCED CONCRETE DESIGN *Holley*	1.541	G(A)	2	Elective	2	4	0
1.551	ADVANCED STRUCTURAL DESIGN *Biggs, Wilbur*	1.44, 1.452	G(A)	1	Elective	2	—	4
1.552	ADVANCED STRUCTURAL DESIGN *Biggs*	1.44, 1.452	G(A)	2	Elective	2	—	4
1.561	ADVANCED STRUCTURAL MECHANICS *Norris*	1.452, M22	G(A)	1	Elective	3	—	6
1.562	ADVANCED STRUCTURAL MECHANICS *Norris*	1.452, M22	G(A)	2	Elective	3	—	6
1.571	STATICALLY INDETERMINATE STRUCTURES *H. Simpson*	1.452	G(A)	1	Elective	4	—	8
1.572	STATICALLY INDETERMINATE STRUCTURES *H. Simpson*	1.452	G(A)	2	Elective	2	—	4
1.58	STRUCTURAL ENGINEERING *Biggs*	1.44	G(A)	1	Elective	4	—	8
1.59	STRUCTURAL ENGINEERING SEMINAR *Norris*	1.571	G(A)	1 or 2	Elective	1	—	2
1.591	NUMERICAL METHODS OF STRUCTURAL ANALYSIS *Namyet*	M22	G(A)	1	Elective	2	—	4
1.592	NUMERICAL METHODS OF STRUCTURAL ANALYSIS *Namyet*	M22	G(A)	2	Elective	2	—	4
1.601	FLUID MECHANICS *Ippen, Daily*	1.40	3	1	I	2	—	4
1.602	FLUID MECHANICS *Ippen, Daily*	1.601.	3	2	I	3	—	6
1.611	FLUID MECHANICS *Harleman*	2.002	3	1	Elective	3	—	6
1.612	FLUID MECHANICS *Eagleson*	2.002	G	1	XIII-A	3	—	6
1.613	FLUID RESISTANCE AND TURBULENT DIFFUSION *Harleman*	2.002	4	2	Elective	3	—	6
1.621	FLUID MECHANICS LABORATORY *Eagleson*	1.602	4	1	Elective	0	6	0
1.63	APPLIED HYDROMECHANICS *Daily*	1.602 or 1.612	G(A)	1	Elective	3	—	6
1.64	HYDRAULIC MACHINERY *Daily*	1.602 or 1.612	G(A)	2	Elective	2	—	4
1.65	FREE SURFACE FLOW *Ippen*	1.602	G(A)	1	Elective	3	—	6
1.66	DESIGN OF HYDRAULIC STRUCTURES *Ippen, G. R. Williams*	1.65	G(A)	2	Elective	0	6	0
1.67	SEMINAR IN HYDROMECHANICS *Ippen*	1.602	G(A)	2	Elective	1	—	2

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TABULATION

CIVIL ENGINEERING

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
1.681	EXPERIMENTAL HYDROMECHANICS *Harleman*	1.602	G(A)	1	Elective	2	—	4
1.682T	EXPERIMENTAL HYDROMECHANICS *Harleman*	1.681	G(A)	2	Elective	0	8	1
1.683	EXPERIMENTAL HYDROMECHANICS *Harleman*	1.63	G(A)	2	Elective	0	6	0
1.69	RIVERS AND HARBORS *Ippen*	1.65 or 1.681	G(A)	2	Elective	2	—	4
1.701	HYDROLOGY AND HYDRAULIC ENGINEERING *G. R. Williams*	1.602	4	1	Elective	3	—	6
1.702	HYDROLOGY AND HYDRAULIC ENGINEERING *G. R. Williams*	1.701	4	2	Elective	3	—	6
1.71	HYDROLOGY *G. R. Williams*	——	G(A)	1	Elective	3	—	6
1.731	WATER POWER ENGINEERING *G. R. Williams*	1.702 or 1.71	G(A)	1	Elective	2	3	4
1.732	WATER RESOURCES DEVELOPMENT *G. R. Williams*	1.702 or 1.71	G(A)	2	Elective	2	3	4
1.781	SANITARY SCIENCE *McKinney*	5.02	4	1	Elective	3	—	6
1.782	SANITARY ENGINEERING *Symons*	1.701	4	2	Elective	3	—	6
1.811	ADVANCED SANITARY ENGINEERING *Symons*	1.781, 1.782	G(A)	1	Elective	3	—	6
1.812	ADVANCED SANITARY ENGINEERING *McKinney*	1.781, 1.782	G(A)	2	Elective	3	—	6
1.821	SANITARY ENGINEERING LABORATORY *Eliassen, McCarty*	1.782, *1.831*	G(A)	1	Elective	2	3	4
1.822	SANITARY ENGINEERING LABORATORY *Symons, McCarty*	1.782, 1.831	G(A)	2	Elective	2	3	4
1.831	SANITARY CHEMISTRY *Eliassen, McCarty*	1.781, 5.02	G	1	Elective	2	4	4
1.832	CHEMISTRY AND INDUSTRIAL WASTE TREATMENT *McKinney, McCarty*	1.831	G(A)	2	Elective	2	4	4
1.84	SANITARY MICROBIOLOGY *McKinney*	1.781	G	1	Elective	3	3	4
1.85	SANITARY BIOCHEMISTRY *McKinney*	1.84	G(A)	2	Elective	3	3	4
1.86	PUBLIC HEALTH ENGINEERING *Eliassen*	1.781	G(A)	1	Elective	3	—	6
1.861	AIR POLLUTION *Eliassen, H. L. Hardy*	1.86	G(A)	2	Elective	3	—	6
1.881	ADVANCED SANITARY DESIGN *Eliassen*	*1.811*	G(A)	1	Elective	1	5	2
1.882	ADVANCED SANITARY DESIGN *Eliassen*	*1.812*	G(A)	2	Elective	1	5	2
1.883	SPECIAL STUDIES IN SANITARY ENGINEERING *Staff*	1.811, 1.812, 1.831, 1.84	G(A)	1	Elective		★	
1.884	SPECIAL STUDIES IN SANITARY ENGINEERING *Staff*	1.811, 1.812, 1.831, 1.84	G(A)	2	Elective		★	
1.891	SANITARY ENGINEERING SEMINAR *Symons*	*1.811* or 1.812	G(A)	1	Elective	1	—	2
1.892	SANITARY ENGINEERING SEMINAR *Symons*	1.811 or *1.812*	G(A)	2	Elective	1	—	2
1.901	CIVIL ENGINEERING PROJECTS I *G. R. Williams*	——	2	1	I	2	4	4
1.902	CIVIL ENGINEERING PROJECTS II *G. R. Williams*	——	2	2	I	2	2	2
1.911	ENGINEERING CONSTRUCTION *Babcock, McCreery*	1.902	3	1	I	3	2	4
1.921	BUILDING CONSTRUCTION *Heger*	1.911	4	1	Elective	3	—	3
1.922	CONSTRUCTION MANAGEMENT *McCreery*	1.911	4	2	Elective	3	—	3
1.931	DWELLING HOUSE CONSTRUCTION *Dietz*	——	4	1	Elective	3	—	3

2.

Mechanical Engineering

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
2.001	APPLIED MECHANICS I *Crandall*	8.02, M12	2	1	II, III, IV-A, VI, VI-B, XIII, XVI	3	—	5
2.002	APPLIED MECHANICS II *Dahl*	2.001	2	2	II, III, VI, VI-B, XIII	3	—	5
2.003	APPLIED MECHANICS III *Rona*	2.002, M22	3 3 3	S 1 2	II-B(B) II II-B(A)	4	—	8
2.04	STRENGTH OF MATERIALS *Dahl*	2.001	2	2	IV-A	3	—	6
2.046	STRENGTH OF MATERIALS AND DYNAMICS *Dahl*	——	G	S	XIII-A	6	—	8
2.06	VIBRATIONS *Crandall*	2.003	4	2	Elective	3	—	6
2.07	DYNAMICS *Reswick*	2.002 or 2.04	3	2	Elective	3	—	6
2.081	STRENGTH OF MATERIALS *Den Hartog*	2.001	4 G	1 1	Elective XIII-A	3	—	6
2.082T	MECHANICAL ENGINEERING PROBLEMS *Dahl*	2.003; 2.25; 2.42 or 2.421	4	2	II, II-B	2	—	4
2.11	INDUSTRIAL PLANT ENGINEERING *Schwarz*	2.002 or 2.04	4	2	Elective	3	—	6
2.125	RESEARCH IN EXPERIMENTAL STRESS ANALYSIS *W. M. Murray*	2.126	G(A)	1 or 2	Elective		★	
2.126	EXPERIMENTAL STRESS ANALYSIS *W. M. Murray*	*2.081*	4	1 or 2	II Elective	2	3	4
2.211	ADVANCED MECHANICS *Den Hartog*	2.081	G(A)	1	Elective	3	—	9
2.212	ADVANCED MECHANICS *Den Hartog*	2.003 or 2.06	G(A)	2	Elective	3	—	9
2.213	GAS TURBINES *E. S. Taylor*	2.252 or 2.47; 2.42 or 2.421	G(A)	1	Elective	3	—	9
2.214	GAS TURBINES *E. S. Taylor*	2.213	G(A)	2	Elective	3	—	9
2.215	METHODS OF ENGINEERING ANALYSIS *Crandall*	M351	G(A)	1	Elective	3	—	9
2.216	PLATES AND SHELLS *Dahl*	2.211	G(A)	2	Elective	3	—	6
2.217	GYROSCOPE APPLICATIONS *R. H. Cannon*	2.782 or 6.213 or 16.30	G(A)	1	Elective	3	—	9
2.221	PLASTICITY *McClintock*	2.002 or 2.04	G(A)	2	Elective	3	—	9
2.222	SEMINAR IN PLASTICITY *McClintock*	2.221	G(A)	1 or 2	Elective		★	
2.225	PHYSICS OF STRENGTH AND PLASTICITY *Orowan*	2.37, 3.11	G(A)	1	Elective	3	—	9
2.226	PHYSICS OF STRENGTH AND PLASTICITY *Orowan*	2.225	G(A)	2	Elective	3	—	9
2.228	RESEARCH IN MATERIALS *Orowan*	2.37	G(A)	1 or 2	Elective		★	

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
2.25	FLUID MECHANICS *Erickson*	2.002; *2.40* or *2.403*; M22	3 3 4	1 2 S	II-B(B), XIII II II-B(A)	4	—	8
2.252	FLUID MECHANICS *Erickson*	2.25	4	1, 2	Elective	3	—	6
2.261	LUBRICATION AND FRICTION *Rightmire*	2.25	4	2	Elective	2	—	4
2.262	RESEARCH IN LUBRICATION *Rightmire*	2.261	G(A)	1 or 2	Elective		★	
2.263	LUBRICATION AND FRICTION *Rightmire*	2.25	G(A)	1	Elective	3	—	6
2.28T	FLUID MACHINERY *Erickson, Stenning*	2.25	4	1	Elective	3	—	6
2.32T	MECHANICAL PROPERTIES OF NON-METALLICS *Orowan*	2.002 or 2.04; 3.11	4	2	Elective	3	—	6
2.37	MECHANICAL BEHAVIOR OF MATERIALS *Shank*	2.002 or 2.04; 3.11	2 3 4 4	2 2 1 1 or 2	XVI II, XIII XIII Elective (58–59) II-B, XIII-B Elective (58–59)	3	2	4
2.40	HEAT ENGINEERING *Svenson*	8.02, M21	3 3	S 1	VI-A(A) Elective, XVI-B VI Elective, VI-A(B) Elective, XVI	4	—	5
2.401	HEAT ENGINEERING *Svenson*	2.41 or 8.07	3	1	——	4	—	5
2.402	HEAT ENGINEERING *Wadleigh*	——	G	1	XIII-A	4	—	8
2.403	THERMODYNAMICS I *Keenan*	8.02, M21	3 3 3	S 1 2	II-B(B) II, XIII II-B(A)	4	—	8
2.404	THERMODYNAMICS II *J. A. Fay*	2.403	3	2	II(2,3)	3	—	6
2.405	THERMODYNAMICS OF RATE PROCESSES *Hatsopoulos*	2.404	4	1	Elective	3	—	6
2.41	HEAT ENGINEERING *Svenson*	8.02, M21	4	2	I	4	—	5
2.411	HEAT ENGINEERING *Svenson*	2.41 or 8.07	3	1	——	5	—	7
2.42	HEAT ENGINEERING *Svenson*	2.40	3	2	Elective	3	—	6
2.421	HEAT ENGINEERING *Svenson*	2.403	3 3 4	1 2 S	II-B(B) II(1,4), XIII II-B(A)	3	—	6
2.422	HEAT ENGINEERING *Wadleigh*	2.402	G	2	——	2	1	4
2.43	HEAT ENGINEERING *Kaye*	2.25; 2.40 or 2.403	4	1, 2	Elective	3	—	6
2.451	ADVANCED ENGINEERING THERMODYNAMICS *Keenan*	2.40 or 2.403; *M351*	G(A)	1	Elective	3	—	9
2.452	ADVANCED ENGINEERING THERMODYNAMICS *Keenan*	2.451	G(A)	2	Elective	3	—	9
2.453	ADVANCED PROJECTS IN THERMODYNAMICS *Collins, Keenan, Kaye*	2.451	G(A)	1	Elective		★	
2.46	STATISTICAL MECHANICS *J. A. Fay*	2.451	G(A)	2	Elective	3	—	9
2.48T	GAS TURBINES AND JET PROPULSION *E. S. Taylor*	2.28T	4	2	Elective	3	—	6
2.49	ADVANCED FLUID MECHANICS *A. H. Shapiro*	2.25, *M351*	G(A)	1	Elective	3	—	9
2.491	COMPRESSIBLE FLUID MECHANICS *A. H. Shapiro*	2.403, 2.49, *M352*	G(A)	2	Elective	3	—	9
2.492	ADVANCED TOPICS IN FLUID MECHANICS *A. H. Shapiro*	2.49	G(A)	1 or 2	Elective		★	
2.493	VISCOUS AND TURBULENT FLOWS *A. H. Shapiro*	2.49, 2.491, M352	G(A)	1	Elective	3	—	9

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
2.494	DYNAMICS OF RAREFIED GAS FLOWS *A. H. Shapiro*	2.49, M351	G(A)	2	Elective	3	—	9
2.495	MAGNETOHYDRODYNAMICS *Mawardi*	2.49, *M352*	G(A)	2	Elective	3	—	9
2.496	HYDROMAGNETICS OF COMPRESSIBLE FLUIDS *Mawardi*	2.495, *M352*	G(A)	1	Elective	3	—	9
2.50	HEAT TRANSFER *Rohsenow*	2.40 or 2.403 or 3.01	4	2	Elective	2	2	4
2.501	HEAT TRANSFER *Rohsenow*	——	G	2	XIII-A	3	—	3
2.521	ADVANCED HEAT TRANSFER *Rohsenow*	2.42 or 2.421; *M351*	G(A)	1	Elective	3	—	9
2.522	ADVANCED HEAT TRANSFER *Rohsenow*	2.42 or 2.421; *M351*	G(A)	2	Elective	3	3	6
2.53	HEAT MEASUREMENTS *Rohsenow, Kaye*	2.43 or 2.50	4	1 or 2	Elective		★	
2.56T	POWER PLANT ENGINEERING *Holt*	2.42 or 2.421	4	2	Elective	3	—	6
2.57	ADVANCED POWER PLANTS *Holt*	2.56T	G(A)	1	Elective	3	—	9
2.58	HEAT TRANSFER *Rohsenow*	2.25, 2.421	4	1	Elective	3	—	6
2.581	NUCLEAR POWER PLANT ENGINEERING I *Wadleigh*	2.003, 2.25, 2.37, 2.421	4	1	Elective	3	—	6
2.582	NUCLEAR POWER PLANT ENGINEERING II *Wadleigh*	2.581, *22.21*	G(A)	2	Elective	3	3	3
2.601	FOOD ENGINEERING *Hesselschwerdt*	8.04	3 4	1 1	XX (not 58–59), XX-B (not 58–59) XX (58–60)	2	2	2
2.602	FOOD ENGINEERING *Hesselschwerdt*	2.601	3 4	2 2	XX (not 58–59) XX (58–60)	2	2	2
2.621	REFRIGERATION *Svenson*	2.41 or 2.42 or 2.421	4	2	Elective	3	—	6
2.642‡	LOW TEMPERATURE REFRIGERATION *Collins*	2.40 or 2.403	G(A)	1 or 2	Elective	3	3	6
2.661	HEATING AND VENTILATION *Hesselschwerdt*	——	4	1	IV-A	2	—	4
2.662	HEATING AND VENTILATION *Hesselschwerdt*	2.661	4	2	IV-A	2	—	4
2.663	AIR CONDITIONING *Hesselschwerdt*	2.40 or 2.403 or 2.41	4	1	Elective	3	—	6
2.671	ADVANCED AIR CONDITIONING *Hesselschwerdt*	2.663	G(A)	2	Elective	3	—	9
2.68	ENGINEERING LABORATORY *Wadleigh*	2.25; 2.40 or 2.403 or 2.41 or 10.29	4 4	1 1 or 2	XIII Elective (58–59) II Elective, XIII-B Elective (58–59)	1	3	4
2.685	APPLICATIONS OF STATISTICS TO MECHANICAL ENGINEERING *McClintock*	M21	3 or 4	1	Elective	1	—	1
2.693	REFRIGERATION AND AIR CONDITIONING LABORATORY *Hesselschwerdt*	*2.621;* 2.663; 2.68 or 2.681	4	2	Elective	0	3	6
2.73	MACHINE DESIGN *T. P. Goodman*	2.002	3 3 3	S 1 2	II-B(B) II(1,3,4) II-B(A)	2	2	2
2.731	MACHINE DESIGN *Reswick*	2.002 or 2.04; 2.73; 3.11	3 3 4 4	1 2 S 1 or 2	II-B(B) II(1,4) II-B(A) II(3)	2	3	4

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
2.732	MACHINE DESIGN *R. W. Mann*	2.731	4	1	Elective	2	2	5
2.735	HUMAN FACTORS IN DESIGN *Reswick*	——	4	2	Elective	0	6	3
2.751	ANALYSIS AND DESIGN OF ENGINEERING SYSTEMS I *Paynter*	2.003 or 2.07; 2.25; 2.403	G(A)	1	Elective	3	—	9
2.752	ANALYSIS AND DESIGN OF ENGINEERING SYSTEMS II *Paynter*	2.751	G(A)	2	Elective	3	—	9
2.78	HYDRAULIC AND PNEUMATIC CONTROLS *S. Y. Lee*	2.003 or 2.07; 2.25	4	1	Elective	2	3	4
2.782	INTRODUCTION TO AUTOMATIC CONTROL *Shearer*	2.003 or 2.07; 2.25; M22	4	1	Elective	3	—	6
2.783	ADVANCED AUTOMATIC CONTROL *Shearer*	2.003 or 2.07; 2.403; 2.751 or 2.78 or 2.782	G(A)	2	Elective	3	—	9
2.784	INSTRUMENTS FOR MEASUREMENT AND CONTROL *S. Y. Lee*	2.003 or 2.07	G(A)	2	Elective	3	—	6
2.79	ELEMENTARY INTERNAL COMBUSTION ENGINES *Rogowski*	2.002 or 2.04; 2.40 or 2.403 or 2.41 or 10.29	4	1	Elective	3	—	6
2.791	INTERNAL COMBUSTION ENGINES *Rogowski*	2.002 or 2.04; 2.42 or 2.421	4	1	Elective	3	—	6
2.792	INTERNAL COMBUSTION ENGINES *Rogowski*	2.79 or 2.791	4	2	Elective	3	—	6
2.7941	INTERNAL COMBUSTION ENGINE LABORATORY *Rogowski*	*2.79* or *2.791*	4	1	II Elective	0	2	2
2.7942	INTERNAL COMBUSTION ENGINE LABORATORY *Rogowski*	2.7941	4	2	II Elective	0	2	2
2.797	ADVANCED INTERNAL COMBUSTION ENGINES *C. F. Taylor*	2.79 or 2.791	G(A)	1	Elective	3	—	9
2.798	ADVANCED INTERNAL COMBUSTION ENGINES *C. F. Taylor*	2.797	G(A)	2	Elective	3	—	9
2.80	AUTOMOTIVE VEHICLES *C. F. Taylor*	2.003 or 2.07	4	2	Elective	3	—	6
2.801	SPECIAL PROBLEMS IN INTERNAL COMBUSTION ENGINES *C. F. Taylor*	2.48 or 2.79 or 2.791	G(A)	1	Elective		★	
2.821	COMBUSTION AERODYNAMICS *Toong*	2.25 or 16.02	G(A)	1	Elective	3	—	9
2.822	ADVANCED TOPICS IN COMBUSTION *Toong*	2.821 or 10.70	G(A)	1 or 2	Elective	3	—	9
2.83	RESEARCH IN COMBUSTION *Toong*	2.821 or 10.70	G(A)	1 or 2	Elective		★	
2.855	THEORY OF METAL CUTTING *M. C. Shaw*	2.862; 3.11	G(A)	1 or 2	Elective	3	—	6
2.858	RESEARCH IN MACHINE TOOLS AND METAL CUTTING *M. C. Shaw*	2.85 or 2.851	G(A)	1 or 2	Elective		★	
2.859	MANUFACTURING TECHNOLOGY *M. C. Shaw*	2.85 or 2.851	4	2	Elective	3	—	6
2.861	ENGINEERING DESIGN AND MANUFACTURE *Mann, Shaw*	——	2	1	II, XIII	4	4	4
2.862	MACHINE TOOL FUNDAMENTALS *P. A. Smith*	2.85, 3.11	3 3 4 4	S 2 S 2	II-B(B) II(1,4) II-B(A) II(3)	2	1	2
2.863	EXPERIMENTAL TECHNIQUES *Cook, Rabinowicz*	2.701 and 2.85; or 2.861	4 4 4	1 1 or 2 2	XIII Elective (58–59) XIII-B Elective (58–59) II Elective	2	1	5
2.901	PRINCIPLES OF FABRIC STRUCTURE *Schwarz*	8.02	4	1	Elective	3	—	6
2.902	PRINCIPLES OF FABRIC STRUCTURE *Schwarz*	2.901	4	2	Elective	3	—	6

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
2.903	ELEMENTS OF TEXTILE MANUFACTURING *Schwarz*	8.02	4	1	Elective	3	—	6
2.904	PRINCIPLES OF TEXTILE MANUFACTURING *Schwarz*	2.903	4	2	Elective	3	—	6
2.905	TEXTILE ENGINEERING ANALYSIS *Backer*	2.002 or 2.04; 8.03	G(A)	1	Elective	3	—	6
2.906	TEXTILE ENGINEERING ANALYSIS *Backer*	2.905	G(A)	2	Elective	3	—	6
2.907	TEXTILE MICROSCOPY *Schwarz*	8.04	G(A)	1	Elective	2	3	2
2.908	TEXTILE MICROSCOPY *Schwarz*	2.907	G(A)	2	Elective	2	3	2
2.911	TEXTILE RESEARCH LABORATORY *Backer, Morgan*	*2.905, 2.93*	G(A)	1	Elective	0	6	2
2.912	TEXTILE RESEARCH LABORATORY *Backer, Morgan*	*2.906*, 2.911	G(A)	2	Elective	0	6	2
2.913	TEXTILE TECHNOLOGY SEMINAR *Backer, Schwarz*	*2.905, 2.907*	G(A)	1	Elective	2	—	2
2.914	TEXTILE TECHNOLOGY SEMINAR *Backer, Schwarz*	*2.906, 2.908*	G(A)	2	Elective	2	—	2
2.93	EXPERIMENT PLANNING AND ANALYSIS *Schwarz*	M22	G(A)	1	Elective	3	—	6
2.951	INDUSTRIAL PRACTICE *W. M. Murray*	——	3 4	S S	II-B(A) II-B(B)	40 h.p.w.		
2.952	INDUSTRIAL PRACTICE *W. M. Murray*	——	3 3	1 2	II-B(A) II-B(B)	40 h.p.w.		

3.

Metallurgy

3.00	EXTRACTIVE METALLURGY *Gaudin*	——	2	2	III	4	2	4
3.01	METALLURGICAL ENGINEERING I *Elliott*	5.61	3	2	III	4	—	4
3.011	METALLURGICAL ENGINEERING LABORATORY I *Elliott*	*3.01*	3	2	III	0	3	1
3.02	METALLURGICAL ENGINEERING II *T. B. King*	3.01	4	1	Elective	4	—	4
3.021	METALLURGICAL ENGINEERING LABORATORY II *T. B. King*	*3.02*	4	1	Elective	0	3	1
3.03	METALLURGICAL ENGINEERING III *T. B. King*	3.02	4	2	Elective	3	—	6

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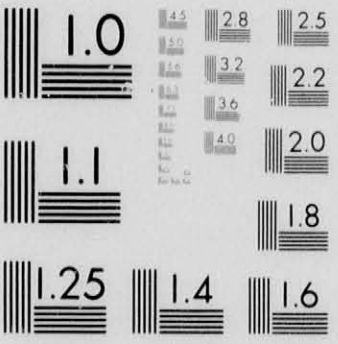
Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
3.10	METALLURGICAL PLANT VISITS *C. M. Adams*	——	4	S	III	0	3	1
3.11	ENGINEERING MATERIALS *Wulff, Spacil*	——	2	1	III	4	2	4
			2	2	II, XIII			
3.113	ENGINEERING MATERIALS *Wulff, Spacil*	——	2,3,4	1, 2	Elective	4	—	4
3.13	FOUNDRY ENGINEERING *H. F. Taylor*	3.11 or 3.31	4	2	Elective	2	—	4
3.15	WELDING ENGINEERING *C. M. Adams*	3.11 or 3.31	4	1, 2	Elective	2	—	4
3.16	POWDER METALLURGY *Wulff*	3.11 or 3.31	4	1	Elective	2	—	4
3.18	PLASTIC WORKING OF METALS *Backofen*	3.11 or 3.31	4	1, 2	Elective	2	—	4
3.20	METALLURGICAL THERMODYNAMICS *Elliott*	5.62	4	1	III	4	—	4
3.21	THERMODYNAMICS IN PROCESS METALLURGY *Chipman*	3.20	G(A)	1	Elective	3	—	6
3.22	THERMODYNAMICS OF METALLIC SOLUTIONS *Elliott*	3.20, 3.32	G(A)	2	Elective	2	—	4
3.25	EXPERIMENTAL METHODS IN METALLURGY *Grant*	5.62 or 8.04	G(A)	1	Elective	1	2	0
3.26‡	KINETIC PROBLEMS IN METALLURGY *T. B. King*	——	G(A)	2	Elective	2	—	4
3.31	PHYSICAL METALLURGY I *Bever, D. A. Thomas*	5.02, 8.04	3	1	II(3), III	4	3	4
3.32	PHYSICAL METALLURGY II *M. Cohen, D. A. Thomas*	3.31	3	2	II(3)	3	3	6
3.33	PHYSICAL METALLURGY III *Floe*	3.32	4	2	Elective	2	4	4
3.34T	ADVANCED PHYSICAL METALLURGY *Bever, Averbach*	3.20, 3.32, 3.50	G(A)	1	Elective	4	—	6
3.35T	ADVANCED PHYSICAL METALLURGY *Averbach, Bever*	3.20, 3.32, 3.50	G(A)	2	Elective	4	—	6
3.391	PROPERTIES OF METALS *Floe*	——	G	1	XIII-A	2	1	3
3.392	PROPERTIES OF METALS *Bever*	3.391	G	2	XIII-A	2	1	3
3.396	NUCLEAR METALLURGY *Ogilvie*	3.11 or 3.31 or 3.391	G	1	Elective	2	—	4
3.42	ELECTROCHEMISTRY *Uhlig*	5.62	4	1	Elective	2	—	4
3.43	CORROSION *Uhlig*	5.62	G(A)	2	Elective	2	—	4
3.44	BEHAVIOR OF METALS AT ELEVATED TEMPERATURES *Grant*	3.32	G(A)	2	Elective	2	—	4
3.50	X-RAY METALLURGY *J. T. Norton*	3.31	4	1	II Elective, III	2	2	4
3.51	PHYSICS OF METALS *J. T. Norton*	3.50	4	2	Elective	2	—	4
3.52	ADVANCED PHYSICS OF METALS *Ogilvie*	3.50 or 3.396	G(A)	1	Elective	2	—	4
3.53	ADVANCED X-RAY METALLURGY *J. T. Norton*	3.50	G(A)	2	Elective		★	
3.54	RADIOGRAPHIC INSPECTION *Ogilvie*	——	G	2	Elective	1	3	2
3.61T	ELECTRIC AND MAGNETIC MATERIALS *Averbach*	3.11 or 3.31; 8.051	G(A)	1	Elective	2	—	4
3.62	SPECIAL PROBLEMS IN METALLURGY *Staff*	——	G(A)	1, 2	Elective		★	
3.70	CERAMICS *F. H. Norton*	5.02, 8.04	4	1	Elective	2	—	4
3.701	CERAMICS LABORATORY *Kingery*	*3.70*	4	1	Elective	0	3	0
3.71	CERAMICS SEMINAR *Economos*	3.70	G(A)	1	Elective	1	—	2
3.72	CERAMICS SEMINAR *Economos*	3.70	G(A)	2	Elective	1	—	2



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

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
3.73	FUNDAMENTALS OF CERAMIC PROCESSES I *F. H. Norton*	3.70, 5.62	G(A)	2	Elective	3	—	4
3.74	FUNDAMENTALS OF CERAMIC PROCESSES II *F. H. Norton*	3.73	G(A)	1	Elective	3	—	4
3.75	SPECIAL PROBLEMS IN CERAMICS *F. H. Norton*	3.70	G(A)	1, 2	Elective		★	
3.77	ADVANCED CERAMICS LABORATORY *Kingery*	3.70	G(A)	2	Elective	1	5	4
3.79	ADVANCED CERAMIC PRODUCTS *Kingery*	3.70	G(A)	1	Elective	3	—	6
3.81	MINERAL ENGINEERING I *de Bruyn*	8.04	3	1	Elective	3	3	6
3.82	MINERAL ENGINEERING II *de Bruyn*	3.81	3	2	Elective	3	3	6
3.83	MINERAL ENGINEERING III *de Bruyn, Gaudin*	3.82	4	1	Elective	3	—	6
3.85	QUANTITATIVE MINERAGRAPHY *de Bruyn, J. H. Brown*	3.82	4	1 or 2	Elective	1	4	2
3.86	QUANTITATIVE MINERAGRAPHY *J. H. Brown*	3.83	G(A)	1 or 2	Elective		★	
3.87	ORE TESTING *de Bruyn, J. H. Brown*	3.83	4	1	Elective	0	10	0
3.89	MINERAL DRESSING DESIGN *Gaudin*	3.83	G(A)	1 or 2	Elective		★	
3.90	ADVANCED MINERAL ENGINEERING *Gaudin, de Bruyn*	3.83	G(A)	1 or 2	Elective	3	—	6
3.901	ADVANCED MINERAL DRESSING LABORATORY *Gaudin*	3.83	G(A)	1 or 2	Elective		★	

4.

Architecture and Planning

4.00	STRUCTURE OF THE CITY *Hudnut*	——	1	2	Elective	3	—	3
4.02	FORM AND DESIGN *Filipowski*	——	2 2	1 2	IV-A Elective	0	9	11
4.031	VISUAL DESIGN PROBLEMS *Preusser*	21.04	3, 4	1	Elective	2	6	0
4.032	VISUAL DESIGN PROJECTS *Preusser*	4.031	3, 4	2	Elective	2	6	0
4.04	LIGHT AND COLOR *Kepes*	4.02	5	1	IV-A	0	9	11
4.06	ADVANCED VISUAL DESIGN *Kepes*	4.04	G(A)	1, 2	Elective		★	
4.11	ARCHITECTURAL DESIGN *Staff*	——	2 2	2 1	IV-A Elective	0	9	11

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TABULATION

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec	Lab Rec	Draw	Prep
4.131	ARCHITECTURAL DESIGN *Staff*	4.11	3	1	IV-A	0		9	11
4.132	ARCHITECTURAL DESIGN *Staff*	4.131	3	2	IV-A	0		9	11
4.141	ARCHITECTURAL DESIGN *Staff*	4.132, 4.32	4	1	IV-A	0		12	8
4.142	ARCHITECTURAL DESIGN *Staff*	4.141	4	2	IV-A	0		12	8
4.151	ARCHITECTURAL DESIGN *Staff*	4.142	5	1	IV-A	0		12	8
4.161	ARCHITECTURAL DESIGN *Staff*	4.151	G(A)	1	Elective	0		15	15
4.162	ARCHITECTURAL DESIGN *Staff*	4.161	G(A)	2	Elective			★	
4.17	ARCHITECTURAL DESIGN, SPECIAL PROBLEMS *Staff*	——	5	1, 2	Elective			★	
4.18	COLLABORATIVE DESIGN *Staff*	4.142	5	1	Elective	0		9	11
4.233	REPRESENTATION *Lynch*	——	4	1	Elective	0		5	1
4.241T	COMMUNITY PLANNING DESIGN *Lynch*	*4.233, 451T*	G	1	Elective	0		12	6
4.261	CITY AND REGIONAL PLANNING *Greeley, Kelly*	4.241T	G(A)	1	Elective	0		12	12
4.262	CITY AND REGIONAL PLANNING *Kelly, F. J. Adams*	4.261	G(A)	2	Elective	0		12	12
4.31	STRUCTURAL ANALYSIS *Gelotte*	2.002 or 2.04; 4.11	3	1	IV-A	2		6	0
4.32	STRUCTURAL ANALYSIS *Gelotte*	4.131, 4.31	3	2	IV-A	2		6	0
4.33	STRUCTURES SEMINAR *Weidlinger*	4.32	4	1	Elective	2		—	4
4.34	STRUCTURES SEMINAR *Weidlinger*	4.33	4	2	Elective	2		—	4
4.41	ARCHITECTURAL ACOUSTICS *Newman*	8.02	4	1	Elective	3		—	5
4.42	SPECIAL PROBLEMS IN ARCHITECTURAL ACOUSTICS *Newman*	4.41	G(A)	1 or 2	Elective			★	
4.43	INDUSTRIALIZED HOUSE *C. Koch*	4.142	G(A)	1	Elective	2		2	4
4.51T	CHARACTERISTICS OF BASIC LAND USES *Lynch*	——	G	1	Elective	3		—	3
4.53	CITY PLANNING PRINCIPLES *Greeley, F. J. Adams*	——	3	1	IV-A	2		—	4
4.54	CITY PLANNING TECHNIQUES *J. T. Howard*	4.53	G	2	Elective	3		—	6
4.55	CITY PLANNING TECHNIQUES *J. T. Howard*	4.54	G(A)	1	Elective	3		—	6
4.56	REGIONAL PLANNING SEMINAR *Greeley*	4.55	G(A)	2	Elective	2		—	4
4.57‡	URBAN LANDSCAPE *Lynch*	——	G(A)	2	Elective	2		—	4
4.58	THEORY OF CITY FORM *Lynch, Rodwin*	4.53	G(A)	2	Elective	2		—	6
4.59	PLANNING THEORY AND RESEARCH *Rodwin, Lynch*	4.53	G(A)	1	Elective	2		—	6
4.61	ARCHITECTURE OF CITIES *Hudnut*	21.04	3, 4	1	Elective	3		—	5
4.63	TECHNICS AND CIVILIZATION *Mumford*	——	G(A)	1	Elective	2		—	4
4.65	INTRODUCTION TO ART AND ARCHITECTURE *Bush-Brown*	21.04	3	1	IV-A	3		—	5
			3, 4	1	Elective				
4.66	MODERN ART AND ARCHITECTURE *Bush-Brown*	21.04	3	2	IV-A	3		—	5
			3, 4	2	Elective				
4.67	THEORIES OF ARCHITECTURE *Bush-Brown*	4.65 or 4.66	G(A)	1	Elective			★	
4.68	ARCHITECTURAL CRITICISM *Bush-Brown*	4.65 or 4.66	G(A)	2	Elective			★	
4.70	URBAN SOCIOLOGY *Greeley*	——	4	2	Elective	2		—	4

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
4.71	PLANNING LEGISLATION *Kelly*	4.54 or 14.941	G(A)	1	Elective	2	—	4
4.77‡	HOUSING PROBLEMS *Rodwin*	4.53 or 14.01	G(A)	1	Elective	2	—	5
4.78	HOUSING SEMINAR *Abrams*	4.77	G(A)	2	Elective	3	—	6
4.81	LAND ECONOMICS *Abrams*	14.01	5	1	Elective	2	—	6
4.82	LAND ECONOMICS SEMINAR *Rodwin*	4.81	G(A)	2	Elective	2	—	6
4.84‡	LAND-USE PROBLEMS IN DEVELOPING AREAS *Rodwin*	4.81	G(A)	2	Elective	2	—	6
4.85	REAL ESTATE ECONOMICS *Abrams*	14.01	4, 5	2	Elective	2	—	4
4.95	THESIS RESEARCH *F. J. Adams*	4.261	G(A)	1	Elective	0	6	0
4.96	CITY PLANNING RESEARCH *Kelly*	—	G(A)	2	Elective	0	6	0
4.97	OFFICE PRACTICE *F. J. Adams*	4.54	G	S	Elective	0	30	0

5.

Chemistry

5.01	GENERAL CHEMISTRY *Stephenson*	—	1	1	All Courses, except IV-A	4	2	5
			1	1	IV-A Elective			
5.02	GENERAL CHEMISTRY *J. S. Waugh*	5.01	1	2	All Courses, except IV-A	4	2	5
			1	2	IV-A Elective			
5.03	PRINCIPLES OF INORGANIC CHEMISTRY I *Cotton*	5.02, 5.42	3	1	V	2	—	4
			4	1	V (58–59)			
5.031‡	INORGANIC CHEMISTRY LABORATORY *Gamble, Irvine*	*5.03*	4	1	Elective	1	4	1
5.04	PRINCIPLES OF INORGANIC CHEMISTRY II *Cotton*	5.02, 5.62	4	2	Elective	2	—	4
5.065	ADVANCED INORGANIC CHEMISTRY *Seyferth*	5.04	G(A)	1	Elective	2	—	4
5.067‡	TOPICS IN THEORETICAL INORGANIC CHEMISTRY *Cotton*	5.04	G(A)	1	Elective	2	—	4
5.071T	SPECIAL TOPICS IN INORGANIC CHEMISTRY *Coryell, Seyferth*	5.04	G(A)	1	Elective	1	—	2
5.072	SPECIAL TOPICS IN INORGANIC CHEMISTRY *Coryell, Seyferth*	5.071T	G(A)	2	Elective	1	—	2
5.09	RADIOCHEMISTRY *Coryell, Irvine*	5.03, 5.62	G(A)	1	Elective	3	—	3

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
5.091	RADIOCHEMISTRY LABORATORY *Coryell, Irvine*	*5.09*	G(A)	1	Elective	0	3	2
5.14	ANALYTICAL CHEMISTRY I *Simpson*	5.03, 5.41	3	2	V, VII (not 58–59), XX (not 58–59), XX-B (not 58–59)	3	—	3
5.141	ANALYTICAL CHEMISTRY LABORATORY I *S. G. Simpson*	*5.14*	3	2	V	1	8	0
5.142	ANALYTICAL CHEMISTRY LABORATORY I *S. G. Simpson*	*5.14*	3 3	2 2	Elective VII (not 58–59), XX (not 58–59), XX-B (not 58–59)	1	4	0
5.15	INSTRUMENTAL ANALYSIS *Hume, Rogers*	5.42, 5.62	3 4	2 2	XX (58–59), XX-B (58–59) Elective	2	—	2
5.151	INSTRUMENTAL ANALYSIS LABORATORY *Ross*	*5.15*	3 4	2 2	XX (58–59), XX-B (58–59) Elective	0	4	2
5.16‡	ANALYTICAL CHEMISTRY II *Hume, Rogers*	5.14, 5.62	4	1	V, XX-B	3	—	3
5.161‡	ANALYTICAL CHEMISTRY LABORATORY II *Ross*	*5.16*	4	1	V, XX-B	1	4	2
5.192	ADVANCED ANALYTICAL CHEMISTRY I *Rogers*	5.14	G(A)	2	Elective	2	—	4
5.193	ADVANCED ANALYTICAL CHEMISTRY II *S. G. Simpson*	5.14	G(A)	1	Elective	2	—	4
5.194‡	ADVANCED ANALYTICAL CHEMISTRY III *Hume*	5.14	G(A)	2	Elective	2	—	4
5.196‡	ADVANCED ANALYTICAL CHEMISTRY IV *Biemann*	5.14	G(A)	1	Elective	2	—	4
5.41	ORGANIC CHEMISTRY I *Sheehan*	5.02, 8.02	2 3	1 1	V, X, XX, XX-B, XXI-C VII, XX (58–59), XX-B (58–59)	4	—	4
5.412	ORGANIC PREPARATIONS I *Nelson*	5.02, *5.41*	2	1	V	1	4	0
5.416	ORGANIC PREPARATIONS I *Ashdown, Swain*	*5.41*	2 3	1 1	X, XX, XX-B, XXI-C VII, XX-B (58–59)	1	5	0
5.42	ORGANIC CHEMISTRY II *F. D. Greene*	5.41	2 3	2 2	V, XX-B XX-B (58–59)	4	—	4
5.422	ORGANIC PREPARATIONS II *Nelson*	5.412, *5.42*	2	2	V	1	4	2
5.426	QUALITATIVE ORGANIC ANALYSIS *Nelson, Ashdown*	5.416	3	2	XX-B (58–59)	1	5	0
5.428	QUALITATIVE ORGANIC ANALYSIS *House*	5.42, 5.422	3	1	V	2	7	1
5.43	ORGANIC CHEMISTRY III *F. D. Greene*	5.42	4	1	V (58–59)	2	—	4
5.44	ORGANIC CHEMISTRY IV *Sheehan*	5.43	4	2	V (58–59)	2	—	4
5.51	ADVANCED ORGANIC CHEMISTRY: SYNTHESIS *House*	5.44	G(A)	1	Elective	2	—	4
5.54	ADVANCED PHYSICAL ORGANIC CHEMISTRY *Swain*	5.43	G(A)	2	Elective	2	—	4
5.55	ORGANIC CHEMISTRY: NATURAL PRODUCTS *Buchi*	5.44	G(A)	1	Elective	2	—	4
5.60	PHYSICAL CHEMISTRY *Beattie*	5.02, 8.02, *M21*	2	1	XXI-C	3	—	6
5.61	PHYSICAL CHEMISTRY I *Stockmayer*	5.02, 8.03, M21	3	1	III, V, VII, XX, XX-B	4	—	4
5.611	PHYSICAL CHEMISTRY LABORATORY I *Shoemaker, Garland*	*5.61*	3	1	VII	0	4	2
5.613T	PHYSICAL CHEMISTRY LABORATORY I *Shoemaker, Garland*	*5.61*	3	1	V	0	6	3

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
5.62	PHYSICAL CHEMISTRY II *Amdur*	5.61	3	2	III, V, VII, XX, XX-B	4	—	4
5.621	PHYSICAL CHEMISTRY LABORATORY II *Shoemaker, Garland*	5.611, *5.62*	3	2	VII	0	4	2
5.623T	PHYSICAL CHEMISTRY LABORATORY II *Shoemaker, Garland*	5.613T, *5.62*	3	2	V	0	6	3
5.67	INTRODUCTION TO ATOMIC AND MOLECULAR STRUCTURE *Lord*	5.62	4	1	Elective	2	—	4
5.68	KINETICS OF CHEMICAL REACTIONS *Amdur*	5.62	4	2	Elective	2	—	4
5.70	INTRODUCTION TO STATISTICAL THERMODYNAMICS *J. S. Waugh*	5.62	G(A)	1	Elective	2	—	4
5.71	CHEMICAL THERMODYNAMICS I *Beattie*	5.62	G(A)	1	Elective	2	—	4
5.72	CHEMICAL THERMODYNAMICS II *Beattie*	5.71, *M351*	G(A)	2	Elective	3	—	6
5.73T	THEORY OF SOLUTIONS *Stockmayer*	5.70, 5.71, M351	G(A)	1	Elective	3	—	6
5.74	ELEMENTARY THEORY OF VALENCE *J. S. Waugh*	5.75, *M352*	G(A)	2	Elective	3	—	6
5.75	INTRODUCTION TO QUANTUM THEORY *L. Harris*	5.62, 8.04	G(A)	1	Elective	2	—	4
5.76	MOLECULAR SPECTRA AND MOLECULAR STRUCTURE *Lord*	5.75, M351	G(A)	2	Elective	3	—	6
5.77	CRYSTAL STRUCTURE AND THE CHEMICAL BOND *Shoemaker*	5.75	G(A)	1	Elective	3	—	6
5.78	STATISTICAL MECHANICS *Garland*	5.70, 5.71, 5.75, M351	G(A)	2	Elective	3	—	6
5.79	KINETIC THEORY *Amdur*	5.71, M351	G(A)	1	Elective	3	—	6
5.90	SPECIAL PROBLEMS IN CHEMISTRY *Sheehan*	——	G(A)	1, 2	Elective		★	
5.912	SEMINAR IN INORGANIC CHEMISTRY	——	G(A)	2	Elective	1	—	2
5.913	SEMINAR IN ORGANIC CHEMISTRY *Cope*	——	G(A)	1	Elective	1	—	2
5.914	SEMINAR IN ORGANIC CHEMISTRY *Cope*	5.913	G(A)	2	Elective	1	—	2
5.915	SEMINAR IN ANALYTICAL CHEMISTRY *Biemann*	——	G(A)	1	Elective	1	—	2
5.916	SEMINAR IN ANALYTICAL CHEMISTRY *Ross*	——	G(A)	2	Elective	1	—	2
5.931	SEMINAR IN PHYSICAL CHEMISTRY *Shoemaker*	——	G(A)	1	Elective	1	—	2
5.932	SEMINAR IN PHYSICAL CHEMISTRY *Shoemaker*	——	G(A)	2	Elective	1	—	2
5.941	RESEARCH CONFERENCE IN INORGANIC CHEMISTRY *Cotton, Irvine*	5.066	G(A)	1	Elective	1	—	2
5.942	RESEARCH CONFERENCE IN INORGANIC CHEMISTRY *Cotton, Irvine*	5.941	G(A)	2	Elective	1	—	2
5.951	RESEARCH CONFERENCE IN ANALYTICAL CHEMISTRY *Ross*	——	G(A)	1	Elective	1	—	2
5.952	RESEARCH CONFERENCE IN ANALYTICAL CHEMISTRY *Biemann*	——	G(A)	2	Elective	1	—	2
	RESEARCH *Chemistry Staff*	——	G(A)	1, 2	Elective		★	

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6.

Electrical Engineering

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
6.00	INTRODUCTORY CIRCUIT THEORY *Guillemin, Searle, Thornton*	*8.031, M21*	2	1	VI, VI-B	4	3	5
6.001	INTRODUCTORY CIRCUIT THEORY *Guillemin*	*8.031, M21*	2	1	Elective	4	—	5
6.002	INTRODUCTORY CIRCUIT THEORY LABORATORY *Searle, Thornton*	6.001	2	1	Elective	0	3	0
6.01	INTRODUCTORY CIRCUIT THEORY *Guillemin, Searle, Thornton*	6.00	2	2	VI, VI-B	4	3	5
6.011	INTRODUCTORY CIRCUIT THEORY *Guillemin*	6.001	2	2	Elective	4	—	5
6.012	INTRODUCTORY CIRCUIT THEORY LABORATORY *Searle, Thornton*	6.002, 6.011	2	2	Elective	0	3	0
6.02	ELECTRONIC DEVICES AND CIRCUITS *Zimmermann, Searle, Thornton*	6.01	3 3 3	S 1 2	VI-A(A) VI, VI-B VIII	4	3	5
6.021	ELECTRONIC DEVICES AND CIRCUITS *Zimmermann*	6.01	3	S	VI-A(B)	4	—	4
6.022	ELECTRONIC DEVICES AND CIRCUITS LABORATORY *Searle, Thornton*	6.021	3	1	VI-A(B)	0	3	1
6.03	FIELDS, ENERGY AND FORCES *Haus*	6.01; 8.041; M22 or *M351*	3 3	S 1	VI-A(A) VI, VI-A(B), VI-B	4	3	5
6.05	ELECTRONIC CIRCUITS AND SIGNALS *Mason, Searle, Thornton*	6.02	3 4	2 S	VI, VI-A(A), VI-B VI-A(B)	4	3	5
6.051	ELECTRONIC CIRCUITS AND SIGNALS *Mason*	6.02	3	2	Elective	4	—	4
6.052	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY *Searle, Thornton*	6.051	3	2	Elective	0	3	1
6.06T	ELECTROMECHANICAL ENERGY CONVERSION *Woodson*	6.03	3 4	2 S	VI, VI-A(A) VI-A(B)	4	3	5
6.063	ELECTRICAL ENERGY CONVERSION *White*	6.03	3	2	VI-B	3	4	5
6.07	ENERGY TRANSMISSION AND RADIATION *Kyhl*	6.03, M351	4	1	VI, VI-A(A)	3	3	6
6.071	ENERGY TRANSMISSION AND RADIATION *Kyhl*	6.03, M351	4	1	VI-A(B)	3	—	6
6.072	ENERGY TRANSMISSION AND RADIATION LABORATORY *Kyhl*	6.071	4	2	VI-A(B)	0	3	0
6.073	ENERGY TRANSMISSION AND RADIATION *Adler*	6.03, M351	4	1	VI-B	3	3	6
6.08	MOLECULAR ENGINEERING *Epstein*	6.03, 6.06T	4 4	1 2	VI, VI-A(A) VI-A(B)	4	3	5
6.083	MOLECULAR SCIENCE AND ENGINEERING *Epstein*	6.03, 6.063, 8.052	4	2	VI-B	4	3	5
6.10	ELEMENTARY ELECTRIC CIRCUIT THEORY *Huffman*	8.031, M21	2 3	2 1	VIII II(2)	4	—	8
6.11	SEMINAR *Adler*	——	4	1	VI-B	2	—	4
6.12	SEMINAR *Adler*	——	4	2	VI-B	2	—	4
6.16	ELECTRICITY *Eager*	8.03	3, 4	1	Elective	3	—	6

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
6.17	ILLUMINATION *Moon*	8.03	4	2	Elective	2	—	4
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING *Frazier, Kingsley*	8.03, M22	3 3 4 4	1 2 1 1 or 2	I, II(1,4), II-B(B), XVI II-B (A), XVI-B XXI-C II(3)	3	1	6
6.19	FUNDAMENTALS OF ELECTRONICS *Eager*	6.18	4	2	Elective	3	1	6
6.20	ELECTRONIC CONTROL AND MEASUREMENT *Gray*	6.05	4	1	Elective	3	—	6
6.211	ANALYSIS OF NONLINEAR SYSTEMS *Boehne*	6.06, 6.07	4	2	Elective	3	—	6
6.213	FEEDBACK CONTROL PRINCIPLES *L. A. Gould*	6.06T or 6.18; M351	4	1, 2	Elective	3	2	5
6.216	DYNAMICS OF ELECTRIC MACHINES *Kingsley*	6.06T G(A) except VI	4	2 2	Elective VI Elective	3	—	6
6.227	ENGINEERING ELECTRODYNAMICS *Moon*	6.03	4	2	Elective	3	—	6
6.231	CIRCUIT AND FIELD ANALOGS AND MODELS *Frazier*	6.03, 6.06T	4	2	Elective	3	—	6
6.232	ELECTROMECHANICAL CONTROL COMPONENTS *Frazier*	6.03, 6.06T, 6.08	4	2	Elective	3	—	6
6.241	ENGINEERING PROBLEMS *C. E. Tucker, White, Adler*	*6.06T*	4	1 or 2	Elective	3	—	6
6.25T	INTRODUCTION TO DIGITAL COMPUTERS *Arden, Arthurs*	6.05 or M352	4	1	Elective	3	—	6
6.251	PRINCIPLES OF MACHINE COMPUTATION *Verzuh*	——	4	1	Elective	3	1	5
6.252	DIGITAL SYSTEMS ENGINEERING *Susskind*	6.05	4	2	Elective	3	—	6
6.254	PRINCIPLES OF SWITCHING CIRCUITS *Caldwell*	6.01 or 6.18; M22	4	2	Elective	3	1	6
6.281	PRINCIPLES OF WIRE COMMUNICATIONS *C. E. Tucker*	6.02	4	1	Elective	3	—	6
6.291	RADAR-SYSTEM ENGINEERING *Reintjes*	6.05, *6.07*	4	2	Elective	3	—	6
6.30	COMMUNICATION AND CONTROL CIRCUIT THEORY *Guillemin*	6.01, *6.05*	4	1, 2	Elective	3	—	6
6.311	PRINCIPLES OF COMMUNICATION *Elias*	6.05	4	1	Elective	3	—	6
6.312	COMMUNICATIONS SYSTEM ENGINEERING *Granlund*	6.20 or 6.311	4	2	Elective	3	—	6
6.322	ELECTROMAGNETIC WAVES *Chu*	6.07	4	2	Elective	3	—	6
6.35	COMMUNICATIONS ACOUSTICS *Stevens*	6.01, M351	4	1	Elective	3	1	5
6.351	ENGINEERING ACOUSTICS *Stevens*	6.10, M22	G	1	——	2	2	5
6.36	ENGINEERING ACOUSTICS *Stevens*	6.07 or 6.35	4	2	Elective	3	1	5
6.38	PULSE CIRCUIT ANALYSIS *Zimmermann*	6.05	4	2	Elective	3	—	6
6.50	ELECTRICAL ENGINEER SEMINAR *Reintjes*	——	G(A)	2	Elective	2	—	4

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec	Lab Rec	Draw	Prep
6.521	ELECTRICAL ENERGY CONVERSION DEVICES *Kusko*	6.06T	G(A)	2	Elective	3		2	6
6.522	DYNAMICS OF ROTATING MACHINE SYSTEMS *White*	6.06T or 6.063	G(A)	1	Elective	3		2	6
6.524	NON-LINEAR IMPEDANCES AS CONTROL ELEMENTS *Woodson*	6.02; 6.06T or 6.063	G(A)	1	Elective	3		2	6
6.531	DISCRETE SYSTEMS *Arden, Arthurs*	6.254 or 6.537 or M352	G(A)	1	Elective	3		—	6
6.534	SEQUENTIAL PROCESSES *Arden, Arthurs*	6.531 or M76	G(A)	2	Elective	3		—	6
6.537	SWITCHING CIRCUITS *Caldwell*	6.254 or M351	G(A)	1	Elective	3		2	7
6.538‡	ELECTRONIC COMPUTATIONAL LABORATORY *Verzuh*	M22	G(A)	1, 2	Elective	3		1	5
6.54	PULSED-DATA SYSTEMS *Widrow*	6.56 or 6.581 or M39	G(A)	2	Elective	3		—	6
6.55	LINEAR SYSTEM ANALYSIS *Guillemin*	6.01	G(A)	1	Elective	3		—	6
6.56	MATHEMATICAL METHODS IN ELECTRICAL ENGINEERING *Guillemin*	M351	G(A)	1	Elective	3		—	6
6.561	NETWORK ANALYSIS AND SYNTHESIS *Guillemin*	6.30 or 6.55; 6.56	G(A)	1, 2	Elective	3		—	6
6.562	NETWORK ANALYSIS AND SYNTHESIS *Guillemin*	6.561	G(A)	1	Elective	3		—	6
6.568	SWITCHING CIRCUITS *S. H. Caldwell*	6.567	G(A)	1	Elective	3		1	6
6.571	STATISTICAL THEORY OF COMMUNICATION *Y. W. Lee*	6.30 or 6.561 or 6.581	G(A)	1 or 2	Elective	3		—	6
6.573	STATISTICAL THEORY OF NOISE AND MODULATION *Wiesner, Siebert*	6.30 or 6.311 or 6.55	G(A)	1	Elective	3		—	6
6.574	STATISTICAL THEORY OF INFORMATION *Fano*	6.573 or M76	G(A)	2	Elective	3		—	6
6.575	ADVANCED TOPICS IN INFORMATION THEORY *Elias*	6.574	G(A)	1	Elective	3		—	6
6.581	TRANSIENTS IN LINEAR SYSTEMS *Gardner*	6.01, M351	G(A)	1 or 2	Elective	3		—	6
6.582	TRANSIENTS IN LINEAR SYSTEMS *Gardner*	6.581	G(A)	2	Elective	3		—	6
6.583	FOUNDATIONS OF ELECTROMAGNETIC THEORY *Chenea*	6.07 or 8.72	G(A)	1 or 2	Elective	3		—	6
6.586	ENGINEERING APPLICATIONS OF FIELD THEORY *Moon*	M22	G(A)	2	Elective	3		—	6
6.59	BIOELECTRIC SIGNALS *Rosenblith*	——	G(A)	1	Elective	3		—	6
6.602	NON-LINEAR AND TIME-VARYING SYSTEMS *Seifert*	6.571 or 6.573 or 6.605	G(A)	1 or 2	Elective	3		—	6
6.604	FEEDBACK CONTROL THEORY AND APPLICATIONS *Newton*	6.05, M351	G(A)	1	Elective	3		2	6
6.605	FEEDBACK CONTROL THEORY AND APPLICATIONS *Newton*	6.05, M351	G(A)	1	Elective	3		—	6
6.606	FEEDBACK CONTROL THEORY AND APPLICATIONS *Newton*	6.605	G(A)	2	Elective	3		—	6
6.607	FEEDBACK CONTROL LABORATORY	——	G(A)	1 or 2	Elective			★	
6.61	PRODUCTION AND APPLICATION OF ATOMIC RADIATIONS *Trump*	8.031 or 8.041	G(A)	1	Elective	3		—	6
6.621	MICROWAVE CIRCUITS *Haus*	6.07	G(A)	1	Elective	3		2	6
6.622	ANTENNAS *Chu*	6.07	G(A)	2	Elective	3		—	6
6.623	PRINCIPLES OF PULSE CIRCUITS *Zimmermann*	6.20 or 6.311	G(A)	1	Elective	3		—	6

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
6.626	MODULATION THEORY *Baghdady*	6.311	G(A)	1	Elective	3	—	6
6.629	RADAR SYSTEM ENGINEERING *Reintjes*	6.02, 6.213	G(RA)	1	——	3	—	6
6.631	GASEOUS DISCHARGE PHENOMENA *Edgerton*	6.20	G(A)	1	Elective	1	3	5
6.632	ELECTRONIC INSTRUMENTATION AND CONTROL *Gray*	6.05	G(A)	1	Elective	3	—	6
6.633	ACTIVE CIRCUIT THEORY *Mason*	6.02	G(A)	1 or 2	Elective	3	—	6
6.635	TRANSISTORS *Adler*	6.05; 6.08 or 6.64 or 8.051 or 8.08	G(A)	2	Elective	3	—	9
6.637	BEAM-TYPE MICROWAVE TUBES *Smullin*	6.07 or 6.322; 8.08	G(A)	1	Elective	3	—	6
6.64	INSULATORS, SEMICONDUCTORS, AND METALS *von Hippel*	8.04 or 8.041	G(A)	2	Elective	3	—	9
6.67	PRINCIPLES OF CONTROL SYSTEMS *Gyftopoulos*	8.03, M22	G(A) except VI	1	Elective	3	—	6
6.68	SPECIAL PROBLEMS IN ELECTRICAL ENGINEERING *Gardner*	——	G(A)	1 or 2	Elective		★	
6.692‡	ADVANCED ENGINEERING ACOUSTICS *Baruch*	6.35	G(A)	2	Elective	3	—	6
6.695	SPECIAL PROBLEMS IN ACOUSTICS *Beranek*	——	G(A)	1 or 2	Elective		★	
6.696	HEARING, SPEECH, AND LANGUAGE *Rosenblith, Halle*	6.35	G(A)	2	Elective	3	—	6
6.73	ADVANCED ELECTRICAL CIRCUITS AND ELECTRONICS LABORATORY *Searle, Thornton*	6.02	G(A)	1 or 2	Elective		★	
6.74	ADVANCED ELECTRICAL ENERGY CONVERSION LABORATORY *White*	6.06T	G(A)	1 or 2	Elective		★	
6.80	ELECTRICAL CIRCUITS AND ELECTRONICS LABORATORY *Searle, Thornton*	——	4	1 or 2	Elective		★	
6.86	ELECTRICAL ENERGY CONVERSION LABORATORY *Woodson*	6.01 or 6.18	4	1 or 2	Elective		★	
6.901	INDUSTRIAL PRACTICE — GENERAL ELECTRIC COMPANY *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.902	INDUSTRIAL PRACTICE — GENERAL ELECTRIC COMPANY *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.903	INDUSTRIAL PRACTICE — GENERAL ELECTRIC COMPANY *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.904	INDUSTRIAL PRACTICE — GENERAL ELECTRIC COMPANY *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.905	INDUSTRIAL PRACTICE — I.B.M. CORPORATION *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.906	INDUSTRIAL PRACTICE — I.B.M. CORPORATION *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.907	INDUSTRIAL PRACTICE — I.B.M. CORPORATION *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Lab Prep
6.908	INDUSTRIAL PRACTICE — I.B.M. CORPORATION *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.911	PUBLIC UTILITIES PRACTICE — BOSTON EDISON COMPANY *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.912	PUBLIC UTILITIES PRACTICE — BOSTON EDISON COMPANY *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.913	PUBLIC UTILITIES PRACTICE — BOSTON EDISON COMPANY *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.914	PUBLIC UTILITIES PRACTICE — BOSTON EDISON COMPANY	——	G	S	VI-A	40 h.p.w.		
6.921	SPECIAL INDUSTRIAL PRACTICE *Boehne*	——	3 3	S 1	—— ——	40 h.p.w.		
6.922	SPECIAL INDUSTRIAL PRACTICE *Boehne*	——	3 4	2 S	—— ——	40 h.p.w.		
6.923	SPECIAL INDUSTRIAL PRACTICE *Boehne*	——	4 4	1 2	—— ——	40 h.p.w.		
6.924	SPECIAL INDUSTRIAL PRACTICE *Boehne*	——	G	S	——	40 h.p.w.		
6.931	INDUSTRIAL PRACTICE — RAYTHEON MANUFACTURING COMPANY *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.932	INDUSTRIAL PRACTICE — RAYTHEON MANUFACTURING COMPANY *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.933	INDUSTRIAL PRACTICE — RAYTHEON MANUFACTURING COMPANY *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.934	INDUSTRIAL PRACTICE — RAYTHEON MANUFACTURING COMPANY *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.941	INDUSTRIAL PRACTICE — BELL TELEPHONE LABORATORIES, INC. *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.942	INDUSTRIAL PRACTICE — BELL TELEPHONE LABORATORIES, INC. *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.943	INDUSTRIAL PRACTICE — BELL TELEPHONE LABORATORIES, INC. *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.944	INDUSTRIAL PRACTICE — BELL TELEPHONE LABORATORIES, INC. *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.951	INDUSTRIAL PRACTICE — GENERAL RADIO COMPANY *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.952	INDUSTRIAL PRACTICE — GENERAL RADIO COMPANY *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.953	INDUSTRIAL PRACTICE — GENERAL RADIO COMPANY *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.954	INDUSTRIAL PRACTICE — GENERAI RADIO COMPANY *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.961	INDUSTRIAL PRACTICE — PHILCO CORPORATION *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.962	INDUSTRIAL PRACTICE — PHILCO CORPORATION *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.963	INDUSTRIAL PRACTICE — PHILCO CORPORATION *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.964	INDUSTRIAL PRACTICE — PHILCO CORPORATION *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.971	ELECTRIC POWER SYSTEM DESIGN AND PRACTICE — AMERICAN ELECTRIC POWER CORPORATION *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.972	ELECTRIC POWER SYSTEM DESIGN AND PRACTICE — AMERICAN ELECTRIC POWER CORPORATION *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		

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6.973	ELECTRIC POWER SYSTEM DESIGN AND PRACTICE — AMERICAN ELECTRIC POWER CORPORATION *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.974	ELECTRIC POWER SYSTEM DESIGN AND PRACTICE — AMERICAN ELECTRIC POWER CORPORATION *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.981	RESEARCH AND DEVELOPMENT — NAVAL ORDNANCE LAB. *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.982	RESEARCH AND DEVELOPMENT — NAVAL ORDNANCE LAB. *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.983	RESEARCH AND DEVELOPMENT — NAVAL ORDNANCE LAB. *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.984	RESEARCH AND DEVELOPMENT — NAVAL ORDNANCE LAB. *Boehne*	——	G	S	VI-A	40 h.p.w.		
6.991	RESEARCH AND DEVELOPMENT — AIR FORCE CAMBRIDGE RESEARCH CENTER *Boehne*	——	3 3	S 1	VI-A(B) VI-A(A)	40 h.p.w.		
6.992	RESEARCH AND DEVELOPMENT — AIR FORCE CAMBRIDGE RESEARCH CENTER *Boehne*	——	3 4	2 S	VI-A(B) VI-A(A)	40 h.p.w.		
6.993	RESEARCH AND DEVELOPMENT — AIR FORCE CAMBRIDGE RESEARCH CENTER *Boehne*	——	4 4	1 2	VI-A(B) VI-A(A)	40 h.p.w.		
6.994	RESEARCH AND DEVELOPMENT — AIR FORCE CAMBRIDGE RESEARCH CENTER *Boehne*	——	G	S	VI-A	40 h.p.w.		

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7.

Biology

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
7.00	PERSPECTIVES IN LIFE SCIENCE *Wall*	——	1	2	Elective	3	—	3
7.01	GENERAL BIOLOGY I *Herbert*	——	2	1	VII, XX, XX-B	3	—	4
7.011	GENERAL BIOLOGY LABORATORY I *Herbert*	——	2	1	VII	0	3	0
7.02	GENERAL BIOLOGY II *Rich*	7.01	2	2	VII	3	—	4
7.021	GENERAL BIOLOGY LABORATORY II *Rich*	7.01	2	2	VII	0	3	1
7.03	GENETICS AND CYTOLOGY *H. W. Lewis*	7.02, 7.021	3	1	VII	2	4	4
7.04	DEVELOPMENTAL BIOLOGY *Bell*	7.03	3	2	VII	2	6	4
7.05	GENERAL BIOCHEMISTRY AND PHYSIOLOGY I *Buchanan*	5.41, 5.62	4	1	VII, XX, XX-B	3	—	6
7.051	GENERAL BIOCHEMISTRY AND PHYSIOLOGY LABORATORY I *Gould, G. M. Brown*	*7.05*	4	1	VII	0	8	0
7.06	GENERAL BIOCHEMISTRY AND PHYSIOLOGY II *D. F. Waugh*	7.05	4	2	VII	3	—	6
7.061	GENERAL BIOCHEMISTRY AND PHYSIOLOGY LABORATORY II *Jenerick*	*7.06*	4	2	VII	0	6	0
7.08	INTRODUCTION TO BIOPHYSICS *Levinthal*	5.02; 7.00 or 7.02; 8.04	3, 4	2	Elective	2	—	4
7.13	GENETICS *H. W. Lewis*	7.02	4	2	Elective	2	—	4
7.31	BIOLOGY SEMINAR *Bell*	7.06	G(A)	1	VII	1	—	2
7.32	BIOLOGY SEMINAR *Bell*	7.06	G(A)	2	VII	1	—	2
7.35	CELLULAR PHYSIOLOGY *Jenerick*	7.06	G(A)	1	Elective	2	—	4
7.36	ADVANCED NEUROPHYSIOLOGY *Wall*	7.06	G(A)	1	Elective	2	—	4
7.50	PHYSICAL CHEMISTRY OF PROTEINS *D. F. Waugh*	7.05	G(A)	2	Elective	2	—	4
7.68	INTERMEDIARY METABOLISM *Buchanan, Hartman*	7.05	G(A)	2	Elective	2	—	4
7.69	SEMINAR IN BIOCHEMISTRY *Hartman, Buchanan*	7.05	G(A)	2	Elective	2	—	4
7.77	BIOPHYSICS SEMINAR *Levinthal*	7.06	G(A)	1	Elective	1	—	2
7.78	BIOPHYSICS SEMINAR *Levinthal*	7.06	G(A)	2	Elective	1	—	2
7.81	ENZYMOLOGY *Sizer*	7.05	G(A)	1	Elective	2	—	4
7.811	ENZYMOLOGY LABORATORY *Hartman*	*7.81*	G(A)	1	Elective	0	4	2
7.82	ADVANCED BIOCHEMISTRY *Gould*	7.05	G(A)	2	Elective	2	4	4
7.831	BIOCHEMISTRY OF MICROORGANISMS *Gould*	7.05	4	2	Elective	3	4	4
7.832	BIOCHEMISTRY OF MICROORGANISMS *Gould*	7.831	G(A)	2	Elective	0	6	0
7.85	METHODS IN BIOPHYSICS I *Hall*	7.06, 8.04	G(A)	1	Elective	2	2	4
7.86	MOLECULAR GENETICS *Levinthal*	7.06, 8.04	G(A)	2	Elective	2	—	4
7.882	BIOPHYSICS LABORATORY *D. F. Waugh*	7.06, 8.04	G(A)	2	Elective	0	4	0

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
7.90	SEMINAR IN ENZYMOLOGY *Sizer*	7.81	G(A)	2	Elective	2	—	4
7.911	INSTRUMENTATION AND RESEARCH METHODS *Lion*	8.04	G(A)	1	Elective	2	—	4
7.912	INSTRUMENTATION AND RESEARCH METHODS LABORATORY *Lion*	8.04	G(A)	1	Elective	0	4	0
7.92	ELECTRICAL INSTRUMENTATION IN BIOLOGY *Lion*	7.911, 7.912	G(A)	2	Elective	0	4	0
7.93	SELECTED TOPICS IN BIOLOGY *Staff*	*7.05*	G(A)	1 or 2	Elective		★	
7.941	RESEARCH PROBLEMS *Staff*	——	G(A)	1	Elective		★	
7.942	RESEARCH PROBLEMS *Staff*	——	G(A)	2	Elective		★	
7.95	ELECTRON MICROSCOPY *Hall*	7.85 or 8.04	G(A)	2	Elective	2	—	4
7.96	ELECTRON MICROSCOPY LABORATORY *Hall*	7.95	G(A)	2	Elective	0	2	1
7.97	BIOPHYSICAL AND BIOCHEMICAL CYTOLOGY SEMINAR *Schmitt, Hodge*	7.06	G(A)	1	Elective	2	—	4
7.98	BIOPHYSICAL AND BIOCHEMICAL CYTOLOGY SEMINAR *Schmitt, Hodge*	7.97	G(A)	2	Elective	2	—	4
7.99	MOLECULAR CONFIGURATION IN BIOLOGICAL SYSTEMS SEMINAR *Rich*	7.06	G(A)	1	Elective	2	—	4

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8.

Physics

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
8.01	PHYSICS (MECHANICS) *Ingard*	——	1	1	All Courses	4	1	6
8.02	PHYSICS (MECHANICS: HEAT AND KINETIC THEORY) *Ingard*	8.01	1	2	All Courses	4	1	6
8.03	PHYSICS (ELECTRICITY AND MAGNETISM) *Mueller*	8.02, M12	2	1	All Courses except VI, VI-B, VIII, XII, XVIII	4	1	5
8.03S	PHYSICS ——	——	G	S	XIII-A	4	—	6
8.031	PHYSICS (ELECTROMAGNETISM) *Rossi*	8.02, M12	2	1	VI, VI-B, VIII, XII, XVIII	4	1	5
8.04	PHYSICS (OPTICS AND ATOMIC PHYSICS) *Mueller*	8.03	2	2	All Courses except VI, VI-B, VIII, XII, XVIII	4	1	5
8.041	PHYSICS (ELECTROMAGNETISM AND ELECTROMAGNETIC THEORY OF LIGHT) *Rossi*	8.031	2	2	VI, VI-B, VIII, XII, XVIII	4	1	5
8.05	PHYSICS OF ATOMS, MOLECULES, AND NUCLEI I *F. L. Friedman*	8.04 or 8.041	3	1	VIII	4	—	6
8.051	ATOMIC AND NUCLEAR PHYSICS I *Buechner*	8.04 or 8.041	3 3 4	S 1 1	VI-A(A) Elective, VI Elective, VI-A(B) Elective, VI-B, XXI-C II (2)	4	—	5
8.052	ATOMIC AND NUCLEAR PHYSICS II *Slater*	8.05 or 8.051	3	2	VI-B	4	—	5
8.053	INTRODUCTION TO NUCLEAR PHYSICS *Enge*	8.05 or 8.051	4	1	Elective	4	—	5
8.06	PHYSICS OF ATOMS, MOLECULES, AND NUCLEI II *F. L. Friedman*	8.05	3	2	VIII	4	—	6
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS *Frisch*	8.05 or 8.051	4	2	VI-B, VIII	4	—	6
8.08	ELECTRONICS *Harvey*	8.04 or 8.041	3 4	1 1	VIII XXI-C	4	—	6
8.09	EXPERIMENTAL ATOMIC PHYSICS I *Pless*	8.04 or 8.041	3	1	VIII	0	6	3
8.10	EXPERIMENTAL ATOMIC PHYSICS II *Kraushaar*	8.05, 8.08, 8.09	3	2	VIII	0	4	2
8.11	EXPERIMENTAL PHYSICS AND THESIS *Frisch*	8.10	4	1	VIII	2	10	4
8.12	SPECIAL PROBLEMS IN UNDERGRADUATE PHYSICS *Staff*	——	2, 3, 4	1, 2	Elective		★	
8.135	SPECIAL PROBLEMS IN ACOUSTICS *Staff*	8.71	G(A)	1 or 2	Elective		★	
8.14‡	SOUND PROPAGATION IN MOVING MEDIA *Ingard*	8.71	G(A)	1	Elective	3	—	6
8.15	PHOTOGRAPHY *A. C. Hardy*	——	3	2	Elective	2	—	1
8.16	OPTICS *A. C. Hardy*	8.04 or 8.041	3	2	Elective	3	—	6
8.17	COLOR MEASUREMENTS *A. C. Hardy*	8.04 or 8.041	4	2	Elective	0	3	2
8.18	SPECIAL PROBLEMS IN OPTICS *Staff*	8.16	G(A)	1 or 2	Elective		★	
8.191	SELECTED TOPICS IN PHYSICAL OPTICS I *Mueller*	8.72	G(A)	1	Elective	2	—	4

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
8.192	SELECTED TOPICS IN PHYSICAL OPTICS II *Mueller*	8.191	G(A)	2	Elective	2	—	4
8.21	PHYSICAL ELECTRONICS *Nottingham*	8.08	G(A)	1	Elective	3	—	6
8.212	PHYSICAL ELECTRONICS LABORATORY *Nottingham*	8.21	G(A)	2	Elective	2	3	3
8.231	ELECTRICAL DISCHARGES IN GASES *S. C. Brown*	8.05, 8.07	G(A)	1	Elective	3	—	6
8.232	THEORY OF ELECTRICAL DISCHARGES IN GASES *Allis*	8.231, *8.72*	G(A)	2	Elective	3	—	6
8.25	SPECIAL PROBLEMS IN ELECTRONICS *Staff*	8.08, *8.21*	G(A)	1 or 2	Elective		★	
8.27	X-RAYS AND CRYSTAL PHYSICS *Warren*	8.05, M352	G	1	Elective	3	1	6
8.28	X-RAY DIFFRACTION *Warren*	8.27	G(A)	2	Elective	3	—	6
8.30	SPECIAL PROBLEMS IN CRYSTAL PHYSICS *Staff*	8.27	G(A)	1 or 2	Elective		★	
8.31	HIGH RESOLUTION SPECTROSCOPY *Bitter*	8.06	G(A)	1	Elective	3	—	6
8.32	THEORY OF ATOMIC SPECTRA *Bradley*	8.06	G(A)	1	Elective	3	—	6
8.34	SPECIAL PROBLEMS IN SPECTROSCOPY AND NUCLEAR MAGNETISM *Staff*	8.06	G(A)	1 or 2	Elective		★	
8.361	QUANTUM THEORY OF MATTER I *Slater*	M351	G(A)	1	Elective	3	—	6
8.362	QUANTUM THEORY OF MATTER II *Slater*	8.361	G(A)	2	Elective	3	—	6
8.363	SELECTED TOPICS IN THE THEORY OF SOLIDS I *Koster*	8.362	G(A)	1	Elective	2	—	4
8.364‡	SELECTED TOPICS IN THE THEORY OF SOLIDS II *Koster*	8.363	G(A)	2	Elective	2	—	4
8.37	NEUTRON DIFFRACTION *Shull*	3.50 or 8.27	G(A)	2	Elective	3	—	6
8.411‡	STATISTICAL THERMODYNAMICS I *Tisza*	*8.731*	G(A)	1	Elective	3	—	9
8.412‡	STATISTICAL THERMODYNAMICS II *Tisza*	8.411	G(A)	2	Elective	3	—	9
8.43	MICROWAVE PHYSICS *Strandberg*	8.361 or 8.731	G(A)	2	Elective	3	—	6
8.45	SPECIAL PROBLEMS IN SOLID STATE PHYSICS *Staff*	8.362 or 8.412	G(A)	1 or 2	Elective		★	
8.511	NUCLEAR PHYSICS I *M. Deutsch*	8.06, *8.71*	G(A)	1	Elective	3	—	6
8.512	NUCLEAR PHYSICS II *M. Deutsch*	8.511	G(A)	2	Elective	3	—	6
8.513	NUCLEAR PHYSICS LABORATORY *M. Deutsch*	8.511	G(A)	2	Elective	1	3	3
8.52	ADVANCED APPLIED NUCLEAR PHYSICS *R. D. Evans*	8.512 or 8.532	G(A)	1	Elective	3	—	6
8.531	NUCLEAR PHYSICS FOR ENGINEERS I *R. D. Evans*	8.051 or 8.06	G(A)	1	Elective	3	—	6
8.532	NUCLEAR PHYSICS FOR ENGINEERS II *R. D. Evans*	8.531	G(A)	2	Elective	3	—	6

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
8.541	ADVANCED TOPICS IN NUCLEAR PHYSICS *Schluter*	8.06	G(A)	1	Elective	2	—	4
8.551	THEORY OF NUCLEAR STRUCTURE I *Weisskopf*	8.732	G(A)	1	Elective	3	—	9
8.552	THEORY OF NUCLEAR STRUCTURE II *Weisskopf*	8.551	G(A)	2	Elective	3	—	9
8.56	COSMIC PHYSICS *Rossi*	8.71, 8.72	G(A)	2	Elective	3	—	6
8.58‡	MESON PHYSICS *Feld*	8.06, 8.732	G(A)	2	Elective	3	—	6
8.59	STATISTICAL FLUCTUATIONS IN PHYSICAL PROCESSES *R. D. Evans*	8.052 or 8.06	G(A)	2	Elective	2	—	4
8.60	SPECIAL PROBLEMS IN NUCLEAR PHYSICS *Staff*	8.511 or 8.531	G(A)	1 or 2	Elective		★	
8.71	INTRODUCTION TO THEORETICAL PHYSICS I (MECHANICS) *M. H. Friedman*	M351	G(A) except VIII 4	2 2	Elective VIII	4	—	8
8.72	INTRODUCTION TO THEORETICAL PHYSICS II (ELECTROMAGNETIC THEORY) *M. H. Friedman*	M351	G(A) except VIII 4	1 1	Elective VIII	4	—	8
8.731	INTRODUCTION TO QUANTUM THEORY I *Haber-Schaim*	8.71, 8.72	G(A)	1	Elective	3	—	9
8.732	INTRODUCTION TO QUANTUM THEORY II *Haber-Schaim*	8.731	G(A)	2	Elective	3	—	9
8.74	APPLICATIONS OF GROUP THEORY TO THEORETICAL PHYSICS *Koster*	8.361 or 8.731	G(A)	2	Elective	3	—	9
8.791‡	METHODS OF THEORETICAL PHYSICS I *Feshbach*	8.71, 8.72	G(A)	1	Elective	3	—	9
8.792‡	METHODS OF THEORETICAL PHYSICS II *Feshbach*	8.791	G(A)	2	Elective	3	—	9
8.80	ADVANCED MECHANICS *Harvey*	8.71, 8.72	G(A)	2	Elective	3	—	9
8.861‡	RELATIVISTIC QUANTUM MECHANICS I *Villars*	8.732	G(A)	1	Elective	3	—	9
8.862‡	RELATIVISTIC QUANTUM MECHANICS II *Villars*	8.861	G(A)	2	Elective	3	—	9
8.90	SPECIAL PROBLEMS IN THEORETICAL PHYSICS *Staff*	8.791	G(A)	1 or 2	Elective		★	

10.

Chemical Engineering

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
10.11	CHEMICAL ENGINEERING *Fairbanks*	5.02	2	2	Elective	2	—	3
10.15	THESIS REPORTS *Baddour*	——	4	1	x	0	3	0
10.17	INDUSTRIAL CHEMISTRY *Baddour*	5.02	2 3	1 1	x xx-b (58–59)	3	—	4
10.18	INDUSTRIAL CHEMISTRY *Baddour*	5.61, 10.17	3	1	Elective	3	—	6
10.21	INDUSTRIAL CHEMISTRY *Satterfield*	5.42, 5.62	4	1	Elective	3	—	6
10.25	INDUSTRIAL CHEMISTRY *Meissner*	5.42, 5.62	G(A)	1	Elective	3	—	6
10.26	INDUSTRIAL CHEMISTRY LABORATORY *Merrill*	10.17	4	1	Elective	0	10	0
10.27	CHEMICAL ENGINEERING LABORATORY *Gilliland*	10.17	4	1	Elective	0	10	0
10.28	CHEMICAL ENGINEERING THERMODYNAMICS *Sherwood*	10.17	3	1	Elective	4	—	6
10.29	CHEMICAL ENGINEERING *Sherwood*	10.28	3 3	2 2	Elective xx-b (not 58–59)	4	—	6
10.31	CHEMICAL ENGINEERING *Gilliland*	2.41, 10.17; or *3.20;* or 10.17, 10.26	4	1	Elective	4	—	6
10.32	CHEMICAL ENGINEERING *Vivian*	10.29	4	1, 2	Elective	4	—	6
10.33	ANALYTICAL TREATMENT OF CHEMICAL ENGINEERING PROCESSES *Mickley*	5.62, M22	G(A)	2	Elective	3	—	6
10.36	PROCESS DESIGN *Sherwood*	10.31	4	2	Elective	3	—	5
10.37	CHEMICAL KINETICS *G. C. Williams*	5.62, 10.17, 10.29	4	1	Elective	3	—	6
10.40	CHEMICAL ENGINEERING THERMODYNAMICS *Meissner*	5.62, 10.29	G(A)	1, 2	Elective	4	—	8
10.41	DISTILLATION *Gilliland*	10.32	G(A)	2	Elective	3	—	6
10.43	SEPARATION PROCESSES *Sherwood*	5.62	G(A)	1	Elective	3	—	6
10.45	DISTILLATION AND ABSORPTION *Vivian*	10.32	G(A)	1	Elective	4	—	8
10.46	ABSORPTION AND EXTRACTION *Sherwood*	10.32	G(A)	2	Elective	3	—	6
10.47	ION EXCHANGE *Baddour*	5.62, 10.32	G(A)	2	Elective	2	—	4
10.50	HEAT TRANSMISSION *McAdams*	10.31	G(A)	1	Elective	2	—	4
10.52	CHEMICAL ENGINEERING II *Mickley*	10.32	G(A)	1	Elective	3	—	6
10.53	CHEMICAL ENGINEERING DESIGN *G. C. Williams*	10.31, *10.32*	G(A)	2	Elective	3	—	6

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
10.55	ECONOMIC BALANCE IN CHEMICAL INDUSTRY *G. C. Williams*	10.32	G(A)	1 or 2	Elective	3	—	6
10.62	ADVANCED THERMODYNAMICS *Meissner*	10.40	G(A)	2	Elective	3	—	6
10.63	MOLECULAR FORCES AND PROPERTIES OF MATTER *Michaels*	5.42, 5.62	G(A)	2	Elective	3	—	6
10.65	APPLIED CHEMICAL KINETICS *Satterfield*	5.62, 10.29	G(A)	2	Elective	3	—	6
10.66T	COLLOID CHEMISTRY *Michaels*	5.42, 5.62	G(A)	1	Elective	3	—	6
10.67	APPLIED SURFACE CHEMISTRY *Michaels*	10.21 or 10.63 or 10.66T	G(A)	2	Elective	3	—	6
10.69	HIGH POLYMER TECHNOLOGY *Michaels*	5.42, 5.62	G(A)	2	Elective	3	—	6
10.70	PRINCIPLES OF COMBUSTION *Hottel*	——	G(A)	1	Elective	3	—	6
10.72	SELECTED COMBUSTION PROBLEMS *G. C. Williams*	——	G(A)	2	Elective	2	—	4
10.74	PRINCIPLES OF FURNACE DESIGN *Hottel*	10.31	G(A)	2	Elective	3	—	6
	School of Chemical Engineering Practice:							
10.81T	BAYWAY STATION *Reid*	10.32	G(A)	1 or 2	Elective	0	24	0
10.82T	BOUND BROOK STATION *Reid*	10.32	G(A)	1 or 2	Elective	0	24	0
10.83T	BAYWAY STATION *Reid*	10.32	4	2	X-B	0	18	0
10.84T	BOUND BROOK STATION *Reid*	10.32	4	2	X-B	0	18	0
10.90	EXPERIMENTAL RESEARCH PROBLEM *G. C. Williams*	——	G(A)	1, 2	Elective		★	
10.991	SEMINAR IN CHEMICAL ENGINEERING *Mickley*	10.32	G(A)	1	Elective	2	—	4
10.992	SEMINAR IN CHEMICAL ENGINEERING *Mickley*	10.32	G(A)	2	Elective	2	—	4

12.

Geology and Geophysics

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
12.00	EARTH SCIENCE (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) *Pinson*	——	1	2	Elective	2	—	4
12.001	ASTRONOMY *Pinson*	——	1	1, 2	Elective	3	—	3
12.003	PHYSICAL OCEANOGRAPHY I *Staff*	M22	3	1	Elective	3	—	6
12.004	PHYSICAL OCEANOGRAPHY II *Staff*	M22	3	2	Elective	3	—	6
12.011	MINERALOGY I *Dennen*	5.02	2	1	XII	3	4	3
12.012	MINERALOGY II *Dennen*	12.011	2	2	Elective	3	4	3
12.05	MINERALOGICAL SEMINAR *Buerger*	12.202	G(A)	1 or 2	Elective	2	—	4
12.14	PETROLOGY *Fairbairn*	12.011, 12.301	3	2	Elective	2	—	4
12.15	PETROLOGY LABORATORY *Fairbairn*	12.231	3	2	Elective	0	6	0
12.161‡	MINERAL DEPOSITS AND PETROLOGY SEMINAR *Fairbairn, Hurley*	12.14, 12.40	G(A)	1	Elective	2	—	4
12.162‡	MINERAL DEPOSITS AND PETROLOGY SEMINAR *Hurley, Fairbairn*	12.161	G(A)	2	Elective	2	—	4
12.17	ADVANCED PETROLOGY LABORATORY *Fairbairn*	12.15	G(A)	1	Elective	0	4	2
12.201	CRYSTALLOGRAPHY *Buerger*	——	2	1	Elective	2	2	2
12.202	CRYSTALLOGRAPHY *Buerger*	12.201	4	2	Elective	2	—	4
12.231	OPTICAL CRYSTALLOGRAPHY *Fairbairn*	12.011 or 12.201	3	1	Elective	0	6	2
12.232	ADVANCED OPTICAL CRYSTALLOGRAPHY *Fairbairn*	12.231	G(A)	2	Elective	0	3	1
12.27	CRYSTALLOGRAPHIC RESEARCH *Buerger*	12.201	G(A)	1 or 2	Elective		★	
12.301	PHYSICAL GEOLOGY *Dennen*	——	2	1	XII	3	4	4
12.302	HISTORICAL GEOLOGY *Boucot*	12.301	2	2	XII	3	4	4
12.303	GEOLOGICAL SURVEYING *Parks*	12.301	3	S	XII	0	7	0
12.304	FIELD INVESTIGATIONS AND REPORTS *Staff*	12.301	3	S	XII	0	17	0
12.308T	SEDIMENTATION AND STRATIGRAPHY *Mencher*	12.302	3	2	Elective	3	4	5
12.321	ENGINEERING GEOLOGY *Brace*	——	3	1	I	2	2	2
12.322	ENGINEERING GEOLOGY *Brace*	12.321	G	2	Elective	2	—	4
12.40	MINERAL DEPOSITS *Hurley*	12.011, 12.301	4	1	Elective	3	—	5
12.41	MINERAL DEPOSITS LABORATORY *Hurley*	12.301	4	1	Elective	0	4	0
12.432	ADVANCED MINERAL DEPOSITS LABORATORY *Hurley*	12.40	G(A)	2	Elective	0	4	1

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
12.44	PETROLEUM GEOLOGY *Mencher*	12.308T, 12.702	4	1	Elective	3	—	5
12.45	PETROLEUM GEOLOGY LABORATORY *Mencher*	*12.44*	4	1	Elective	0	4	2
12.461T‡	PETROLEUM GEOLOGY SEMINAR *Mencher*	12.44	G(A)	1	Elective	2	—	6
12.462T‡	PETROLEUM GEOLOGY SEMINAR *Mencher*	12.461T	G(A)	2	Elective	2	—	6
12.51T	PALEONTOLOGY *Boucot*	12.302	3	1	Elective	3	3	6
12.52T	ADVANCED TOPICS IN PALEONTOLOGY *Boucot*	12.51T	G(A)	2	Elective	2	—	6
12.58	SEDIMENTARY PETROGRAPHY *Boucot*	12.15	4	2	Elective	2	6	2
12.581T	SEDIMENTOLOGY *Shrock*	12.308T	4	1	Elective	2	—	6
12.582	ADVANCED SEDIMENTOLOGY *Mencher, Boucot*	12.581T	G(A)	1 or 2	Elective		★	
12.583T	SEDIMENTOLOGY SEMINAR *Shrock, Mencher, Boucot*	12.308T	G(A)	2	Elective	2	—	6
12.65	SPECIAL PROBLEMS *Staff*	——	4	1 or 2	Elective		★	
12.66	SPECIAL PROBLEMS *Staff*	——	G(A)	1 or 2	Elective		★	
12.702	STRUCTURAL GEOLOGY *Brace*	12.301	3	1	Elective	3	2	6
12.721	SPECIAL TOPICS IN TECTONICS *Staff*	12.73T	G(A)	1	Elective		★	
12.722	TECTONICS SEMINAR *Fairbairn*	12.15, 12.702	G(A)	2	Elective	2	—	4
12.73T	ADVANCED STRUCTURAL GEOLOGY *Brace*	12.702	4	2	Elective	3	2	6
12.801	THEORETICAL GEOLOGY I *Hughes*	M351	G	1	Elective	3	—	9
12.802‡	THEORETICAL GEOLOGY II *Hughes*	12.801	G	2	Elective	3	—	9
12.803‡	THE EARTH'S INTERIOR *Hughes*	12.831	G(A)	1	Elective	3	—	9
12.804	THE EARTH'S CRUST *Hughes*	12.831	G(A)	2	Elective	3	—	9
12.811	GEOCHEMISTRY I *Winchester*	*5.61*	3	1	Elective	3	—	6
12.812	GEOCHEMISTRY II *Winchester*	*5.62*, 12.811	3	2	Elective	3	—	6
12.82	SPECTROCHEMICAL ANALYSIS *Dennen*	12.811	G(A)	1	Elective	2	2	3
12.831	ELEMENTS OF GEOPHYSICS I *Doell*	8.041, M22	3	1	Elective	3	—	9
12.832	ELEMENTS OF GEOPHYSICS II *Doell*	12.831	3	2	Elective	3	—	9
12.833	GEOPHYSICAL LABORATORY *Doell*	12.831	3	2	Elective	2	4	2
12.851	GEOPHYSICAL ANALYSIS AND COMPUTATION *S. M. Simpson*	12.874, M352	G(A)	1	Elective	2	1	6
12.852	GEOPHYSICAL ANALYSIS AND COMPUTATION *S. M. Simpson*	12.851	G(A)	2	Elective	2	1	6
12.86	ELEMENTS OF SEISMOLOGY *Doell*	M22	4	1	Elective	2	—	4
12.873	ADVANCED GEOPHYSICS *Staff*	M352	G(A)	1	Elective	3	—	6
12.874	ADVANCED GEOPHYSICS *Staff*	12.873	G(A)	2	Elective	3	—	6
12.88	GEOPHYSICS SEMINAR *S. M. Simpson*	12.874	G(A)	1 or 2	Elective	2	—	4
12.89	ISOTOPE GEOLOGY *Hurley*	8.04, 12.301	G(A)	2	Elective	2	—	4
12.91	ELEMENTS OF MINING *Parks*	——	4	1	Elective	3	—	6
12.92	MINING METHODS AND PRACTICE *Parks*	12.91	4	2	Elective	3	—	6

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
12.94	MINERAL ECONOMICS *Parks*	——	4	1	Elective	3	—	6
12.95	VALUATION OF MINERAL PROPERTY *Parks*	12.92	G(A)	2	Elective	3	—	6
12.96	MINERAL ECONOMICS SEMINAR *Parks*	12.94	G(A)	1 or 2	Elective		★	
12.97	MINERAL VALUATION SEMINAR *Parks*	12.95	G(A)	1 or 2	Elective		★	

13.

Naval Architecture and Marine Engineering

13.01T	NAVAL ARCHITECTURE I *Allmendinger*	8.01, M21	3	1	XIII	2	2	5
13.012	NAVAL ARCHITECTURE *Mandel*	8.01, M21	G	2	XIII-A	4	1	7
13.02	NAVAL ARCHITECTURE II *Abkowitz*	2.25, 13.01T	3	2	XIII	3	1	5
13.03T	PRINCIPLES OF SHIP DESIGN *Mandel*	13.46	G(A)	1	Elective	2	4	5
13.031	PRELIMINARY DESIGN OF SHIPS *Term 1: J. H. Evans Term 2: Powell*	*13.03*	G(A)	1, 2	Elective		★	
13.04	ADVANCED SHIP DESIGN *Arentzen*	13.03	G(A)	2	Elective	2	—	8
13.05	ADVANCED HYDROMECHANICS OF SHIP DESIGN *Abkowitz*	13.02	G(A)	1	Elective	3	—	5
13.06	[1]SPECIAL PROBLEMS IN NAVAL ARCHITECTURE AND MARINE ENGINEERING *Troost*	——	G(A)	1, 2	Elective		★	
13.12	WARSHIP GENERAL ARRANGEMENTS *Arentzen*	13.20	G(R)	2	XIII-A	3	—	5
13.13	WARSHIP STRUCTURE THEORY I *J. H. Evans*	2.046, 2.081	G(RA)	1	XIII-A	3	—	6
13.14	WARSHIP STRUCTURE THEORY II *J. H. Evans*	13.13	G(RA)	2	——	3	—	6
13.15T	WARSHIP BASIC DESIGN I *Mandel*	13.012, 13.12, 13.13	G(RA)	1	XIII-A	2	4	5
13.16	WARSHIP BASIC DESIGN II *Arentzen*	13.12, 13.22	G(RA)	1	XIII-A	3	—	6
13.17	HISTORY OF WARSHIPS *Arentzen*	——	G(R)	1	XIII-A	3	—	4
13.20	ELEMENTARY WARSHIP DESIGN *Arentzen*	——	G(R)	S	XIII-A	1	7	2

[1] Background in naval architecture or marine engineering is required.

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
13.22	WARSHIP GENERAL DESIGN *Mandel*	13.012, 13.12, 13.20	G(R)	1	XIII-A	0	5	0
13.24	WARSHIP STRUCTURE DESIGN I *Mandel*	13.13	G(RA)	2	——	0	5	0
13.241	WARSHIP STRUCTURE DESIGN I *Mandel*	13.13	G(RA)	2	XIII-A	0	3	0
13.25	WARSHIP STRUCTURE DESIGN II *J. H. Evans*	13.14, 13.24	G(RA)	1	——	0	5	0
13.26	PRELIMINARY DESIGN OF WARSHIPS *Obermeyer*	13.15, 13.16	G(RA)	2	XIII-A	0	9	0
13.43	SHIP STRUCTURAL DRAWING *J. H. Evans*	13.45	4	1	XIII (58–59), XIII-B (58–59)	0	3	0
13.45	SHIP STRUCTURES *J. H. Evans*	2.002, *13.02*	3	2	XIII	3	—	6
13.46	SHIP DESIGN *Allmendinger*	13.02, 13.43, 13.53	4	2	XIII (58–59), XIII-B (58–59)	1	8	2
13.52T	MARINE ENGINEERING I *Powell*	2.403, *13.02*	3	2	XIII	2	—	4
13.53	MARINE ENGINEERING II *Powell*	1.611, 2.42, 6.18, 13.52	4	1	XIII (58–59), XIII-B (58–59)	3	—	5
13.54	MARINE ENGINEERING DYNAMICS *F. M. Lewis*	2.002	4 G	2 1	XIII (58–59), XIII-B (58–59)	2	—	4
13.56‡	MARINE ENGINEERING ECONOMICS *Powell*	6.18, 13.02, 13.53	G(A)	2	Elective	3	—	9
13.61	MARINE ENGINEERING DESIGN III *Powell*	2.002	3 4	1 1	XIII XIII (58–59), XIII-B (58–59)	1	4	0
13.62	MARINE ENGINEERING DESIGN IV *Burtner*	13.53, 13.61	4	2	XIII (58–59), XIII-B (58–59)	1	4	0
13.711	[1]SHIP MACHINERY DESIGN I *Powell*	13.53, 13.54	G(A)	1	Elective	2	—	4
13.721	[1]SHIP MACHINERY DESIGN II *Powell*	13.53, 13.54	G(A)	2	Elective	2	—	4
13.73	MECHANICAL VIBRATION *F. M. Lewis*	2.002 or 2.046	G(A)	1	Elective	3	—	6
13.74	MECHANICAL VIBRATION *F. M. Lewis*	13.73	G(A)	2	Elective	4	—	8
13.75	WARSHIP PROPULSION I *Thornbury*	2.402, 2.501	G(RA)	1	XIII-A	3	2	6
13.76	WARSHIP PROPULSION II *Thornbury*	13.75	G(RA)	2	XIII-A	2	4	4
13.791	MARINE PROPELLERS *Term 1: Troost Term 2: Powell*	1.612 or 2.25; *13.012* or 13.02	G(A)	1, 2	XIII-A	3	—	6
13.90	WARSHIP ELECTRICAL ENGINEERING *Thornbury*	6.18, 6.19	G(RA)	1	XIII-A	3	—	4
13.91T	ADVANCED WARSHIP ELECTRICAL ENGINEERING *Thornbury*	6.10, 6.213	G(RA)	1	——	3	2	4
13.92	PROBLEMS IN SHIPYARD MANAGEMENT *Thornbury*	14.61 or 15.30	G(A)	2	XIII-A	3	—	6

[1] Approximately one year's practical experience with marine engineering plants or design is essential. Each student's experience is to be evaluated prior to acceptance of his enrollment.

14.

Economics and Social Science

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
14.01	ECONOMIC PRINCIPLES I *E. C. Brown*	21.02	2 3 3 3, 4	1 1 2 1, 2	XIV-A, XIV-B, XV VI-A(B) VI-A(A) Elective (but required for graduation by I, II, II-B, III, IV-A, VI, VI-B, XIII, XIII-B, XVI, XVI-B, XX, XX-B)	3	—	5
14.02	ECONOMIC PRINCIPLES II *Adelman*	14.01	2 3, 4	2 1, 2	XIV-A(a), XIV-B(a) Elective	3	—	5
14.03	PRICES AND PRODUCTION *Bishop*	14.02	3, 4	1	Elective	3	—	5
14.04	INDUSTRIAL ORGANIZATION AND PUBLIC POLICY *Adelman*	14.02	3, 4	2	Elective	3	—	5
14.09	ECONOMIC PROBLEMS SEMINAR *Kindleberger*	14.02	4	1, 2	Elective	3	—	5
14.101	MATHEMATICS FOR ECONOMISTS *H. A. Freeman*	——	G	1	Elective	3	—	6
14.102	MATHEMATICS FOR ECONOMISTS *Ando*	14.101	G	2	Elective	3	—	6
14.114	ECONOMICS AND FINANCE: PRINCIPLES AND POLICIES I *E. C. Brown*	——	G	S	——	4	—	9
14.115	ECONOMICS AND FINANCE: PRINCIPLES AND POLICIES II *R. E. Freeman*	14.114	G	1	——	3	—	6
14.116	ECONOMICS AND FINANCE: PRINCIPLES AND POLICIES III *Kindleberger*	14.115	G(A)	2	——	3	—	6
14.117	ECONOMICS AND INDUSTRIAL MANAGEMENT *Solow, E. C. Brown*	——	G	1, 2	——	3	—	6
14.121	ECONOMIC ANALYSIS *Bishop*	14.03	G(A)	1	Elective	3	—	6
14.122	ECONOMIC ANALYSIS *Samuelson*	14.121	G(A)	2	Elective	3	—	6
14.132	SCHOOLS OF ECONOMIC THOUGHT *Bishop*	14.121	G(A)	2	Elective	3	—	6
14.151	MATHEMATICAL APPROACH TO ECONOMICS *Samuelson*	14.122	G(A)	1	Elective	3	—	6
14.161	ECONOMIC HISTORY *Letwin*	*14.121*	G(A)	1	Elective	3	—	6
14.162	ECONOMIC HISTORY *Letwin*	*14.121*	G(A)	2	Elective	3	—	6
14.171	THEORY OF ECONOMIC GROWTH *Rosenstein-Rodan*	14.122, 14.451	G(A)	1	Elective	3	—	6
14.172	RESEARCH SEMINAR IN ECONOMIC DEVELOPMENT *Millikan*	14.171	G(A)	2	Elective	3	—	6
14.174	NON-ECONOMIC FACTORS IN ECONOMIC GROWTH *Hagen*	14.171	G(A)	2	Elective	3	—	6

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
14.182	CAPITALISM, SOCIALISM AND GROWTH *Domar*	14.121, 14.451	G(A)	2	Elective	3	—	6
14.191	ECONOMICS SEMINAR ——	14.121	G(A)	1	Elective	3	—	6
14.192	ECONOMICS SEMINAR ——	14.121	G(A)	2	Elective	3	—	6
14.195	READING SEMINAR IN ECONOMICS ——	14.121	G(A)	1	Elective		★	
14.196	READING SEMINAR IN ECONOMICS ——	14.121	G(A)	2	Elective		★	
14.21	ECONOMICS OF INVENTION *Maclaurin*	14.01	4	2	Elective	3	—	5
14.271	PROBLEMS IN INDUSTRIAL ECONOMICS *Adelman*	14.03	G(A)	1	Elective	3	—	6
14.272	GOVERNMENT REGULATION OF INDUSTRY *Adelman*	14.271	G(A)	2	Elective	3	—	6
14.281	ENTREPRENEURSHIP, INNOVATION, AND ECONOMIC DEVELOPMENT *Maclaurin*	14.03	G(A)	1	Elective	3	—	6
14.282	ECONOMICS OF INNOVATION SEMINAR *Maclaurin*	14.281	G(A)	2	Elective	3	—	6
14.291	INDUSTRIAL ECONOMICS SEMINAR ——	14.271	G(A)	1	Elective	3	—	6
14.292	INDUSTRIAL ECONOMICS SEMINAR ——	14.271	G(A)	2	Elective	3	—	6
14.31	ELEMENTARY STATISTICS *Ando*	M12	3	1	XIV-A(a), XIV-B(a)	3	—	5
14.32	STATISTICAL QUALITY CONTROL *H. A. Freeman*	14.31	4	2	Elective	3	—	6
14.371	STATISTICAL THEORY *H. A. Freeman*	M21	G	1	Elective	3	—	6
14.372	STATISTICAL THEORY *H. A. Freeman*	14.371	G	2	Elective	3	—	6
14.374	DESIGN AND ANALYSIS OF SCIENTIFIC EXPERIMENTS *H. A. Freeman*	14.31 or 14.371 or M32	G(A)	2	Elective	3	—	6
14.381	STATISTICAL METHOD *Ando, Durand*	——	G	1	Elective	3	—	6
14.382	ECONOMIC STATISTICS *Solow*	14.371	G(A)	2	Elective	3	—	6
14.391	RESEARCH SEMINAR IN ECONOMICS *Solow*	14.122, 14.371	G(A)	1	Elective	2	—	7
14.40	MONEY AND INCOME *R. E. Freeman*	14.02	3, 4	2	Elective	3	—	5
14.43	PUBLIC FINANCE *E. C. Brown*	14.02	4	1	Elective	3	—	5
14.451	NATIONAL INCOME *Millikan*	14.40	G(A)	1	Elective	3	—	6
14.461	MONETARY AND BANKING PROBLEMS *Bator*	14.40	G(A)	1	Elective	3	—	6
14.472	FISCAL POLICY *E. C. Brown*	14.451	G(A)	2	Elective	3	—	6
14.481	BUSINESS CYCLES *Solow*	14.451	G(A)	1	Elective	3	—	6
14.51	INTERNATIONAL RELATIONS *Padelford*	21.04	3, 4	1, 2	Elective	3	—	5
14.52	PRINCIPLES AND PROBLEMS OF AMERICAN DIPLOMACY *Pye*	14.51	3, 4	1, 2	Elective	3	—	5
14.521‡	STRATEGIC AND POLITICAL GEOGRAPHY ——	——	G	1	Elective	3	—	6
14.523	NATIONAL SECURITY AND MILITARY TECHNOLOGY *Eastman, J. McCormack*	14.52 or 14.521	G(A)	1	Elective	3	—	6
14.524	POLITICS AND NATIONAL DEFENSE POLICY ——	14.523	G(A)	2	Elective	3	—	6
14.526	RESEARCH AND DEVELOPMENT FOR MILITARY PURPOSES *Eastman*	14.52 or 14.523	G(A)	2	Elective	3	—	6
14.53	SEMINAR IN INTERNATIONAL POLITICS ——	14.52	3, 4	1	Elective	3	—	5
14.531	ASIAN POLITICS AND U. S. FOREIGN POLICY *Pye*	14.121 or 14.52	G(A)	2	Elective	3	—	6

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
14.533	SOCIAL SCIENCE AND U. S. FOREIGN POLICY *Millikan*	14.117	G(A)	1	Elective	3	—	6
14.534	NATIONAL INTEREST AND PRINCIPLES OF INTERNATIONAL COOPERATION *Bloomfield*	14.52 or 14.533	G(A)	2	Elective	3	—	6
14.54	INTERNATIONAL TRADE *Kindleberger*	14.01; 14.02 or 14.51	4	2	Elective	3	—	5
14.55	BASIC IDEAS OF WESTERN POLITICS AND ETHICS 500 B.C.–1500 A.D. *Bursey*	21.04	3, 4	1	Elective	3	—	5
14.56	RISE OF MODERN POLITICAL AND SOCIAL SCIENCE 1500–1914 *Bursey*	14.55 or 21.51 or 21.52	3, 4	2	Elective	3	—	5
14.57‡	CONTEMPORARY IDEAS ON POLITICAL AND ECONOMIC DEVELOPMENT ——	Any two 14 or 21 subjects above 21.04	4, G	1	Elective	3	—	5
14.571	MAJOR PROBLEMS IN U. S. FOREIGN POLICY *Padelford*	——	G	2	——	3	—	6
14.58‡	NATIONALISM AND NATIONAL DEVELOPMENT ——	Any two 14 or 21 subjects above 21.04	4, G	2	Elective	3	—	5
14.581	INTERNATIONAL ECONOMICS *Kindleberger*	14.40	G(A)	1	Elective	3	—	6
14.582	INTERNATIONAL ECONOMICS *Kindleberger*	14.581	G(A)	2	Elective	3	—	6
14.61	INDUSTRIAL RELATIONS *D. V. Brown*	15.30	4	1	Elective	3	—	6
14.63	LABOR RELATIONS *Siegel*	21.04	3	1, 2	Elective	3	—	5
14.64	LABOR ECONOMICS AND PUBLIC POLICY *Myers*	14.01 or 14.73; 14.63	4	1, 2	Elective	3	—	5
14.662	HUMAN RELATIONS AND LABOR RELATIONS *Myers*	——	G	S	——	4	—	8
14.671‡	PROBLEMS IN LABOR ECONOMICS *Myers*	14.61	G(A)	1 or 2	Elective	3	—	6
14.672	PUBLIC POLICY ON LABOR RELATIONS *Myers*	14.61	G(A)	1 or 2	Elective	3	—	6
14.673	LABOR-MANAGEMENT RELATIONS AND PUBLIC POLICY *D. V. Brown, Siegel*	14.672	G(A)	1	——	3	—	6
14.674	THE LABOR MOVEMENT: THEORIES AND HISTORIES *Siegel*	14.61 or 14.63	G(A)	1 or 2	Elective	3	—	6
14.681	SEMINAR IN PERSONNEL ADMINISTRATION *Pigors*	14.61	G(A)	1	Elective	3	—	6
14.682	SEMINAR IN PERSONNEL ADMINISTRATION *Pigors*	14.681	G(A)	2	Elective	3	—	6
14.691	RESEARCH SEMINAR IN INDUSTRIAL RELATIONS *Myers*	14.671 or 14.672	G(A)	1	Elective	3	—	6
14.692	RESEARCH SEMINAR IN INDUSTRIAL RELATIONS *Myers*	14.691	G(A)	2	Elective	3	—	6
14.693	COLLECTIVE BARGAINING AND UNION-MANAGEMENT COOPERATION *Lesieur*	14.61	G(A)	1	Elective	3	—	6
14.694	SEMINAR IN UNION-MANAGEMENT COOPERATION *Lesieur*	14.693	G(A)	2	Elective	3	—	6

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
14.70	INTRODUCTORY PSYCHOLOGY *Howes, Swets*	21.02	3	1, 2	Elective	3	—	5
14.71‡	PERSONALITY AND SOCIAL STRUCTURE ——	14.70	4	2	Elective	3	—	5
14.73	ORGANIZATION AND COMMUNICATION IN GROUPS *Gleicher*	21.02	3, 4	1, 2	Elective	3	—	5
14.75‡	EXPERIMENTAL PSYCHOLOGY ——	14.70	3, 4	2	Elective	3	—	5
14.77	PSYCHOLOGY OF LANGUAGE AND COMMUNICATION *Howes*	14.70	4	1	Elective	3	—	5
14.771‡	INTERPERSONAL RELATIONS SEMINAR ——	——	G	1	Elective	3	—	6
14.772	INDUSTRIAL SOCIOLOGY SEMINAR ——	14.771	G(A)	2	Elective	3	—	6
14.774	SOCIAL PSYCHOLOGY SEMINAR *R. W. Brown*	——	G(A)	1	Elective	3	—	6
14.79	LEARNING ——	14.70	4	2	Elective	3	—	5
14.791	READING SEMINAR IN SOCIAL SCIENCE ——	——	G(A)	1	Elective		★	
14.792	READING SEMINAR IN SOCIAL SCIENCE ——	——	G(A)	2	Elective		★	
14.81	PSYCHOLOGY OF PERCEPTION *Swets*	14.70	3, 4	1, 2	Elective	3	—	5
14.82	PSYCHOLOGY OF MOTIVATION ——	14.70	3, 4	1, 2	Elective	3	—	5
14.84	THEORIES OF PERSONALITY *R. W. Brown*	14.70	3, 4	2	Elective	3	—	5
14.85	SOCIAL PSYCHOLOGY *R. W. Brown*	14.70	3, 4	1	Elective	3	—	5
14.86	BEHAVIOR IN GROUPS *M. E. Shaw*	14.70	3, 4	1	Elective	3	—	5
14.87	MASS COMMUNICATION *R. W. Brown*	14.70	3, 4	2	Elective	3	—	5
14.88	ADVANCED PSYCHOLOGY SEMINAR *Staff*	14.70 and any two subjects in Psychology	3, 4	2	Elective	3	—	5
14.901	CONCEPT FORMATION AND RESEARCH TECHNIQUE IN POLITICAL BEHAVIOR *Lerner*	——	G	1	Elective	3	—	6
14.902	THEORY OF POLITICAL PROCESSES ——	14.901	G	2	Elective	3	—	6
14.91	THE AMERICAN POLITICAL PROCESS *Tillman*	21.02	2 3	2 1, 2	XIV-A(b), XIV-B(b) Elective	3	—	5
14.92	COMPARATIVE POLITICAL AND ECONOMIC SYSTEMS *Totten*	21.04	3	2	Elective	3	—	5
14.93	SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS *Bursey*	14.91 or 14.92	4	1	Elective	3	—	5
14.94	GOVERNMENT, POLITICS, AND TECHNOLOGY *R. C. Wood*	14.91 or 14.92	3, 4	2	Elective	3	—	5
14.941	GOVERNMENT AND PUBLIC ADMINISTRATION *R. C. Wood*	——	G	1	Elective	3	—	6
14.942	METROPOLITANISM, FEDERALISM, AND TECHNOLOGICAL CHANGE *R. C. Wood*	14.93 or 14.941	G(A)	2	Elective	3	—	6
14.95	POLITICS, SOCIETY, AND POLICY MAKING *Pool*	14.01 or 14.51 or 14.91 or 21.41 or 21.42	3, 4	1	Elective	3	—	5
14.951‡	BEHAVIORAL FACTORS IN INTERNATIONAL POLITICS	14.58 or 14.95	G(A)	2	Elective	3	—	6
14.953	MASS MEDIA AND COMMUNICATION SYSTEMS *Lerner*	——	G	1	Elective	3	—	6
14.954	METHODS OF COMMUNICATION RESEARCH *Lerner*	14.953	G(A)	2	Elective	3	—	6

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
14.956	PUBLIC OPINION AND PROPAGANDA *Pool*	14.77	G	2	Elective	3	—	6
14.957	RESEARCH SEMINAR IN INTERNATIONAL COMMUNICATION *Pool*	——	G(A)	1	Elective	2	—	4
14.958‡	RESEARCH SEMINAR IN INTERNATIONAL COMMUNICATION ——	——	G(A)	2	Elective	2	—	4
14.96‡	INFLUENCES ON POLICY DECISIONS ——	14.95	4	2	Elective	3	—	5
14.961	PERSONALITY, SOCIETY AND POLITICS *Erikson*	14.774	G(A)	1	Elective	3	—	6
14.962	IDENTITY AND IDEOLOGY *Erikson*	14.961	G(A)	2	Elective	3	—	6
14.97	POLITICAL SCIENCE SEMINAR *Padelford*	14.53 or 14.57 or 14.93 or 14.96	4	1	XIV-A(b), XIV-B(b)	3	—	5
14.98	POLITICAL SCIENCE SEMINAR *Padelford*	14.97	4	2	XIV-A(b), XIV-B(b)	3	—	5

15.

Industrial Management

15.01	INDUSTRIAL MANAGEMENT I *Alexander*	*14.01*	2	2	XV	3	—	6
15.02	INDUSTRIAL MANAGEMENT II *Durand*	M12	3	1	XV	3	—	6
15.032	SAMPLING OF HUMAN POPULATIONS *Durand*	14.381	G(A)	2	Elective	3	—	6
15.11	INTRODUCTION TO INDUSTRIAL MANAGEMENT *Moore*	14.01	4	1, 2	Elective	3	—	6
15.17	HISTORICAL STUDIES IN INNOVATION *Morison*	15.201	G(A)	2	Elective	3	—	6
15.18	ACCOUNTING AND PRODUCTION *T. M. Hill, Goetz*	——	G	S	——	5	—	10
15.183	STRUCTURE OF AMERICAN LAW AND BUSINESS ENVIRONMENT *Krebs, Morison*	15.18	G(A)	1	——	3	—	6
15.185	MANAGEMENT PROBLEMS *Tallman, Goetz*	15.18	G(A)	1	——	3	—	6
15.201	PROBLEMS IN AMERICAN POLITICAL ECONOMY *Letwin*	——	G	1	——	3	—	6
15.30	PERSONNEL ADMINISTRATION *Pigors*	*14.01*	3	2	XV	3	—	6
15.312	LABOR-MANAGEMENT RELATIONS *D. V. Brown*	——	G	2	——	3	—	6

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
15.322	PROBLEMS IN LABOR RELATIONS AND PERSONNEL ADMINISTRATION *Johnson*	15.312	G(A)	2	Elective	3	—	6
15.362	SEMINAR IN GROUP BEHAVIOR *M. E. Shaw*	——	G(A)	2	Elective	3	—	6
15.371	SOCIAL PSYCHOLOGY *Schein*	——	G	1	——	3	—	6
15.372	LABORATORY IN INDUSTRIAL BEHAVIOR *McGregor*	14.662	G(A)	2	——	3	—	6
15.373	MANAGERIAL BEHAVIOR IN INDUSTRIAL ORGANIZATIONS *McGregor*	15.371	G(A)	1	Elective	2	—	7
15.41	FINANCIAL MANAGEMENT *Kuh*	15.50	3 4	2 1	XV Elective	3	—	6
15.412	FINANCIAL MANAGEMENT *Kuh*	15.501	G	2	——	3	—	6
15.42	INVESTMENTS ——	15.41	4	2	Elective	3	—	6
15.452	TAXATION AND BUSINESS MANAGEMENT *E. Shapiro*	15.412	G(A)	2	Elective	3	—	6
15.46	FINANCIAL ADMINISTRATION OF INDUSTRY *E. Shapiro*	15.412	G(A)	1	Elective	3	—	6
15.50	ACCOUNTING *T. M. Hill*	14.01	3 3	1 2	XV Elective	3	2	4
15.501	MANAGERIAL ACCOUNTING *T. M. Hill*	——	G	1	——	4	—	8
15.51	INDUSTRIAL ACCOUNTING *Shillinglaw*	15.50 or 15.52	4	2	Elective	3	—	6
15.511	ECONOMICS OF THE FIRM *Alexander*	——	G	1	——	3	—	6
15.52	BUSINESS AND NATIONAL INCOME ACCOUNTING *Gordon*	14.01	3	2	XIV-A(a), XIV-B(a)	3	—	5
15.531	PROBLEMS IN ACCOUNTING CONTROL *Gordon*	15.501, 15.511	G(A)	1	Elective	3	—	6
15.542	MANAGEMENT INFORMATION SYSTEMS *Gregory*	15.501 or 15.52	G(A)	2	Elective	3	—	6
15.581	DYNAMIC MODELS AND THE FIRM *Vance*	15.712, M22	G(A)	1	Elective	3	—	6
15.591	ADVANCED TREATMENT OF TECHNIQUES IN SCIENTIFIC MANAGEMENT ——	14.381	G(A)	1	Elective	3	—	6
15.592	ADVANCED TREATMENT OF TECHNIQUES IN SCIENTIFIC MANAGEMENT ——	14.381	G(A)	2	Elective	3	—	6
15.61	BUSINESS LAW *Macmillan*	*14.01*	4	1, 2	Elective	3	—	6
15.65	LABOR LAW *Jacks*	*14.01*	4	2	Elective	3	—	6
15.66	FUNDAMENTAL LEGAL PRINCIPLES *Krebs*	15.312, 15.412 15.712, 15.812T	G(A)	2	Elective	3	—	6
15.71	PRODUCTION MANAGEMENT *Bowman, Goetz*	15.02	3	2	XV	3	—	6
15.712	PRODUCTION MANAGEMENT *Bowman*	14.381, 15.511	G	2	——	3	—	6
15.72	INDUSTRIAL STANDARDIZATION *Moore*	14.01	4	1	Elective	3	—	6
15.73	MANAGEMENT LABORATORY *Goodwin*	14.01	4	1, 2	Elective	3	3	3
15.74	ADVANCED MANAGEMENT LABORATORY *Goodwin*	15.73	4	2	Elective	3	3	3
15.741	ADVANCED MANAGEMENT LABORATORY *Goodwin*	15.712	G(A)	1	Elective	3	3	3
15.75	MANUFACTURING ANALYSIS *Goetz*	15.71	4	1	Elective	3	—	6
15.751	MANUFACTURING ANALYSIS *Goetz*	15.712	G(A)	1	Elective	3	—	6
15.781	STUDIES IN MANUFACTURING ANALYSIS *Bowman*	15.712	G(A)	1	Elective	4	—	5

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
15.792T	MANUFACTURING DECISIONS SEMINAR *Bowman*	15.712	G(A)	2	Elective	3	—	6
15.81	MARKETING *Tallman*	15.01	3	1	XV	3	—	6
			3	2	Elective			
15.812T	MARKETING *P. S. King*	——	G	2	——	4	—	5
15.82	MARKETING MANAGEMENT *P. S. King*	15.81	4	2	Elective	3	—	6
15.821	MARKETING POLICY AND ADMINISTRATION *Cunningham*	15.812T	G(A)	2	Elective	3	—	6
15.83	MARKETING RESEARCH *Cunningham*	15.81	4	1	Elective	3	—	6
15.832T	DEMAND ANALYSIS AND MARKETING RESEARCH *Chow, Cunningham*	14.381, 15.812T	G(A)	2	Elective	3	—	6
15.86	PRODUCT PLANNING AND DEVELOPMENT *Tallman*	15.812T	G(A)	2	Elective	3	—	6
15.90	ORGANIZATION *Haberstroh, Rubenstein*	15.30, 15.41, 15.71, 15.81	4	1	Elective	3	—	6
15.91	ADMINISTRATIVE POLICY *Hudgins*	15.30, 15.41, 15.71, 15.81	4	2	Elective	3	—	6
15.92	ORGANIZATION *Rubenstein*	15.312, 15.412, 15.712, 15.812T	G(A)	1	Elective	3	—	6
15.93	ADMINISTRATIVE POLICY *Hudgins*	15.312, 15.412, 15.712, 15.812T	G(A)	2	Elective	3	—	6
15.942	ADMINISTRATIVE POLICY SEMINAR *Hudgins*	15.18	G(A)	1	——	3	—	6
15.951	SPECIAL STUDIES IN MANAGEMENT *T. M. Hill*	——	G(A)	1	Elective		★	
15.952	SPECIAL STUDIES IN MANAGEMENT *T. M. Hill*	——	G(A)	2	Elective		★	
15.96	ADMINISTRATIVE THEORY AND PRACTICE *Schell*	15.312, 15.412, 15.712, 15.812T	G(A)	1	Elective	3	—	6
15.971T	SEMINAR IN RESEARCH MANAGEMENT *Rubenstein*	——	G	1	Elective	2	—	7
15.972	MANAGEMENT OF RESEARCH AND DEVELOPMENT *Rubenstein*	——	G	2	Elective	3	—	6
15.98	SEMINAR IN ADMINISTRATION *Johnson*	15.18	G(A)	1	——	3	—	6
15.99	SEMINAR IN ADMINISTRATION *Johnson*	15.18	G(A)	2	——	3	—	6

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16.

Aeronautical Engineering

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
16.00	AEROMECHANICS *Halfman*	2.001, M21	2	2	XVI	3	1	5
16.01	AEROMECHANICS *Halfman*	16.00, *M22*	3	S	XVI-B	4	1	5
			3	1	XVI			
16.02	AERODYNAMICS *Ashley*	2.40, 16.01	3	2	XVI, XVI-B	4	2	6
16.03	PRINCIPLES OF AERODYNAMICS *Ashley, Bicknell, Trilling*	16.02	G	1	Elective	4	—	5
16.04	AERODYNAMICS — VISCOUS FLUIDS *Bicknell*	16.02	G(A)	2	Elective	3	—	6
16.051	AERODYNAMICS OF COMPRESSIBLE FLUIDS I *Baron*	16.02, *M351*	G(A)	1	Elective	3	—	9
16.052	AERODYNAMICS OF COMPRESSIBLE FLUIDS II *Baron*	16.051	G(A)	2	Elective	3	—	9
16.061	STEADY AND UNSTEADY POTENTIAL FLOWS *Ashley, Trilling*	16.051	G(A)	1	Elective	3	—	9
16.062	STEADY AND UNSTEADY POTENTIAL FLOWS *Ashley, Trilling*	16.051	G(A)	2	Elective	3	—	9
16.063‡	VISCOUS FLOWS *Finston*	16.052	G(A)	2	Elective	3	—	9
16.064	THERMAL EFFECTS *Finston*	16.04 or 16.052 or 16.063	G(A)	1	Elective	3	—	9
16.065	PHYSICS OF HIGH SPEED GAS FLOWS *Trilling*	16.051	G(A)	1	Elective	3	—	9
16.066	HYPERSONIC FLOW *Trilling*	16.051	G(A)	2	Elective	3	—	9
16.07	AERODYNAMICS AND DYNAMICS OF MISSILES *Ashley*	16.02, 16.13	G(A)	1	Elective	3	—	6
16.10‡	APPLIED AERODYNAMICS *Ober*	*16.01*, 16.82	3	1	Elective	4	—	8
16.105	APPLIED AERODYNAMICS *Ober*	16.02, 16.10	G(A)	1 or 2	Elective	3	—	6
16.11	AIRCRAFT PERFORMANCE AND STABILITY *Ober*	*16.01*, 16.82	3	1	XVI	4	—	8
			4	S	XVI-B			
16.13	AIRPLANE STABILITY AND CONTROL *Bicknell*	16.01, 16.10	4	1	Elective	3	—	6
16.15	ADVANCED STABILITY AND CONTROL OF AIRCRAFT *Larrabee*	16.11 or 16.13	G(A)	1	Elective	3	—	6
16.20	STRUCTURES *Bisplinghoff, Sandorff*	2.37	3	2	XVI	4	—	6
			4	S	XVI-B			
16.21	STRUCTURAL ANALYSES *Dugundji*	16.20	4	1	Elective	4	—	6
16.22	SHELL STRUCTURES *Bisplinghoff*	16.21	G(A)	2	Elective	3	—	6
16.23‡	AIRCRAFT STRUCTURAL DESIGN *Sandorff*	16.20	4	1	Elective	3	—	5
16.25	ADVANCED STRUCTURES *Pian*	16.21	G(A)	1	Elective	3	—	6
16.30	PRINCIPLES OF AUTOMATIC CONTROL *McKay*	16.01	3	2	XVI, XVI-B	3	—	9
			4	1	XVI (58–59), XVI-B (58–59)			
16.302	AERONAUTICAL SYSTEMS *McKay*	16.30	4	1	XVI (not 58–59), XVI-B (not 58–59)	3	—	6
			4	2	Elective			
16.31	PRINCIPLES OF INSTRUMENTATION AND CONTROL *Li*	2.003 or 2.07 or 6.02 or 16.01	G(A)	1	Elective	3	—	9

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Drawv	Prep
16.32	PRINCIPLES OF INSTRUMENTATION AND CONTROL *Li*	16.31	G(A)	2	Elective	3	—	9
16.33	INSTRUMENTATION AND CONTROL LABORATORY *Li*	*16.31*	G(A)	1	Elective	2	2	6
16.35	SPECIAL PROBLEMS IN INSTRUMENTATION AND CONTROL *McKay*	16.32	G(A)	1 or 2	Elective		★	
16.36	DYNAMIC MEASUREMENTS *Li*	2.003 or 2.07 or 13.73 or 16.31	G(A)	2	Elective	2	2	6
16.37	RANDOM PROCESSES IN AUTOMATIC CONTROL *Vander Velde*	16.30, M351	G(A)	2	Elective	3	—	9
16.38	CONTROL SYSTEMS COMPONENTS *R. K. Mueller*	6.18	G(A)	2	Elective	3	—	6
16.39	VECTOR KINEMATICS AND GYROSCOPIC INSTRUMENT THEORY *Wrigley*	2.07 or 8.71 or 16.01	G(A)	1	Elective	3	—	6
16.392	INERTIAL GUIDANCE *Wrigley*	16.39	G(A)	2	Elective	3	—	6
16.40	AUTOMATIC CONTROL OF AIRCRAFT AND MISSILES *Whitaker*	16.13, 16.30, 16.39	G(A)	2	Elective	3	—	6
16.411	INTRODUCTION TO WEAPONS SYSTEMS *Markey*	*16.39*	G(RA)	1	——	4	—	8
16.412	INTRODUCTION TO WEAPONS SYSTEMS *Markey*	*16.39*	G(RA)	1	——	4	—	8
16.421	WEAPONS SYSTEMS *Wrigley, Markey*	16.411	G(RA)	2	——	4	—	8
16.422	INTRODUCTION TO WEAPONS SYSTEMS *Markey*	16.412	G(RA)	2	——	4	—	8
16.43	WEAPONS SYSTEMS LABORATORY *R. K. Mueller*	*16.45*	G(RA)	1	——	1	3	5
16.44	WEAPONS SYSTEMS LABORATORY *R. K. Mueller*	*16.421*	G(RA)	2	——	1	3	5
16.45	WEAPONS SYSTEMS *Wrigley*	16.422	G(RA)	1	——	3	—	9
16.46	ADVANCED WEAPONS SYSTEMS *Wrigley*	16.45	G(RA)	2	——	3	—	6
16.47	ROCKET PROPELLED MISSILES *Stever, Trilling*	16.11 or 16.13	G(A)	1	Elective	3	—	6
16.48	STRUCTURAL PROBLEMS IN WEAPONS *Dugundji*	2.001, 16.422	G(RA)	2	——	3	—	9
16.49	SPECIAL PROBLEMS IN WEAPONS SYSTEMS *Wrigley*	16.421 or 16.422	G(RA)	1 or 2	——		★	
16.50	VERTICAL TAKE-OFF AIRCRAFT *Miller*	16.10 and 16.13; or 16.11	G(A)	1	Elective	3	—	6
16.51	ADVANCED VERTICAL TAKE-OFF AIRCRAFT *Miller*	16.50	G(A)	2	Elective	3	—	6
16.53	AIRCRAFT PROPULSION *E. S. Taylor*	2.25 or *16.02;* 2.40	3	2	XVI, XVI-B	3	—	6
16.56T	ROCKET ENGINES *E. S. Taylor*	2.213; or 2.252 and 16.53; or 2.48T	G(A)	2	Elective	3	—	9
16.60	ADVANCED AERONAUTICAL PROBLEMS *Staff*	16.13 or 16.20	G(A)	1 or 2	Elective		★	
16.605	AERONAUTICAL PROBLEMS *Staff*	——	4	1 or 2	Elective		★	

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec	Lab Rec	Draw	Prep
16.61	AERONAUTICS SEMINAR ——	——	G(A)	1 or 2	——	2	—		2
16.65	AERONAUTICAL ENGINEERING LABORATORY *Ober*	16.13, 16.20, *16.30*	4	1	Elective	3	3		6
16.70	AIRCRAFT DETAIL DESIGN *Bentley*	——	2	1	XVI	3	5		0
16.71	AERONAUTICAL ENGINEERING *Koppen*	16.13, 16.20, 16.70	4	1	XVI (58–59), XVI-B (58–59)	0	10		0
16.71T ‡	AERONAUTICAL ENGINEERING *Koppen*	16.11, 16.20, 16.70	4	1	XVI, XVI-B	2	10		0
16.72	AERONAUTICAL ENGINEERING *Koppen*	16.30, 16.71	4	2	XVI, XVI-B	0	9		3
16.74	ADVANCED DESIGN *Miller*	16.105, 16.72	G(A)	1	Elective	2	6		4
16.76	ORBITAL VEHICLES *Sandorff*	M22	4	2	Elective	3	—		6
16.81	GENERAL AERONAUTICS *Markham*	M21	4	1 or 2	Elective	3	—		6
16.82	INTRODUCTORY AERONAUTICAL ENGINEERING *Markham*	*M21*	2	1	XVI	3	—		3
16.851	INDUSTRIAL PRACTICE *Markham*	——	3	S	XVI-B	40 h.p.w.			
16.852	INDUSTRIAL PRACTICE *Markham*	——	3	1	XVI-B	40 h.p.w.			
16.91	AEROELASTICITY *Mollö-Christensen*	16.02	G(A)	1	Elective	3	—		6
16.92	ADVANCED AEROELASTICITY *Ashley*	16.91	G(A)	2	Elective	3	—		9
16.93	AEROELASTICITY LABORATORY *Halfman*	*16.91*	G(A)	1	Elective	2	2		2
16.94	DYNAMICS OF STRUCTURES *Pian*	16.21	G(A)	2	Elective	3	—		9

17.

Building Engineering and Construction

17.401	ADVANCED JOB MANAGEMENT *McCreery*	1.922	G(A)	1	Elective	3	—		6
17.402	CONSTRUCTION MANAGEMENT SEMINAR *McCreery*	1.921, 1.922	G(A)	2	Elective	3	—		6
17.41	BUILDING MANAGEMENT *McCreery*	——	G(A)	1	Elective	3	—		6
17.44	SPECIFICATIONS *McCreery, Heger*	1.43, 1.921	G(A)	2	Elective	3	—		6
17.531	ADVANCED REINFORCED CONCRETE DESIGN *H. Simpson*	1.42	G(A)	1	Elective	3	—		6
17.532	ADVANCED REINFORCED CONCRETE DESIGN *H. Simpson*	17.531	G(A)	2	Elective	3	—		6
17.542	ADVANCED STRUCTURAL STEEL DESIGN *H. Simpson, Heger*	1.42, 1.44	G(A)	2	Elective	3	—		6
17.73	MATERIALS — WOOD, PLASTICS, FABRICS *Dietz*	8.02	3	2	IV-A	3	—		3
17.74	MATERIALS — MASONRY AND METALS *J. A. Murray, McGarry*	8.03	4	2	IV-A	3	2		4

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
17.741	ENGINEERING PROPERTIES OF PLASTICS *Dietz*	1.41, 2.002	4	1	Elective	2	—	4
17.742	ENGINEERING LAMINATES *Dietz, McGarry*	1.41, 2.002	G(A)	2	Elective	3	—	6
17.76	RESEARCH IN ORGANIC STRUCTURAL MATERIALS *McGarry*	17.741	G(A)	1 or 2	Elective		★	
17.771	CEMENTITIOUS MATERIALS *J. A. Murray*	1.42, 17.74	4	1	Elective	2	—	4
17.772	CONCRETE *J. A. Murray*	17.771	G(A)	2	Elective	3	—	6
17.78	RESEARCH IN CEMENTITIOUS MATERIALS *J. A. Murray*	17.772	G(A)	1 or 2	Elective		★	

19.

Meteorology

19.003	ELEMENTARY METEOROLOGY I *Wurtele*	——	1	1, 2	Elective	3	—	3
19.01	DESCRIPTIVE METEOROLOGY I *Willett*	——	3	1	Elective	3	—	6
19.02	DESCRIPTIVE METEOROLOGY II *Willett*	19.01	3	2	Elective	3	—	6
19.14	LONG-RANGE WEATHER FORECASTING *Willett*	19.44	G(A)	1	Elective	3	8	6
19.21	METEOROLOGICAL OBSERVATIONS *Keily*	8.02	3	1	Elective	1	3	2
19.22	METEOROLOGICAL INSTRUMENTS *Keily*	19.02	G(A)	2	Elective	2	4	6
19.23	MICROMETEOROLOGICAL INSTRUMENTATION *Keily*	19.21	G(A)	1	Elective	2	2	4
19.30	GENERAL CLIMATOLOGY *J. M. Austin*	——	3	2	Elective	2	—	4
19.32	MICROCLIMATOLOGY *J. M. Austin*	8.02, M12	G	1	Elective	2	—	4
19.33	APPLIED CLIMATOLOGY *J. M. Austin*	19.30	G(A)	2	Elective	3	—	6
19.44	SYNOPTIC METEOROLOGY I *Sanders*	19.51, 19.601	4	2	XIX (58–59)	3	—	6
19.45	SYNOPTIC METEOROLOGY II *J. M. Austin*	19.44	G(A)	1	Elective	3	—	6
19.46	NUMERICAL WEATHER PREDICTION *Phillips*	M351	G(A)	2	Elective	3	—	6
19.51	SYNOPTIC LABORATORY I *Sanders*	19.02	4	1	XIX (58–59)	0	15	0

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
19.52	SYNOPTIC LABORATORY II *Sanders*	19.51	4	2	Elective	0	15	0
19.53	SYNOPTIC LABORATORY III *Wurtele*	19.44, 19.51	G(A)	2	Elective	0	15	0
19.601	INTRODUCTION TO THEORETICAL METEOROLOGY *Lorenz*	8.02, M12	4	1	XIX (58–59)	3	—	6
19.62	DYNAMIC METEOROLOGY I *Lorenz*	19.601	4	2	XIX (58–59)	3	—	6
19.64	DYNAMIC METEOROLOGY II *Starr*	19.62	G(A)	1	Elective	3	—	9
19.67	PLANETARY FLUID DYNAMICS *Charney*	*M421*	G(A)	2	Elective	3	—	9
19.70	ELEMENTARY PHYSICS OF THE ATMOSPHERE *Keily*	8.03, M12	3	1	Elective	2	—	4
19.71	RADAR METEOROLOGY *P. M. Austin*	8.03, 19.02	G(A)	1	Elective	2	1	4
19.72	PHYSICAL METEOROLOGY *Houghton*	8.04, M21	G(A)	2	Elective	3	—	6
19.83	OCEANOGRAPHY *Houghton*	8.02, M21	4	1	XIX (58–59)	2	—	4
19.91	METEOROLOGICAL SEMINAR I *Houghton*	19.44, 19.62	G(A)	1	Elective	2	—	4
19.911	METEOROLOGICAL SEMINAR I *Houghton*	19.44, 19.62	G(A)	1	Elective	1	—	2
19.912	METEOROLOGICAL SEMINAR II *Houghton*	19.911	G(A)	2	Elective	1	—	2
19.94	SPECIAL PROBLEMS IN METEOROLOGY *Staff*	19.02	G	1 or 2	Elective		★	
19.95	SPECIAL PROBLEMS IN METEOROLOGY *Staff*	19.44, 19.62	G(A)	1 or 2	Elective		★	

20.

Food Technology

20.00	MAN'S FOOD *Staff*	——	1	1	Elective	3	—	3
20.01	CHEMISTRY AND TECHNOLOGY OF FOOD SUPPLIES I *Charm*	5.41	3	1	XX (58–59)	3	4	3
20.01T	CHEMISTRY AND TECHNOLOGY OF FOOD SUPPLIES I *Charm*	5.41	2	2	XX	3	4	2
20.02	CHEMISTRY AND TECHNOLOGY OF FOOD SUPPLIES II *Charm*	20.01	3 3	1 2	XX (not 58–59) XX (58–59)	3	4	3
20.11	TECHNOLOGY OF FOOD PRODUCTS *Nickerson*	20.02	3 4	2 1	XX (not 58–59) XX (58–60)	2	4	4
20.12	TECHNOLOGY OF FOOD PRODUCTS *Nickerson*	20.11	4 4	1 2	XX (not 58–60) XX (58–60)	2	4	4
20.13	CHEMICAL ENGINEERING FOOD APPLICATIONS *Charm*	5.61	4	1	XX (58–60), XX-B (58–60)	4	—	6
20.13T	‡CHEMICAL ENGINEERING FOOD APPLICATIONS *Charm*	*5.61*	3	1	XX, XX-B	4	3	6
20.14	CHEMICAL ENGINEERING FOOD APPLICATIONS *Charm*	20.13	3 4	2 2	XX (not 58–59), XX-B (not 58–59) XX (58–60), XX-B (58–60)	4	2	4
20.15	FOOD ENGINEERING *Charm, Fuld*	2.602, 20.14	4	2	Elective	1	4	2
20.21	FLAVOR EVALUATION *Proctor*	20.12, 20.32	G(A)	1	Elective	2	2	4
20.22	FOOD ACCEPTANCE *Proctor*	20.12, 20.32	G(A)	2	Elective	2	2	4

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
20.32	CHEMISTRY OF NUTRITION *R. S. Harris*	5.41, *7.05*	4	1	XX (58–60), XX-B (58–60)	2	2	2
20.32T ‡	CHEMISTRY OF NUTRITION *R. S. Harris*	5.41, *7.05*	4	1	XX, XX-B	3	4	3
20.322	CHEMISTRY OF NUTRITION LABORATORY *R. S. Harris*	5.41, 7.05	4	2	Elective	1	4	0
20.34	APPLIED NUTRITION *R. S. Harris*	20.32	G(A)	2	Elective	2	2	4
20.36	ADVANCED NUTRITION *R. S. Harris*	20.32	G(A)	2	Elective	3	3	2
20.38	NUTRITIONAL EVALUATION OF FOOD PROCESSES *R. S. Harris*	20.12, 20.32	G(A)	1 or 2	Elective	3	—	3
20.41	BACTERIOLOGY I *Dunn*	7.01	2	2	XX, XX-B	3	4	3
20.42	INDUSTRIAL MICROBIOLOGY *Dunn*	20.41	3	1	XX (58–59), XX-B	2	4	4
20.43	ADVANCED INDUSTRIAL MICROBIOLOGY *Dunn*	20.42	G(A)	1	Elective	2	4	4
20.44	ADVANCED INDUSTRIAL MICROBIOLOGY *Dunn*	20.43	G(A)	2	Elective	2	4	4
20.45 ‡	BACTERIOLOGY II *Dunn*	20.41	4	2	XX, XX-B	2	4	2
20.46	BACTERIOLOGY OF FOODS *Nickerson*	7.05,20.42	G(A)	2	Elective	2	4	2
20.47	BIOCHEMICAL ENGINEERING *Fuld*	20.42	4	1	XX-B	2	6	2
20.48	BIOCHEMICAL ENGINEERING *Fuld*	20.47	4	2	XX-B	2	6	2
20.51	ADVANCED FOOD TECHNOLOGY *Proctor*	20.12	G(A)	1	Elective	2	6	4
20.52	ADVANCED FOOD TECHNOLOGY *Proctor*	20.51	G(A)	2	Elective	2	4	4
20.53	FOOD APPLICATIONS OF IONIZING RADIATIONS *Proctor, Goldblith*	8.04, 20.12	G(A)	1	Elective	2	—	4
20.531	FOOD APPLICATIONS OF IONIZING RADIATIONS LABORATORY *Goldblith*	20.53	G(A)	2	Elective	1	3	2
20.56	NEW FOOD PRODUCT EVALUATION *Proctor, Goldblith*	20.12	4	2	Elective	2	4	3
20.61	FOOD TECHNOLOGY SEMINAR *Proctor*	20.12	G(A)	1	XX, XX-B	2	—	2
20.62	FOOD TECHNOLOGY SEMINAR *Proctor*	20.61	G(A)	2	XX, XX-B	2	—	2
20.63	FOOD TECHNOLOGY SEMINAR *Proctor*	20.62	G(A)	1	XX, XX-B	2	—	2
20.64	FOOD TECHNOLOGY SEMINAR *Proctor*	20.63	G(A)	2	XX, XX-B	2	—	2
20.71	RESEARCH PROBLEMS *Staff*	——	G(A)	1	Elective		★	
20.72	RESEARCH PROBLEMS *Staff*	——	G(A)	2	Elective		★	
20.83	SELECTED TOPICS IN FOOD TECHNOLOGY *Staff*	——	G(A)	1	Elective		★	
20.84	SELECTED TOPICS IN FOOD TECHNOLOGY *Staff*	——	G(A)	2	Elective		★	
20.85	RESEARCH MANAGEMENT IN THE FOOD AND DRUG INDUSTRIES *C. N. Frey*	——	G(A)	1	Elective	2	—	2
20.86	RESEARCH MANAGEMENT IN THE FOOD AND DRUG INDUSTRIES *C. N. Frey*	——	G(A)	2	Elective	2	—	2
20.91	FOOD INDUSTRY SEMINAR *Proctor*	——	G(A)	1	Elective	2	—	2
20.92	FOOD INDUSTRY SEMINAR *Proctor*	——	G(A)	2	Elective	2	—	2
20.93	FOOD INDUSTRY SEMINAR *Proctor*	20.92	G(A)	1	Elective	2	—	2
20.94	FOOD INDUSTRY SEMINAR *Proctor*	20.92	G(A)	2	Elective	2	—	2

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21.

Humanities

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY *Stahlman*	——	1	1, 2	Elective	2	—	4
21.002	ENGLISH COMPOSITION *Urbach*	——	1	1, 2	Elective	2	—	4
21.003	COMPOSITION WORKSHOP *Rathbone*	——	3, 4	1 or 2	Elective		★	
21.005	PUBLIC SPEAKING	—— ——	1	1	Elective	3	—	3
21.006	PUBLIC SPEAKING	—— 21.005	1	2	Elective	3	—	3
21.01	FOUNDATIONS OF WESTERN CIVILIZATION *Niehaus*	——	1	1	All Courses	3	—	5
21.02	FOUNDATIONS OF WESTERN CIVILIZATION *Niehaus*	21.01	1	2	All Courses	3	—	5
21.03	HUMANITIES							
	THE UNITED STATES: MEN AND ISSUES *Mitchell*	21.02	2	1	All Courses	3	—	5
	MODERN WESTERN IDEAS AND VALUES *Mazlish*	21.02	2	1	All Courses	3	—	5
21.04	HUMANITIES							
	THE UNITED STATES: MEN AND ISSUES *Mitchell*	21.03	2	2	All Courses	3	—	5
	MODERN WESTERN IDEAS AND VALUES *Mazlish*	21.03	2	2	All Courses	3	—	5
21.05	HUMANITIES SEMINAR *Stahlman*	——	4	1	XXI-A, XXI-B, XXI-C	3	—	6
21.06	HUMANITIES SEMINAR *Stahlman*	——	4	2	XXI-A, XXI-B, XXI-C	1	—	4
21.07	PREPARATION AND PRESENTATION OF RESEARCH PAPER *Rathbone*	——	3, 4	1, 2	Elective	1	—	4
21.08	SEMINAR IN TECHNICAL WRITING *Rathbone*	----	3, 4	1 or 2	Elective	2	—	4
21.11	INTRODUCTION TO LITERATURE *W. C. Greene*	21.04	3, 4	1 or 2	Elective	3	—	5
21.12	LITERARY THEORY *W. C. Greene*	21.11	2	2	Elective	3	—	5
21.13	THE EPIC *W. C. Greene*	21.11	3, 4	1	Elective	3	—	5
21.15	COMEDY IN THE THEATRE *Everingham*	21.11	3, 4	1	Elective	3	—	5
21.16	TRAGEDY AND MODERN DRAMA *Everingham*	21.11	3, 4	2	Elective	3	—	5
21.17	SHAKESPEARE *Holland*	21.11	3, 4	1	Elective	3	—	5
21.18	NON-WESTERN LITERATURE *W. C. Greene*	21.11	3, 4	2	Elective	3	—	5
21.19	MAJOR BRITISH AND CONTINENTAL WRITERS OF THE 19TH AND EARLY 20TH CENTURIES *Lamson*	21.11	3, 4	1	Elective	3	—	5
21.20	THE BIBLE *Reiche*	21.11	3, 4	2	Elective	3	—	5
21.21‡	DOSTOEVSKY, TOLSTOI AND MODERN RUSSIAN LITERATURE *MacMaster*	21.11	3, 4	1	Elective	3	—	5
21.22	NATURE OF POETRY *T. Wood*	21.11	3, 4	2	Elective	3	—	5
21.24	THE COMIC SENSIBILITY *Holland*	21.11	3, 4	2	Elective	3	—	5
21.25	THE MODERN NOVEL *C. Collins*	21.11	3, 4	1, 2	Elective	3	—	5

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
21.26	MAJOR WRITERS OF THE ENGLISH RENAISSANCE *Lamson*	21.11	3, 4	2	Elective	3	—	5
21.31	AMERICAN FOLKLORE *T. Wood*	21.11	3, 4	1	Elective	3	—	5
21.33	NINETEENTH-CENTURY AMERICAN LITERATURE *C. Collins*	21.11	3, 4	1	Elective	3	—	5
21.34	TWENTIETH-CENTURY AMERICAN LITERATURE *C. Collins*	21.11	3, 4	2	Elective	3	—	5
21.391	SPECIAL TOPICS IN LITERATURE *Staff*	Any two subjects in Literature	4, G	1	Elective	3	—	5
21.392	SPECIAL TOPICS IN LITERATURE *Staff*	Any two subjects in Literature	4, G	2	Elective	3	—	5
21.41	HISTORY AND THE HISTORIAN *Mitchell*	21.04	3, 4	1, 2	Elective	3	—	5
21.42	POLITICAL PROCESS IN INDUSTRIAL AMERICA *Lichterman*	21.04	3, 4	2	Elective	3	—	5
21.43	GROWTH OF THE AMERICAN INDUSTRIAL ECONOMY *Chandler*	21.04	3, 4	1	Elective	3	—	5
21.44	CHANGING ROLE OF THE INDUSTRIAL LEADER *Chandler*	21.04	3, 4	2	Elective	3	—	5
21.45	AMERICAN FOREIGN POLICY IN ACTION *Lichterman*	21.04	4, G	1	Elective	3	—	5
21.46	RELIGIOUS THOUGHT AND AMERICAN SOCIETY *I. H. Bartlett*	21.04	3, 4	2	Elective	3	—	5
21.48	TECHNOLOGY AND ECONOMIC GROWTH *Rae*	21.04	3, 4	2	Elective	3	—	5
21.51	EUROPE — THE EXPANSION OF EUROPE *Mahoney*	21.04	3, 4	1	Elective	3	—	5
21.52‡	MODERN EUROPE — WAR, SOCIETY, AND THE STATE *Lockwood*	21.04	3, 4	2	Elective	3	—	5
21.54	RUSSIAN REVOLUTION AND THE SOVIET UNION *MacMaster*	21.04	3, 4	2	Elective	3	—	5
21.55	HISTORY OF ENGINEERING *Woodbury*	21.04	3, 4	1	Elective	3	—	5
21.56	HISTORY OF ENGINEERING *Woodbury*	21.04	3, 4	2	Elective	3	—	5
21.58	ART AND INDUSTRIAL CIVILIZATION *Bush-Brown*	21.04	3, 4	2	Elective	3	—	5
21.591	SPECIAL TOPICS IN HISTORY *Staff*	Any two subjects in History	4, G	1	Elective	3	—	5
21.592	SPECIAL TOPICS IN HISTORY *Staff*	Any two subjects in History	4, G	2	Elective	3	—	5
21.61	PHILOSOPHIC PROBLEMS AND SYSTEMS *Reiche*	21.04	3, 4	1	Elective	3	—	5
21.62	PHILOSOPHIC PROBLEMS AND SYSTEMS *Reiche*	21.04	3, 4	2	Elective	3	—	5
21.65	CLASSICAL PHILOSOPHY *Reiche*	21.04	3, 4	1	Elective	3	—	5
21.66	MAJOR RELIGIONS OF THE WEST *H. Smith*	21.04	3, 4	2	Elective	3	—	5
21.67	PHILOSOPHIES AND RELIGIONS OF THE EAST *H. Smith*	21.04	3, 4	1	Elective	3	—	5

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Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
21.69‡	PROBLEMS IN CONTEMPORARY PHILOSOPHY *Chomsky*	21.04	3, 4	1	Elective	3	—	5
21.71	PHILOSOPHY OF HISTORY *Mazlish*	Any two 21 subjects above 21.40	4	1	Elective	3	—	5
21.72	METAPHYSICS *H. Smith*	21.04	3, 4	2	Elective	3	—	5
21.73	NATURE OF MAN *H. Smith*	21.04	3, 4	1	Elective	3	—	5
21.74	PHILOSOPHY IN LITERATURE *I. Singer*	21.61 or 21.62 or 21.81 or 21.82	3, 4	2	Elective	3	—	5
21.75	ETHICAL THEORY ——	21.04	3, 4	1	Elective	3	—	5
21.76‡	SYMBOLIC LOGIC *Chomsky*	21.04	3, 4	2	Elective	3	—	5
21.81	SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS *de Santillana*	21.04	3	1	XXI-A, XXI-B, XXI-C	3	—	5
			3, 4	1	Elective			
21.82	SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT *de Santillana*	21.81	3	2	XXI-A, XXI-B, XXI-C	3	—	5
			3, 4	2	Elective			
21.83	PHILOSOPHY OF SCIENCE *de Santillana*	Any two 21 subjects above 21.40	4, G	1	Elective	3	—	5
21.84	TOPICS IN THE HISTORY AND PHILOSOPHY OF SCIENCE *de Santillana*	Any two 21 subjects above 21.40	4, G	2	Elective	3	—	5
21.891	SPECIAL TOPICS IN PHILOSOPHY *Staff*	Any two subjects in Philosophy	4, G	1	Elective	3	—	5
21.892	SPECIAL TOPICS IN PHILOSOPHY *Staff*	Any two subjects in Philosophy	4, G	2	Elective	3	—	5
21.91	INTRODUCTION TO MUSIC *Liepmann, G. Tucker, Levy*	21.04	3, 4	1, 2	Elective	3	—	5
21.92	WESTERN MUSIC FROM THE MIDDLE AGES TO PRESENT *Liepmann, G. Tucker*	21.91	3, 4	1, 2	Elective	3	—	5
21.94	TWENTIETH-CENTURY MUSIC *G. Tucker*	21.92	4	2	Elective	3	—	5
21.95	THE OPERA *G. Tucker*	21.92	4	1	Elective	3	—	5
21.96	STRING QUARTETS OF BEETHOVEN *Liepmann*	21.92	4	2	Elective	3	—	5
21.991	SEMINAR IN MUSIC *Levy*	21.92	4	1	Elective	3	—	5
21.992	SEMINAR IN MUSIC *Levy*	21.92	4	2	Elective	3	—	5

22.

Nuclear Engineering

22.01	ENGINEERING PRACTICE SCHOOL AT OAK RIDGE *Reid*	——	G(A)	1, 2	Elective	0	16	0
22.02	ENGINEERING PRACTICE SCHOOL AT OAK RIDGE *Reid*	22.01	G(A)	1, 2	Elective	0	16	0
22.03	ENGINEERING PRACTICE SCHOOL AT OAK RIDGE *Reid*	22.02	G(A)	1, 2	Elective	0	16	0
22.10	INTRODUCTION TO NUCLEAR TECHNOLOGY I *Kaplan*	8.04 or 8.041; M22	G	1	Elective	3	—	6
			G	1	XIII-A			
22.11	INTRODUCTION TO NUCLEAR TECHNOLOGY II *E. A. Mason*	8.053 or 22.10; M22	G	2	Elective	3	—	6
			G	2	XIII-A			
22.20	BIOLOGICAL EFFECTS OF NUCLEAR RADIATION *Brownell*	8.053 or 22.10	G(A)	2	Elective	3	—	6

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
22.21	NUCLEAR REACTOR PHYSICS I *Kaplan*	8.053 or 22.10; *M352*	G(A)	1	Elective	3	—	9
22.22	NUCLEAR REACTOR PHYSICS II *Kaplan*	22.21	G(A)	2	Elective	3	—	9
22.23	NUCLEAR REACTOR ENGINEERING *E. A. Mason, Benedict*	2.43 or 2.50 or 2.58 or 10.31; 22.21	G(A)	1, 2	Elective	3	—	9
22.24	NUCLEAR PLANT DYNAMICS *Gyftopoulos*	6.213 or 6.605 or 6.67; 22.21	G(A)	2	Elective	3	—	6
22.31	NUCLEAR CHEMICAL ENGINEERING *Benedict*	10.32	G(A)	1	Elective	3	—	6
22.41	NUCLEAR REACTOR PHYSICS LABORATORY *Thompson, Rasmussen*	*22.21*	G(A)	1, 2	Elective	2	6	4
22.42	NUCLEAR REACTOR LABORATORY *Thompson, Rasmussen*	22.41	G(A)	1, 2	Elective	2	6	4
22.51	NEUTRAL PARTICLE TRANSPORT IN REACTIVE ASSEMBLIES I *M. Clark*	8.791; or 22.21 and M39; or M382	G(A)	1	Elective	3	—	9
22.52‡	NEUTRAL PARTICLE TRANSPORT IN REACTIVE ASSEMBLIES II *M. Clark*	8.791; or 22.21 and M39; or M382	G(A)	1	Elective	3	—	9
22.61	INTRODUCTION TO THERMONUCLEAR PROCESSES *M. Clark*	8.053 or 8.06 or 22.10	G(A)	2	Elective	3	—	9
22.90	SPECIAL PROBLEMS IN NUCLEAR ENGINEERING *E. A. Mason*	——	G(A)	1, 2	Elective		★	
22.91	SEMINAR IN NUCLEAR ENGINEERING *Benedict*	——	G(A)	1	Elective	1	—	2
22.92	SEMINAR IN NUCLEAR ENGINEERING *Benedict*	——	G(A)	2	Elective	1	—	2

AS

Air Science

AS11	AIR SCIENCE	*Jolie*	——	1	1	Elective	2	1	0
AS12	AIR SCIENCE	*Jolie, Strickland*	AS11[1]	1	2	Elective	2	1	0
AS21	AIR SCIENCE	*Vanderpoel*	AS12[1]	2	1	Elective	2	1	0
AS22	AIR SCIENCE	*Vanderpoel*	AS21[1]	2	2	Elective	2	1	0
AS31	ADVANCED AIR SCIENCE	*Remers*	AS11, AS12, AS21, AS22	3	1	——	2	1	1
AS32	ADVANCED AIR SCIENCE	*Remers*	AS31[1]	3	2	——	2	1	1
AS41	ADVANCED AIR SCIENCE	*Keator*	AS32[1]	4	1	——	2	1	1
AS42	ADVANCED AIR SCIENCE	*Keator*	AS41[1]	4	2	——	2	1	1

[1] The sequence of subjects within the first two years and within the Advanced Course may be waived for academic reasons in individual cases by the Professor of Air Science.

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D

Graphics

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
D11	ENGINEERING DRAWING *Reswick*	——	1	1	IV-A	0	4	2
			1	1, 2	Elective, except IV-A			
D111	GRAPHICS LABORATORY I *Preusser*	——	1	1	Elective	0	3	2
D12	DESCRIPTIVE GEOMETRY *D. P. Adams*	——	1	2	IV-A	0	4	2
			1	1, 2	Elective, except IV-A			
D121	GRAPHICS LABORATORY II *Preusser*	——	1	2	Elective	0	3	2
D13	GRAPHICAL PROCESSES *Coons*	——	1	1, 2	Elective	2	—	4
D14	ELEMENTARY NOMOGRAPHY *D. P. Adams*	——	1	2	Elective	2	—	4
D15	BASIC MACHINE DRAWING *Howes*	——	1	1, 2	Elective	0	4	2
D31	NOMOGRAPHY *D. P. Adams*	M12	2, 3, 4	1, 2	Elective	2	—	4
D32	ADVANCED GRAPHICS *Coons*	D12, M12	2, 3, 4	1, 2	Elective	2	—	4

L

Modern Languages

L11	ELEMENTARY GERMAN *Halle*	——	—	1	Elective	3	—	5
L12	ELEMENTARY GERMAN *Halle*	L11	—	2	Elective	3	—	5
L13	INTERMEDIATE GERMAN *Klugman*	L12, or Elem. Entrance German	—	1	Elective	3	—	5
L14	INTERMEDIATE GERMAN *Klugman*	L13	—	2	Elective	3	—	5
L15[1]	GERMAN LITERATURE 1919–1933 *Bon*	L14	—	1	Elective	3	—	5
L16[1]	LITERATURE OF POSTWAR GERMANY *Bon*	L14	—	2	Elective	3	—	5
L17	SCIENTIFIC GERMAN *Klugman*	——	G	1	Elective	3	—	6
L20[1] ‡	GREAT BOOKS AND AUTHORS IN GERMAN LITERATURE *Bon*	L14	—	2	Elective	3	—	5
L21	SPOKEN GERMAN *Bon*	3 yrs. H.S. German	1	1	Elective	3	—	3
L22	SPOKEN GERMAN *Bon*	L21	1	2	Elective	3	—	3
L31	ENGLISH FOR FOREIGN STUDENTS *Applegate*	——	1	1	Elective	3	—	3
L32	ENGLISH FOR FOREIGN STUDENTS *Applegate*	L31	1	2	Elective	3	—	3
L51	ELEMENTARY FRENCH *Dinneen*	——	—	1	Elective	3	—	5
L52	ELEMENTARY FRENCH *Dinneen*	L51	—	2	Elective	3	—	5

[1] The prerequisite is the ability to understand spoken and written German.

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
L53	INTERMEDIATE FRENCH *Bottiglia*	L52 or Elem. Entrance French	—	1	Elective	3	—	5
L54	INTERMEDIATE FRENCH *Bottiglia*	L53	—	2	Elective	3	—	5
L55[1]	CONTEMPORARY FRENCH LITERATURE *Bottiglia*	L54	—	1	Elective	3	—	5
L56[1]‡	FRENCH LITERATURE OF THE THIRD REPUBLIC *Bottiglia*	L54	—	2	Elective	3	—	5
L57	SCIENTIFIC FRENCH *Klugman*	——	G	2	Elective	3	—	6
L59[1]	GREAT BOOKS AND AUTHORS IN FRENCH LITERATURE *Bottiglia*	L54	—	1	Elective	3	—	5
L61	INTRODUCTION TO SPOKEN FRENCH *Hornik*	3 yrs. H.S. French	1	1	Elective	3	—	3
L62	CONVERSATIONAL FRENCH *Hornik*	3 yrs. H.S. French	1	2	Elective	3	—	3
L75	LANGUAGE AND SOCIETY *Chomsky*	——	—	1	Elective	3	—	5
L76	PROBLEMS OF PHONOLOGY *Halle*	L75	—	1	Elective	3	—	5
L78	LINGUISTIC STRUCTURE *Chomsky*	L75	—	2	Elective	3	—	5
L91	ELEMENTARY RUSSIAN *Znamensky*	——	—	1	Elective	3	—	5
L92	ELEMENTARY RUSSIAN *Znamensky*	L91	—	2	Elective	3	—	5
L93	INTERMEDIATE RUSSIAN *Znamensky*	L92	—	1	Elective	3	—	5
L94	INTERMEDIATE RUSSIAN *Znamensky*	L93	—	2	Elective	3	—	5
L97	SCIENTIFIC RUSSIAN *Znamensky*	——	G	2	Elective	3	—	6

[1] The prerequisite is the ability to understand spoken and written French.

M

Mathematics

M100	ELEMENTARY NUMBER THEORY *Franklin*	——	1	1	Elective	2	—	4
M101	TOPICS IN DISCRETE MATHEMATICS *H. Rogers*	——	1	2	Elective	2	—	4
M11	CALCULUS *Douglass*	——	1	1	All Courses	3	—	6
M12	CALCULUS *Douglass*	M11	1	2	All Courses	3	—	6
M21	CALCULUS *Zeldin*	M12	2	1	All Courses except IV-A	3	—	6
M22	DIFFERENTIAL EQUATIONS *Zeldin*	*M21*	2	2	All Courses except IV-A, XV, XX, XX-B	3	—	6
M221	PROBABILITY AND OPERATIONS ANALYSIS *Wadsworth*	M21	2	2	XV, XX, XX-B	3	—	6
M32	ELEMENTARY STATISTICS *Wadsworth*	M21	3 3	1 2	Elective XXI-C	3	—	6
M341‡	MODERN STATISTICAL THEORY *G. B. Thomas*	M22; M32	4	2	Elective	3	—	6

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M342‡	MODERN STATISTICAL THEORY *G. B. Thomas*	M341	4	2	Elective	3	—	6
M351	ADVANCED CALCULUS FOR ENGINEERS *Hildebrand*	M22 or M221	G(A)	1	XIII-A	3	—	6
			3	1	II (2), VI, VI-A, VI-B, VIII			
			3	2	Elective			
M352	ADVANCED CALCULUS FOR ENGINEERS *Hildebrand*	M351	G(A)	2	XIII-A	3	—	6
			3	1	Elective			
			3	2	II (2), VI-A (B)			
			4	S	VI-A (A)			
M371	OPERATIONS RESEARCH *Wadsworth*	M32; M351 or M831	G(A)	1	Elective	3	—	6
M372	OPERATIONS RESEARCH *Wadsworth*	M371	G(A)	2	Elective	3	—	6
M381	THEORY OF FUNCTIONS *Ambrose*	M352 or M831	G(A)	1	Elective	3	—	9
M382	THEORY OF FUNCTIONS *Ambrose*	M381	G(A)	2	Elective	3	—	9
M39	METHODS OF APPLIED MATHEMATICS *Hildebrand*	M351	G(A)	1, 2	Elective	3	—	9
M411	NUMERICAL ANALYSIS *Hildebrand*	M351	G(A)	1	Elective	3	2	7
M412	NUMERICAL ANALYSIS *Hildebrand*	M411	G(A)	2	Elective	3	2	7
M42‡	INTRODUCTION TO HYDROMECHANICS *Lin*	M351, *M352*	4	1	Elective	3	—	6
M421	THEORETICAL HYDROMECHANICS *Lin*	M42	G(A)	1	Elective	3	—	9
M422	THEORETICAL HYDROMECHANICS *Lin*	M42	G(A)	2	Elective	3	—	9
M442	ELEMENTARY DIFFERENTIAL GEOMETRY *Struik*	*M832*	4	2	XVIII	3	—	6
M451	FOURIER SERIES AND INTEGRALS *Wiener*	M381 or M831	G(A)	1	Elective	3	—	9
M452	FOURIER SERIES AND INTEGRALS *Wiener*	M451	G(A)	2	Elective	3	—	9
M461‡	SEMINAR IN MATHEMATICS *Lin*	M352 or M381 or M832	G(A)	1	Elective		★	
M47	MATHEMATICAL THEORY OF HYDROMAGNETICS I *Backus*	8.041, M42	G(A)	2	Elective	3	—	9
M481	TOPOLOGY *Peterson*	M62; M381 or M831	G(A)	1	Elective	3	—	9
M482	TOPOLOGY *Peterson*	M481	G(A)	2	Elective	3	—	9
M483‡	ADVANCED TOPOLOGY *G. W. Whitehead*	M482	G(A)	1	Elective	3	—	9
M491‡	GEOMETRY OF MANIFOLDS *Ambrose*	*M481*, M832	G(A)	1	Elective	3	—	9
M492‡	GEOMETRY OF MANIFOLDS *Ambrose*	M491	G(A)	2	Elective	3	—	9
M50‡	FUNDAMENTALS OF MECHANICS OF CONTINUA *Lin*	M352	4	2	Elective	3	—	6
M521‡	TOPICS IN THE THEORY OF NUMBERS *Ankeny*	M381	G(A)	1	Elective	3	—	9
M522‡	TOPICS IN THE THEORY OF NUMBERS *Ankeny*	M521	G(A)	2	Elective	3	—	9
M53‡	LOCALLY COMPACT GROUPS *Singer*	M551 or M651	G(A)	2	Elective	3	—	9
M54‡	MATHEMATICAL LABORATORY *Douglass*	M22	3	2	Elective	3	—	6
M551	FUNCTIONS OF A REAL VARIABLE *Kunze*	M832	G(A)	1	Elective	3	—	9
M552	FUNCTIONS OF A REAL VARIABLE *Kunze*	M551	G(A)	2	Elective	3	—	9
M553	SINGULAR INTEGRALS AND APPLICATIONS *Calderon*	M381, M552	G(A)	1	Elective	3	—	9
M554	SINGULAR INTEGRALS AND APPLICATIONS *Calderon*	M553	G(A)	2	Elective	3	—	9

Number	Subject and instructor in charge	Prerequisite subjects	Scheduled for: Year	Term	Course Numbers	Time in units: Lec Rec	Lab Draw	Prep
M561	FUNCTIONS OF COMPLEX VARIABLES *Singer*	M382, *M481*	G(A)	1	Elective	3	—	9
M562	FUNCTIONS OF COMPLEX VARIABLES *Singer*	M561	G(A)	2	Elective	3	—	9
M571	DIFFERENTIAL EQUATIONS *Levinson*	M381; M39 or M62	G(A)	1	Elective	3	—	9
M572	DIFFERENTIAL EQUATIONS *Levinson*	M571	G(A)	2	Elective	3	—	9
M573‡	DYNAMICAL SYSTEMS *Moser*	M351	G(A)	1	Elective	3	—	9
M574‡	DYNAMICAL SYSTEMS *Moser*	M573	G(A)	2	Elective	3	—	9
M581‡	CONTINUOUS GROUPS *Singer*	*M481*, M551	G(A)	1	Elective	3	—	9
M582‡	CONTINUOUS GROUPS *Singer*	M581	G(A)	2	Elective	3	—	9
M591	PARTIAL DIFFERENTIAL EQUATIONS *Moser*	M352 or M381	G(A)	1	Elective	3	—	9
M592	PARTIAL DIFFERENTIAL EQUATIONS *Moser*	M591	G(A)	2	Elective	3	—	9
M61	MATHEMATICAL LOGIC *H. Rogers*	M62	G(A)	1	Elective	3	—	9
M62	LINEAR ALGEBRA *Crowell*	M22	3	1	XVIII	3	—	6
			3	2	Elective			
M63	MODERN ALGEBRA *Mattuck*	M62	G(A)	2	Elective	3	—	9
M631‡	INTEGRAL EQUATIONS *Crout*	M22	G(A)	2	Elective	3	—	9
M633	ALGEBRA *Iwasawa*	M63	G(A)	1	Elective	3	—	9
M634	TOPICS IN ALGEBRA *Iwasawa*	M63 or M633	G(A)	2	Elective	3	—	9
M641	TENSOR CALCULUS *L. N. Howard*	M39 or M62	G(A)	2	Elective	3	—	9
M651‡	FUNCTIONAL ANALYSIS *Calderon*	M381; M551 or M832	G(A)	1	Elective	3	—	9
M652‡	FUNCTIONAL ANALYSIS *Calderon*	M651	G(A)	2	Elective	3	—	9
M661	TOPICS IN FOUNDATIONS OF MATHEMATICS *H. Rogers*	M62	G(A)	2	Elective	3	—	9
M671‡	ALGEBRAIC FUNCTIONS *Mattuck*	M381, M633	G(A)	1	Elective	3	—	9
M672‡	ALGEBRAIC FUNCTIONS *Mattuck*	M671	G(A)	2	Elective	3	—	9
M711	THEORY OF GAMES *Nash*	M22	G	1	Elective	3	—	9
M72	AUTOMATA AND ARTIFICIAL INTELLIGENCE *Minsky*	M39 or M62 or M76	G(A)	2	Elective	3	—	9
M73	REVIEW OF MATHEMATICS *Douglass*	——	G	S	XIII-A	8	—	12
M76	PROBABILITY *G. B. Thomas*	M351	3	2	VI-B	3	—	6
M761	THEORY OF PROBABILITY *Ray*	M551 or M832	G(A)	1	Elective	3	—	9
M762	THEORY OF PROBABILITY *McKean*	M761	G(A)	2	Elective	3	—	9
M78	INTRODUCTION TO ELASTICITY *Reissner*	M351	4	2	Elective	3	—	6
M791‡	THEORETICAL AND APPLIED ELASTICITY *Reissner*	2.081 or M78; M352	G(A)	1	Elective	3	—	9
M792‡	THEORETICAL AND APPLIED ELASTICITY *Reissner*	M791	G(A)	2	Elective	3	—	9
M831	ANALYSIS *G. B. Thomas*	M21, *M62*	3	1	XVIII	3	—	9
M832	ANALYSIS *G. B. Thomas*	M831	3	2	XVIII	3	—	9
M90	MATHEMATICAL READING *W. T. Martin*	——	G(A)	1 or 2	Elective		★	

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MS

Military Science

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
MS11	MILITARY SCIENCE *Cox*	——	1	1	Elective	2	1	0
MS12	MILITARY SCIENCE *Cox*	——	1	2	Elective	2	1	0
MS21	MILITARY SCIENCE *Cox*	MS11, MS12	2	1	Elective	2	1	0
MS22	MILITARY SCIENCE *Cox*	MS21	2	2	Elective	2	1	0
MS312	ADVANCED CORPS OF ENGINEERS *Stefanik*	MS22	3	1	——	2	1	1
MS313	ADVANCED SIGNAL CORPS *Mays*	MS22	3	1	——	2	1	1
MS314	ADVANCED ORDNANCE CORPS *Walters*	MS22	3	1	——	3	—	1
MS316	ADVANCED CHEMICAL CORPS *L. A. Tucker*	MS22	3	1	——	3	—	1
MS318	ADVANCED QUARTERMASTER CORPS *Mulligan*	MS22	3	1	——	2	1	1
MS322	ADVANCED CORPS OF ENGINEERS *Stefanik*	MS312	3	2	——	3	—	1
MS323	ADVANCED SIGNAL CORPS *Mays*	MS313	3	2	——	3	—	1
MS324	ADVANCED ORDNANCE CORPS *Walters*	MS314	3	2	——	2	1	1
MS326	ADVANCED CHEMICAL CORPS *L. A. Tucker*	MS316	3	2	——	2	1	1
MS328	ADVANCED QUARTERMASTER CORPS *Mulligan*	MS318	3	2	——	3	—	1
MS412	ADVANCED CORPS OF ENGINEERS *Stefanik*	MS322	4	1	——	3	—	1
MS413	ADVANCED SIGNAL CORPS *Mays*	MS323	4	1	——	3	—	1
MS414	ADVANCED ORDNANCE CORPS *Walters*	MS324	4	1	——	2	1	1
MS416	ADVANCED CHEMICAL CORPS *L. A. Tucker*	MS326	4	1	——	2	1	1
MS418	ADVANCED QUARTERMASTER CORPS *Mulligan*	MS328	4	1	——	3	—	1
MS422	ADVANCED CORPS OF ENGINEERS *Stefanik*	MS412	4	2	——	2	1	1
MS423	ADVANCED SIGNAL CORPS *Mays*	MS413	4	2	——	2	1	1
MS424	ADVANCED ORDNANCE CORPS *Walters*	MS414	4	2	——	3	—	1
MS426	ADVANCED CHEMICAL CORPS *L. A. Tucker*	MS416	4	2	——	3	—	1
MS428	ADVANCED QUARTERMASTER CORPS *Mulligan*	MS418	4	2	——	2	1	1

NS

Naval Science

Number	*Subject and instructor in charge*	*Prerequisite subjects*	*Scheduled for:* Year	Term	Course Numbers	*Time in units:* Lec Rec	Lab Draw	Prep
NS11	ORIENTATION AND SEA POWER *Burton*	——	1	1	——	3	1	5
NS12	ORIENTATION AND SEA POWER *Burton*	NS11	1	2	——	3	1	5
NS21	NAVAL GUIDED MISSILES *Weatherup*	NS12	2	1	——	1	—	0
NS22	NAVAL GUIDED MISSILES *Weatherup*	NS21	2	2	——	1	—	0
NS31	NAVAL NUCLEAR PROPULSION ——	NS22	3	1	——	1	—	0
NS32	NAVAL NUCLEAR PROPULSION ——	NS31	3	2	——	1	—	0
NS41‡	NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP ——	NS32	4	1	——	3	1	5
NS42‡	NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP ——	NS41	4	2	——	3	1	5

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HARRIET LOUISE HARDY, M.D.
Assistant Medical Director; in charge of Occupational Medical Service

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THORNTON BROWN, M.D.
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Physician

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Physician

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Psychiatrist

EDWIN MUNCKS COLE, M.D.
Neurologist and Psychiatrist

RICHARD SCHATZKI, M.D.
Radiologist

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Assistant Surgeon

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Radiation Biophysicist; Reactor Protection Officer
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Associate Professor of Naval Science
HERBERT ORAN BURTON, S.B.
Lieutenant, U. S. Navy
Assistant Professor of Naval Science

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M. BRYCE LEGGETT
Assistant Director of Admissions

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REGISTRAR*
DIRECTOR OF THE MEDICAL DEPARTMENT*
DIRECTOR OF STUDENT AID*
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HOWARD SIMPSON 1959
THOMAS H. D. MAHONEY 1960
S. CURTIS POWELL 1960
E. CARY BROWN 1961
NATHAN H. COOK 1961
GEORGE B. THOMAS, JR.‡

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DIRECTOR OF STUDENT AID*
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NORMAN C. DAHL 1960
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RICHARD FILIPOWSKI 1961
DELBAR P. KEILY 1961
BURNHAM KELLY‡

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ALBERT BUSH-BROWN 1961

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SHATSWELL OBER
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Library

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ASSOCIATE LIBRARIAN*
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RICHARD H. FRAZIER 1961
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[1] The dates to the right indicate the years in which the terms of appointment expire.

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RAYMOND L. BISPLINGHOFF
JAY W. FORRESTER
GEORGE G. HARVEY
MAURICE E. SHANK
JOHN C. SHEEHAN
HAROLD C. WEBER

Hobby Shop Committee

BENJAMIN L. AVERBACH (CHAIRMAN)
CARVEL COLLINS
ROBERT J. HOLDEN
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Patent Management Committee

CARL F. FLOE (CHAIRMAN)
PAUL V. CUSICK
F. LEROY FOSTER
MELVIN R. JENNEY
WILLIAM H. RADFORD
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Safety Council

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CARL M. F. PETERSON
LAWRENCE J. ROMANO
MALCOLM S. STEVENS

Student Activities Development Board

ROBERT W. MANN (CHAIRMAN)
DEAN OF STUDENTS*
NORMAN N. HOLLAND
KEVIN A. LYNCH
CHARLES O. STAPLES (STUDENT)
GERARD J. STEPHENSON, JR. (STUDENT)
LYNN R. SYKES (STUDENT)

**Ex officio*

Student Financial Aid Board

THOMAS P. PITRÉ (CHAIRMAN)
J. SAMUEL JONES (SECRETARY)
WARREN M. ROHSENOW (CHAIRMAN OF COMMITTEE ON STUDENT AID*)
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Technology Museum Committee

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ERNEST H. HUNTRESS
HERMAN P. MEISSNER
ITHIEL D. POOL

* *Ex officio*

ACADEMIC COUNCIL

President (*Chairman*)
Chancellor (*Vice Chairman*)
Vice President
Vice President and Treasurer
Dean of the School of Engineering
Dean of the School of Science
Dean of the School of Architecture and Planning
Dean of the School of Humanities and Social Studies
Dean of the School of Industrial Management
Dean of the Graduate School
Dean of Students
Administrative Vice Chancellors
Chairman of the Faculty
Executive Assistant to the President

ADMINISTRATIVE COUNCIL

President
Chancellor
Vice President
Vice President and Treasurer
Dean of the School of Engineering
Dean of the School of Science
Dean of the School of Architecture and Planning
Dean of the School of Humanities and Social Studies
Dean of the School of Industrial Management
Dean of the Graduate School
Dean of Students
Administrative Vice Chancellors
Comptroller
Vice Treasurer
Bursar
Chairman of the Faculty
Dean of Residence
Director of Admissions
Medical Director
Director of Athletics
Director of the Division of Sponsored Research
Director of the Industrial Liaison Office
Director of Libraries
Director of Lincoln Laboratory
Director of Public Relations
Director of Student Aid
Director of the Summer Session
Executive Assistant to the President
Executive Vice President of the Alumni Association
Placement Officer
President of the Alumni Association
Registrar
Secretary of the Institute
Special Advisers to the President
Administrative Assistant to the President

FACULTY COUNCIL

Chairman of the Corporation
President
Chancellor
Vice President
Dean of the School of Engineering
Dean of the School of Science
Dean of the School of Architecture and Planning
Dean of the School of Humanities and Social Studies
Dean of the School of Industrial Management
Dean of the Graduate School
Dean of Students
Administrative Vice Chancellors
Director of the Division of Sponsored Research
Chairman of the Faculty
Secretary of the Faculty
Director of the School for Advanced Study
Director of Libraries
Registrar
Director of Admissions
Director of the Research Laboratory of Electronics
Chairman of Directing Committee, Laboratory for Nuclear Science
Director of the Spectroscopy Laboratory
Director of the Lincoln Laboratory
Director of the Summer Session
Heads of Departments and Professional Courses
Chairman of the Committee on Undergraduate Policy

APPENDIX A: STUDENT AID AND PRIZES

Financial Aid for Undergraduates

A wide range of scholarship assistance is available to students entering from secondary schools; grants range from small awards up to and including amounts covering full tuition and living costs.

In addition, M.I.T. loan funds are available in amounts less than full tuition during the freshman year—and thereafter in amounts up to full tuition for each year.

The Student Financial Aid Committee will also make selections for on-the-campus part-time jobs to supplement requests for financial assistance.

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 February 15 of the calendar year in which they will enter. Selection for an award is based in general upon the Student Financial Aid Committee's evaluation of the candidate's total record; this includes College Entrance Examination Board test scores, high school or preparatory school records, evidence of need of financial assistance as determined from the Parents' Confidential Statement to the College Scholarship Service, and recommendations from his former teachers, prominent citizens of his community, or Institute alumni.

FRESHMAN SCHOLARSHIPS

The principal four-year scholarships—the William Barton Rogers Scholarships, the Alumni Fund National Scholarships, the 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.

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.

Alumni Regional Scholarships (1926). As a means of cooperating with M.I.T. alumni in various centers in attracting to the Institute students of exceptional ability and promise, several Regional Scholarships, carrying an award based on demonstrated need for the freshman year, are offered in Chicago, Denver, Detroit, District of Columbia, Kansas City, Los Angeles, New York, New Jersey, Northern Ohio, Philadelphia, Pittsburgh, Portland, Ore., Rochester, N.Y., San Francisco, St. Louis, Seattle, Schenectady, Southern Ohio, and Westchester County, New York. These are open to American citizens of good character and health whose standing in their preparatory school studies has been high and who have satisfied with high standing all entrance requirements.

Army and Navy Scholarships (1930). Sons of regular Army, Navy, Air Force, Marine Corps, and Coast Guard officers who are admitted as undergraduate students to the Institute will be considered for grants toward their tuition based on their demonstrated need, with a maximum of one-half tuition, upon recommendation of the Student Financial Aid Committee—the total number not to exceed ten each year. Preference will be given to qualified applicants admitted to the first-year class. Applications should be addressed to the Director of Student Aid and should be accompanied by documentary evidence that the applicant's father is a commissioned officer in the regular Army, Navy, Air Force, Marine Corps, or Coast Guard. Holders of these scholarships, if recommended by the Committee, may continue their grants during their second and succeeding undergraduate years.

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.

Cincinnati Milling Machine Scholarship (1952). Established by the Cincinnati Milling Machine Company as a four-year undergraduate scholarship in engineering at the Institute, carrying a maximum grant of $1,400 annually, this award is open to a secondary school graduate who plans to study in the field of engineering, preferably mechanical. First preference is given to a resident of the Middle West (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin). For favorable consideration, the applicant is expected (1) to meet all the academic requirements for admission to M.I.T. with better-than-average standing; (2) to give suitable evidence of his need for financial aid; and (3) to have demonstrated high qualities of character and have shown potentialities for future leadership. During the undergraduate period, the recipient of this scholarship may be offered employment at the Company's plant during the normal summer vacation periods.

Class of 1895 Scholarship Memorial Fund (1945). This fund was given by the Class of 1895 on its fiftieth anniversary, "the income annually to be used to provide scholarships for suitably

qualified descendants of members of the Class of 1895. If in any year the total income is not required for this purpose, the balance shall be added to the Technology Loan Fund."

Class of 1922 Scholarship Fund (1942). Established at the twentieth reunion of the Class of 1922, income and principal of this fund is used to "assist students entering the Institute as freshmen from secondary schools, with preference being given to sons (or daughters) of members of the Class." Beneficiaries "are expected to issue notes agreeing to repay the face value, without interest, of amounts received."

Class of 1931 Compton Memorial Freshman Scholarship Fund (1956). The income from this fund, established at the twenty-fifth reunion of the Class of 1931 as a memorial to Dr. Karl Taylor Compton, is used for freshman scholarships.

Class of 1938 Scholarship Fund (1938). Gifts from the Class of 1938, "the income for scholarships."

W. A. Conant Scholarship Fund (1943). A bequest of $150,000 was made "for the purpose of establishing a permanent fund to be known as the W. A. Conant Scholarship Fund, the income therefrom to be used for the education of native born American Protestant boys of New England of American Protestant parents, who are graduates of some high or preparatory school, public or private, in New England, preference to be given to the graduates of the public schools of Brookline, Massachusetts, but without limitation thereto, and whose parents are financially unable to send them to the Institute and whose own means are insufficient to allow them to attend the Institute." One scholarship, carrying a grant of full tuition for each of the four undergraduate years, is annually offered to an entering freshman.

Thomas C. Desmond Scholarship (1952). Established by the gift of Thomas C. Desmond '09, a $1,200 scholarship for the freshman year is available to a student who plans to study civil engineering.

Development Fund Scholarships (1950). Scholarships provided by gifts to the M.I.T. Development Fund consist of four-year grants to students who maintain academic ranking in the top quarter of the class and demonstrate continued need for financial assistance. A number of these awards are for full tuition, others for three-quarters tuition, and some for half tuition. They are open to all candidates from secondary schools. Application for renewal of these awards for each succeeding year should be made to the Student Financial Aid Committee.

William H. Donner Prize Scholarships (1956). Six prize scholarships donated by Mrs. John J. Ide to honor the memory of her father, the late William H. Donner. These are prize awards for the freshman year, carrying a stipend of $2,200, and are limited to students who are planning to study aeronautical engineering.

East Bridgewater Scholarship (1932). Established by the Institute through a bequest from Horace T. Smith '98, this grant is known as the Horace T. Smith Scholarship Fund. A scholarship carrying a stipend depending on demonstrated need, with a maximum of full tuition for the freshman year, is annually offered a graduate of the High School of East Bridgewater, Massachusetts.

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.

Francis Morgan Frasher, Jr., '52, Memorial Scholarship (1951). This award was established by Mr. Frasher's parents for a graduate entering directly after acquiring his entire high school education in the secondary schools of San Antonio, Alamo Heights, or Bexar County, Texas, who wishes to pursue work for a degree in science. The award covers tuition for the freshman year only.

Freshman Competitive Scholarships (1932). These awards cover part tuition for the first year. There are no geographical restrictions of eligibility, and any candidate for admission to the freshman class directly from secondary school may apply. Competition is based upon academic records and evidences of non-academic merit of the competitors, and no special examinations are required.

General Motors Scholarships (1955). These four-year grants, established under the General Motors College Scholarship Plan, are open to citizens of the United States and are intended for outstanding individuals. Five awards are made to entering first-year students. Stipends will be fixed on the basis of demonstrated need.

Charles Hayden Memorial Scholarships (1939). Established through a grant from the Charles Hayden Foundation, these scholarship awards are in memory of the late Charles Hayden, a graduate of the English High School Class of 1886 and of the M.I.T. Class of 1890.

Jakobson Scholarship (1951). Established by Jakobson Shipyard, Inc., this annual freshman scholarship carries a grant of $1,000. First preference is given to a son of an employee of Jakobson Shipyard, Inc.; second preference is to graduates of the following New York high schools: Glen Cove, Huntington, Manhasset, Oyster Bay, Port Washington, Roslyn, Sea Cliff; and third preference is to secondary school graduates who reside on Long Island, excepting the counties of Kings or Queens.

Knapp Memorial Scholarships (1951). Gift of the Knapp Fund, these scholarships are for students entering M.I.T. from the Buffalo area and Erie County. Applicants will be expected to have demonstrated good ability and achievement in their secondary school performance, show need of financial aid, and evidence an active interest in their school and community. Selection will be made by a committee from the M.I.T. Alumni Club of Buffalo and the Director of Student Aid.

Amelia S. Kniesner Scholarship Fund (1944). Gift of William T. Kniesner '16 and his sisters, the income is used "to provide scholarship aid to meritorious or needy students, either entering freshmen or undergraduate students of the Institute, preference to be given to graduates of the high school or high schools of Danbury, Connecticut."

Jacob and Jennie Lichter Fund (1949). This scholarship fund is "for the aid of students who shall satisfy all entrance requirements of the Institute and be endorsed as to character and personality."

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.

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.

Martin Aircraft Scholarship (1954). This endowment of $25,000 establishes scholarships for male students planning to pursue Courses most applicable to the activities of The Glenn L. Martin Company. Preference will be given to residents of Maryland (including the District of Columbia) and special consideration will be given to sons of employees of The Glenn L. Martin Company.

Waldo A. Martin Scholarship Fund (1950). This fund was established by Eleanor P. Martin in memory of her brother,

Waldo A. Martin '90. Until 1975 first preference in awards is to be given to friends or relatives of Waldo A. Martin and the donor, and second preference to graduates of Milton High School, Milton Academy, or a resident of Milton. Awards are for the freshman year only, on the basis of character, integrity, and ability.

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."

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.

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.

Pittsburgh Consolidation Coal Company Scholarship (1957). Awards under this four-year grant, open to male residents of the northeastern United States who wish to study chemical engineering or chemistry, are made on the basis of evaluated financial need. The recipient of this grant will be considered as a candidate for summer employment by the Company.

Proctor and Gamble Scholarship (1955). Two four-year scholarships, open to entering students, are sponsored by The Proctor and Gamble Company. One student following a science Course and one student following an engineering Course are chosen each year. Grants cover tuition plus an added amount for books and supplies.

Willis Ward Reeves, Jr., Fund (1945). Established by Mr. and Mrs. Willis Ward Reeves of Hazard, Kentucky, "as a memorial to their son, Willis Ward Reeves, Jr., '46, late Lieutenant, U.S. Army Air Forces, killed in action over France during World War II . . . the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Kentucky."

William Barton Rogers Scholarships (1947). A limited number of four-year grants established in honor of William Barton Rogers, founder of the Institute, enable young men of superior ability and future promise but of limited financial means to pursue an education in either engineering, science, or architecture. A stipend of $1,600 (full tuition plus $300) is granted for the first year. Successful applicants who maintain honor standing continue to hold full-tuition awards for their undergraduate course and are eligible to apply to borrow up to the amount of tuition annually from the Technology Loan Fund. These scholarships are open to all freshmen with no restrictions of geographical location.

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, covering all expenses for a college year. 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.

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."

Granger Whitney Fund (1957). Income of this bequest, made by the will of Julia Whitney in the name of Granger Whitney '87, is used to assist worthy students of the Institute, with first preference being given to students nominated by the Detroit M.I.T. alumni club.

Arthur Williams Scholarship in Engineering (1958). Established by the Trustee under the will of the late Arthur Williams of Roslyn, Long Island, this scholarship is used to assist one or more needy and deserving young men to qualify in the engineering professions and business administration.

SCHOLARSHIPS FOR UPPERCLASSMEN

In addition to the scholarships for freshmen, the Institute holds funds from the income of which awards are made to students in the upper undergraduate years. It is the policy of the Student Financial Aid Committee to assist as many well-qualified students as possible by assigning, in general, amounts less than full tuition. Awards are made only to students who have completed at least one year of satisfactory work at the Institute. The ability of the student, as indicated by his scholastic record, is the primary consideration in making selections. However, account is also taken of the applicant's evidence of need for financial assistance, of his good character, and of his general worthiness and professional promise. Applications should, except as noted below, be made on blanks to be obtained at the Student Aid Center, Room 5-119.

The scholarships or funds described are arranged in the alphabetical order of their names, the figures in parentheses being the dates of establishment.

Frank W. and Carl S. Adams Memorial Fund (1955). Established by Mr. and Mrs. Charles E. Adams, with The First National Bank of Boston as Trustee, and named in memory of their two sons as the Frank W. and Carl S. Adams Memorial Fund, this fund is used to assist needy and deserving students at M.I.T. A limited amount may also be available to assist an impecunious student who is unable to participate in recognized functions incident to graduation.

American Brake Shoe Company Scholarships (1948). Established by the American Brake Shoe Company to assist worthy students studying in the general fields of metallurgy and mechanical engineering, this is a full-tuition grant open to one third-year and one fourth-year student. The recipients are selected by the departments, in cooperation with the Student Financial Aid Committee and the American Brake Shoe Company.

American Chicle Educational Trust (1954). Two part-tuition scholarships are open to seniors who are American citizens in their final year for a Bachelor's degree. Recipients will be offered summer employment between their junior and senior years. Seniors in chemistry, chemical engineering, food technology, and business and engineering administration are considered. Selection is by the Student Financial Aid Committee in cooperation with the departments.

American Smelting and Refining Company Scholarships (1946). This gift of the Company was made to establish a scholarship of $500 to a student in metallurgy, with preference to third- or fourth-year students.

American Society for Metals Award (1954). A grant of $500 is awarded annually to a second-year student in metallurgy under this scholarship. Selection is made on the recommendation of the Department of Metallurgy to the Student Financial Aid Committee from among students who have applied for assistance for the sophomore year and who have demonstrated good ability and need.

Anonymous (1948). This gift of an alumnus is used for scholarship purposes.

Anonymous (1952). This gift of $20,000 to the Institute was designated for scholarships or some alternate form of student aid.

Louie G. Applebee Fund (1942). This bequest is "to be expended in assisting deserving students."

Elisha Atkins Fund (1894). This fund was established by Mrs. Mary E. Atkins of Boston with a gift of $5,000.

Julian M. Avery Fund (1957). Established by Julian M. Avery '18, this fund is designated for undergraduate scholarships in metallurgy.

Jason S. Bailey Fund (1952). Established by the estate of Jason S. Bailey, this fund is used for undergraduate scholarships at the Institute.

Thomas Wendell Bailey Fund (1914). The income from this bequest of Thomas Wendell Bailey is used to assist "needy students in the Department of Architecture."

Charles Tidd Baker Fund (1922). One-half of the net income of this bequest of $20,000 from Charles Tidd Baker is "applied each year to the assistance of poor and worthy students."

Billings Student Fund (1900). A bequest of $50,000 from Robert C. Billings founded the Billings Student Fund. "Any student receiving benefit from this fund is expected to abstain from the use of alcohol or tobacco in any of their varied forms."

Huse Templeton Blanchard Fund (1946). This bequest of Huse T. Blanchard '01 is for "the benefit of worthy boys of the State of New Hampshire."

Levi Boles Fund (1915). The net income of this bequest of $10,000 from Frank W. Boles in memory of his father, Levi Boles, is "applied annually to the assistance of needy and deserving students."

Jonathan Bourne Fund (1915). This bequest of $10,000 from Hannah B. Abbe constitutes a fund "known as the Jonathan Bourne Scholarship Fund, the income only to be used in aid of deserving students."

Albert G. Boyden Fund (1931). This bequest of $40,000 from Elizabeth R. Stevens is a permanent fund, known as the Albert G. Boyden Fund, "income only to be awarded as scholarships to assist worthy and needy students, preference to be given to young men or women residents of the town of Swansea or the city of Fall River."

Bertram Brewer Scholarships (1952). The income from this bequest under the will of Bertram Brewer is used "to provide annual scholarships for deserving undergraduates of good character and ability. . . ."

Harriet L. Brown Fund (1932). This bequest of Harriet L. Brown is "to be held in trust as a scholarship . . . the income to be given to such needy and deserving young women desiring to become students at M.I.T., as would otherwise be unable to attend; and in case of two or more applicants of equal merit, preference shall be given to a native of either Massachusetts or New Hampshire."

Cabot Endowed Scholarship (1955). The income from this endowment, a gift of Godfrey L. Cabot, Inc., is used as scholarships for undergraduate students of the Institute in accordance with the general Institute practices and procedures.

Godfrey L. Cabot Fund (1950). Scholarships made possible by this gift are awarded with preference to students of chemistry or chemical engineering.

Mabel Blake Case Fund (1920). This bequest of $25,000 from Caroline S. Freeman is "known as Mabel Blake Case Fund, income to be used to aid deserving students (preferably women) who are in need of assistance."

Nino Tesher Catlin Fund (1926). A gift from Maria T. Catlin established this fund in memory of her son, Nino T. Catlin '18, the income "to be awarded to needy and deserving students."

Chemical Club of New England Fund (1955). This annual grant, established by the Chemical Club of New England, is designed to promote interest in work in chemistry or chemical engineering in New England. It is open to junior and senior students who are residents of New England who are majoring in chemistry or chemical engineering, and who have demonstrated substantial academic achievement and financial need.

Lucius Clapp Fund (1905). This gift from Lucius Clapp formed a fund "to aid worthy students who may not 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."

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 of $3,000, the income of this fund is "to be awarded to a student, preferably in the Course in Civil Engineering or in some related field of study giving preparation for public service and government. Prior to matriculation, the recipient, who need not necessarily be a candidate for a degree, must have acquired practical experience and earned his living by working in some field, preferably for one year or more. Candidates are to be judged upon their evidences of character, sincerity of purpose and need for assistance."

John G. Crane Scholarships (1951). This gift of J. G. Crane '90 is for undergraduate awards.

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.

Arthur Davis Dean Fund (1952). Through the bequest of Arthur Davis Dean '95, the Institute has established a number of grants to cover a portion of the rental of rooms in the undergraduate houses so that young men of limited means may live on the Institute campus. Grants are made by the Student Financial Aid Committee to undergraduates (including entering freshmen) who have demonstrated need for financial assistance.

Carl Pullen Dennett Memorial Scholarship Fund (1956). Established by a gift in memory of Carl Pullen Dennett, this fund provides an award for a student, either graduate or undergraduate, in the School of Science who is deemed qualified by scholastic performance, intelligence, character and promise. The annual selection is made by the Director of Student Aid and the Dean of Students.

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."

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.

Frances and William Emerson Fund (1930). Awards not exceeding $600 are available to students in the School of Architecture. Applications should be made directly to the Dean of the School.

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 Joseph F. 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."

Goodyear Scholarship (1957). A stipend of $750 made available by the Goodyear Foundation, Inc. is granted to a male U.S. citizen majoring in engineering in his junior or senior year. Awards will be made on the basis of academic standing, character and leadership qualities and financial need.

Barnett D. Gordon Fund (1942). The income from this gift of $21,000 from Barnett D. Gordon '16 is to be used "as scholarships for deserving students at M.I.T."

John A. Grimmons Fund (1952). This fund was established by the estate of Katie M. A. Grimmons in memory of her son, John A. Grimmons '21. The income is to be used for scholarships for students . . . with preference to those in the Department of Electrical Engineering.

Lucia G. Hall Scholarships (1945). The income from this bequest of Louise K. Gunn, to "be known as 'The Lucia G. Hall Scholarships' . . . is to be used for the aid of worthy students."

Hall-Mercer Scholarship Fund (1940). The income from this bequest of Alexander G. Mercer is to be used "for the benefit of such poor students as have passed through some of the public schools with the best reputation for character and ability."

James H. Haste Fund (1930). This bequest of James H. Haste '96 is "for the aid of deserving students . . . of insufficient means."

George Hollingsworth Scholarship (1916). A bequest of $5,000 from Rose Hollingsworth founded this George Hollingsworth Scholarship.

Loren C. Holm Scholarship Fund (1950). Established by Marie Holm in memory of her father, this fund is designated for worthy and needy students.

Elias Howe, Jr., Scholarships (1949). The income from a fund established under the will of Julia Howe Stockwell Smith "shall be available for aiding such students and in such amounts as shall be recommended by the Faculty."

Samuel P. Hunt Fund (1945). This gift of Samuel P. Hunt '95 was designated for scholarship purposes.

T. Sterry Hunt Scholarship (1894). A bequest of $3,000 from T. Sterry Hunt, for seven years Professor of Geology at M.I.T., was designated to found a scholarship in his name. The award is restricted to students in chemistry, and preference is given to those in the higher years.

William F. Huntington Fund (1892). From Susan E. Covell the Institute received a gift of $5,000 to constitute a fund in memory of William F. Huntington '75, the "income to apply to payments of tuition of needy and deserving students . . . preference to be given to students in civil engineering."

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 $500 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."

William R. Kales Scholarship Fund (1953). This fund, endowed by a gift of the Whitehead and Kales Company for scholarship purposes, provides income to assist worthy and needy undergraduates.

Kennecott Copper Corporation Scholarship (1954). Established by the Corporation, this scholarship is open to incoming seniors in business and engineering administration. Selection is made by the Student Financial Aid Committee on recommendation of candidates by the Department, in cooperation with a representative of the company.

Bo Kwang Kim Scholarship Fund (1957). Established under the will of Bo Kwang Kim, this scholarship is for students of complete Korean ancestry. It is open to any deserving and needy Korean students. An award of $500 is made only when the income of the Fund permits.

Kurrelmeyer Fund (1947). This fund was raised by contributions "for an undergraduate scholarship award to a needy student."

Gustaf Robert Lindberg Fund (1957). This fund was established by Otto C. Lindberg, President of the General Drafting Company, to create the Gustaf Robert Lindberg Scholarships. The income is used for scholarships "that shall provide tuition, board and other necessary expenses preferably to one or more students who are citizens and residents of . . . . . Finland; second preference to citizens and residents of Sweden. If no worthy candidates from either Finland or Sweden, the scholarships may be awarded to the best qualified candidates who are citizens of the United States preferably of Finnish or Swedish extraction."

Paul Weeks Litchfield Scholarship (1954). Established in honor of Paul W. Litchfield '96, this scholarship fund aids worthy and needy students at the Institute. Preference in selection is given to those students who have been members of the Boy Scouts of America.

William Litchfield Scholarship (1910). A bequest of $5,000 from William Litchfield established "a single scholarship . . . known as William Litchfield Scholarship, income to be awarded and paid annually to such student in said Institute as may, upon a competitive examination, be determined by the President of said Institute to be entitled thereto for excellence in scholarship and conduct."

Richard W. Lodge Fund (1955) The income of this fund, established by the will of Mary L. Lodge in memory of Richard W. Lodge '79, is used for worthy and needy students.

Elisha T. Loring Fund (1890). This bequest of $5,000 from Elisha Thacker Loring is for "the assistance of needy and deserving pupils."

Lowell Institute Fund (1923). Gifts from the alumni of the Lowell Institute School founded this fund, the income of which is annually awarded to assist some graduate of that School who desires to enter upon undergraduate studies at M.I.T. Applications must be filed at the Office of the Director of Student Aid.

Percival Lowell Scholarships (1955). The income of this gift is used for scholarships awarded from time to time at the discretion of the President of the Massachusetts Institute of Technology to students in astronomy, physics and mathematics.

Alice Maclaurin Scholarship (1951). Gifts created a scholarship in memory of Mrs. Richard C. Maclaurin.

Francisco Marcucella Fund (1953). This gift of Francisco Marcucella '27 was designated for scholarship purposes.

Rupert Anderson Marden Fund (1933). This fund was established by an anonymous gift "toward a memorial to be known

as the Rupert Anderson Marden Scholarship Fund, income available annually to aid a worthy student at M.I.T.—Protestant and of American origin—preference to a student taking the Cooperative Course in Electrical Engineering."

Margaret A. Matthews Fund (1947). The income of this bequest from Margaret A. Matthews is "for the benefit of such of the women students at M.I.T. who intend to become teachers."

George J. Mead Prize Scholarships (1951). This bequest of George J. Mead '16 established prize scholarships in aircraft propulsion open to juniors, seniors, and graduate students in this field. Consideration is also given to candidates from related engineering fields as applied to aircraft propulsion. Recommendation is made by the Department of Aeronautical Engineering 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 deomonstrated 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.

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 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. . . ."

National Association of Engine and Boat Manufacturers, Inc. (1950). This scholarship of $600 is awarded to a student in naval architecture and marine engineering who is particularly interested in small boat design.

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."

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."

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."

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.

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 the curriculum in Science and Mathematics Teaching (Course XXI-C). Grants are based on demonstrated need with a maximum of full tuition; they will be renewable through the balance of the five-year program.

Paul D. Seghers, Jr., Scholarship (1948). This award was established by the estate of May Towles Kirk Seghers in memory of Second Lieutenant Paul Dotrenge Seghers, Jr., '45, U.S. Army Corps of Engineers, who was killed in action in the Asiatic area on July 11, 1945, to aid worthy and needy students at the discretion of the Institute.

Irving Shaknov Scholarship (1954). The income from this fund, established as a memorial for Irving Shaknov '43, is available for an undergraduate scholarship for a student in the Department of Physics.

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.

Skidmore, Owings and Merrill Travelling Fellowship (1950). This award, a gift from the firm of Skidmore, Owings and Merrill, makes possible foreign travel for a student graduating in the Department of Architecture.

H. Hilliard Smith Fund (1950). This bequest of Grace J. F. Smith in memory of her husband, H. Hilliard Smith '96, is for the purpose of assisting young men in architecture.

Horace T. Smith Fund (1931). This bequest from Horace T. Smith '98 provides scholarships to worthy students, with preference given to graduates of the East Bridgewater (Massachusetts) and Bridgeport (Connecticut) High Schools.

Sons and Daughters of New England Puritan Colony Scholarship (1931). Holders of this scholarship, made possible by a gift of $600 from the Sons and Daughters of New England Puritan Colony, must be of New England ancestry.

Anna Spooner Fund (1939). The income from this bequest of approximately $7,500 is used "in assisting meritorious students."

Wentworth Stevens Fund (1957). One-half of the income from this fund, established by William Wentworth Stevens '98 in honor of his mother and father, is added to principal; the remainder is made available for scholarship aid.

Mary Thacher Scholarship (1956). This bequest established a scholarship fund, the income of which is applied against the tuition of needy students, with first preference to students from Yarmouth, Massachusetts; second to students from the Cape Cod region; and third to students from the Commonwealth of Massachusetts.

Samuel E. Tinkham Fund (1924). Established by the Boston Society of Civil Engineers, this fund is to aid a worthy student in civil engineering.

F. B. Tough Fund (1924). This fund was established "for the purpose of extending financial assistance to worthy students." Preference is given to students in mining or oil production.

Y. T. Tsai Memorial Scholarship (1955). This fund for worthy and needy students was established by gift.

United States Rubber Company Foundation Scholarships (1957). These grants, established by a gift from the United States Rubber Company Foundation, are awarded to students who demonstrate need for financial assistance, who show capacity for higher education, and who are interested in a career in industry. The Foundation expects that beneficiaries will assume a moral obligation to repay a part of their grants after graduation and over a reasonable period of time; such repayments will be made to the Institute's scholarship fund and will then be used to help other needy students.

Susan Upham Fund (1892). This gift of $1,000 from Susan Upham is "to assist students deserving financial aid."

Samson R. Urbino Fund (1927). This bequest of $1,000 from Samson R. Urbino is "to be used to aid students who need assistance, Germans preferred."

Vermont Scholarship (1924). This scholarship "in memory of Vermonters who, having received their education at the Institute, served as engineers in the Armies of the Allies in the World War" was founded by a gift of $76,000 from Redfield Proctor '02. The income is awarded annually "to worthy students . . . preference to any *bona fide* residents of Vermont doing undergraduate work at the Institute, and also Vermont students doing graduate work, or students who are graduates of or transfer from Middlebury College or Norwich University . . . who shall meet regular scholastic and other requirements."

Ann White Vose Fund (1896). This bequest from Ann White Vose of $25,000 "plus one half of the remainder of my estate" was designated "to establish free scholarships in M.I.T. . . . such persons enjoying benefit . . . shall be worthy young men of American origin."

Arthur M. Waitt Fund (1925). This bequest of $10,000 from Arthur M. Waitt was designated for "assisting needy and deserving students in the second-, third-, and fourth-year classes of the Mechanical Engineering Course."

Grant Walker Fund (1943). The income from this bequest of $50,000 is used "for scholarships for deserving students."

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 (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 three scholarships in engineering, established by the Western Electric Company, are awarded on the basis of need and ability, with a maximum grant of $800.

Westinghouse Air Arm Division Scholarships (1956). Established by the Westinghouse Electric Corporation, these scholarships provide $500 grants to sophomores in mechanical engineering, electrical engineering, physics, and applied mechanics. Recipients will be offered summer employment at the company's Baltimore plant.

Frances Erving Weston Fund (1912). This bequest of Frances Erving Weston is "to aid a native-born American Protestant girl of Massachusetts."

Samuel Martin Weston Fund (1912). This bequest of Frances Erving Weston was made to found a scholarship in memory of her husband, Samuel Martin Weston, "to aid a native-born American Protestant boy, preference to be given one from Roxbury."

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.

TECHNOLOGY LOAN FUND.

Since its establishment in 1930, the Technology Loan Fund has provided more than $4,700,000 in loans to over 5,400 M.I.T. students.

In general, loans are made by the Student Financial Aid Committee to (a) students entering the Institute directly from secondary schools who are well recommended, (b) students who have completed at least one term of residence with a good academic record.

The maximum amount loaned to an individual in a single year may not exceed the tuition fee, and the maximum total loans granted to an applicant may not exceed $5,000 during his undergraduate period or $6,000 during his undergraduate and graduate periods.

Application forms are available from the Student Aid Center. To receive favorable consideration an applicant must:

1. Be endorsed as to character and personality by: (a) an alumnus of the Institute from the community in which he has resided or by some other citizen of standing in that community; (b) the principal or head master of the high school or preparatory school or the president or dean of the college or university he has previously attended; and (c) his Registration Officer or the Head of his Course.
2. Have passed, with a standing satisfactory to the Committee, the physical examination required of all Institute students.
3. Submit a statement of his financial needs and such other information as the Committee may deem necessary, on the application form supplied by the Committee, such application to have the approval of his parent or guardian.
4. Be prepared to furnish as collateral such life insurance as may be required by the Committee.

The recipient of a loan signs promissory notes in $150 units up to the amount of his loan. Each such loan carries interest at one per cent per annum during the period of enrollment and at two per cent per annum beginning six months after the termination of enrollment. During enrollment interest is paid semiannually; annual payments of $300 on principal start six months after graduation or termination of enrollment. Principal payments may be made on either a monthly, quarterly, semi-annual, or annual basis; they may also be anticipated.

After he leaves the Institute, the recipient of a loan is required to advise the Committee annually, or at more frequent intervals, of his whereabouts, the character of the work in which his is engaged, the remuneration he is receiving, and his plans for the repayment of his obligations to this Fund.

OTHER LOAN FUNDS.

The following funds have been established for special purposes at the Institute. In general, these loan funds are administered under terms similar to those governing the Technology Loan Fund, and inquiries should be made to the Director of Student Aid.

Boston Stein Club Freshman Loan Fund (1953). Established by M.I.T. Boston Stein Club, this fund is designed to assist needy students resident in the Greater Boston area. It is open only to first-year students who show good promise, and, in general, grants are for less than full tuition. Recipients are required to sign notes to repay amounts granted, without interest, after graduation.

Denison K. Bullens Fund (1958). Gift of D. K. Bullens '09, the income of this fund is used as a loan to assist needy and worthy undergraduates, with first preference to a student in metallurgy.

Ethel I. Fryer Scholarship Loan Fund (1951). This fund was a gift of H. Fryer '11 to establish a loan scholarship for deserving students from the states of Wasnington, Oregon, and California. Grants are limited to $600 per student and are repayable within five years of graduation.

Nathan R. George Loan Fund (1943). This bequest of $29,000 from Professor Nathan R. George of the Department of Mathematics is "to be loaned to undergraduates of M.I.T. who are either citizens or who intend to become citizens" and who are members of the third- or fourth-year classes.

John A. Grimmons Fund (1930). In memory of John A. Grimmons '21 through a deed of trust executed by the late C. Lillian Moore, the Institute received a sum of money to be "used in making loans to undergraduates who are preparing to make electrical engineering their life work; such loans to be known as given from the John A. Grimmons Perpetual Loan Scholarship; such loans are not to exceed $600 to any one student in any one year and are to be made on condition that the loans shall bear interest at five per cent and shall be repaid within ten years, and that repaid loans shall be treated as income to revert into the Perpetual Loan Fund and to be reloaned from time to time; such loans are to be protected by life insurance. . . . Loans are to be awarded to male, white, native born citizens of the United States, who are loyal to the State and Nation, are of sound physical body, and show steadiness of purpose and zeal in educational acquirements."

Rebecca R. Joslin Fund (1924-36). This fund is open to undergraduate and graduate students in chemical engineering and is restricted to students who are residents of Massachusetts and who abstain from using tobacco in any form.

Lamson-Virgin Loan Fund (1946). This bequest of $5,000 from Elizabeth H. Lamson, is used in aiding a worthy student of excellent character who "must have shown not only respect for his parents but also proper consideration for the rights of others." Students thus aided shall repay if and when they find themselves able to do so.

George J. Mead Fund (1951). This bequest of George J. Mead '16 is for loans to students in aeronautical and mechanical engineering.

M. H. Rogers Fund (1945). This bequest of Minnie Hempel Rogers '90 is for loans to worthy students.

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.

Undergraduate Prizes and Awards

To encourage and recognize high achievement by students at M.I.T., a number of prizes have been established by individuals and organizations. In general, these awards are made each year by the Office of the Dean of Students in cooperation with the departments or organizations concerned.

American Society of Tool 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 Engineers.

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.

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 extra-curricular compositions, will be eligible for the prize. Specific topics must be registered and approved at the Headquarters of the Department of Humanities.

The Perkin-Elmer Corporation Prize Award (1956). A monetary prize of $200, gift of the Perkin-Elmer Corporation, is offered annually to an undergraduate student "to encourage students to seek opportunities in the sciences."

Silent Hoist and Crane Company Materials Handling Award (1950). These annual prizes, totalling $200, are awarded for the best papers or theses submitted on subjects in the fields 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.

Stratton Prizes (1930). Two yearly awards are presented to encourage skill in organized debating. They are made possible by the income of a fund established by the late President Samuel W. Stratton.

The following annual prizes are offered to students:

AERONAUTICAL ENGINEERING

James Means Memorial Prize (1925). A medal and monetary prize of $100 is offered annually to a senior for excellence in 16:71 and 16:72 AERONAUTICAL 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 Aeronautical Engineering.

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.

Chamberlin Prize (1913). This $25 prize, gift of the Boston Society of Architects, is awarded in alternate years to a student in the graduate class in architecture.

F. W. Chandler Prizes (1906). Five prizes of $5 each are awarded for sketch problems in the fourth, fifth, and graduate years. The prizes are a gift of the Boston Society of Architects in memory of Professor Chandler.

Class of 1904 Prize (1925). This prize, a gift of the Class of 1904, is awarded to a student in the third-year class in architecture for a sketch problem.

William Emerson Prizes (1940). Gifts of the alumni and staff, five prizes of $10 each are awarded in the first, second, third, fourth and fifth years of Course IV-A, and one prize of $10 is awarded in Course IV-B.

Rotch Prizes (1895). Two prizes, the gift of Arthur Rotch, are awarded at the end of the fifth year to the regular and the special student in architecture having the best general records. The special student must have spent at least two years in residence to be eligible.

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.

Boston Society of Architects Awards (1923). Prizes totalling $50, gifts of the Boston Society of Architects, are given for week-end conjunctive problems with Harvard and the Boston Architectural Club.

William R. Ware Prize (1923). Given by M.I.T. in memory of the founder of the School, prizes totalling $50 are given for weekend conjunctive problems with Harvard.

H. Langford Warren Prize (1923). Given by Harvard in memory of Professor Warren, prizes totalling $50 are given for weekend conjunctive problems with Harvard.

CONSTRUCTION ENGINEERING

Tucker-Voss Award (1953). Gift of the alumni and friends of the Course in Building Engineering and Construction, this prize is awarded annually to an undergraduate or a graduate student with high scholastic standing, leadership, and professional promise in the building field.

CHEMICAL ENGINEERING

Hunneman Prize (1927). Established by William Cooper Hunneman in memory of his son, Roger DeFriez Hunneman '23, this award of $40 is made to the most meritorious senior who has shown outstanding originality in his work in the regular Course in Chemical Engineering.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

American Bureau of Shipping Prize (1924). This award of $100 is provided by the Bureau to the American citizen who attains the highest average in scholarship for the third and fourth years in either the Course in Naval Architecture and Marine Engineering or the Course in Shipping and Shipbuilding Management.

Financial Aid for Graduate Students

Financial aid is available in a number of forms for graduate students. A substantial number of scholarships and fellowships are awarded each year; in addition, there are many opportunities for academic staff appointments as part- or full-time teaching or research assistants. The requirements and application procedures for these financial aids are described in Section 3 of this Catalogue.

The Technology Loan Fund (described on a previous page) is also available to graduate students.

FELLOWSHIPS

The following fellowships will be available for the academic year 1958–59. The name in each case is that of the donor of funds which support the fellowship or of the person(s) memorialized by it.

VARIOUS FIELDS

Boeing Airplane Company. For a graduate student in engineering or science in a field relating to the aircraft industry; tuition plus $1,400.

William Sumner Bolles. For graduate work in any department; $1,200.

Coats and Clark, Inc. Three fellowships, each for a graduate student in a field of textile technology whose thesis research is in that division; tuition plus $900.

Fluor Foundation. Tuition plus $1,400–$1,900; in engineering fields, with preference for (but not restricted to) chemical and mechanical engineering.

Electronics Industries. For graduate work in electronics; tuition plus $1,600 single, $2,400 married, advanced fellowships up to $3,000. Sponsored by the Federal Telecommunication Laboratories, Hughes Aircraft Company, Radio Corporation of America, and Sperry Gyroscope Company.

International Business Machines Corporation. For a graduate student in certain areas of chemistry, communication theory, electronics, information theory, mathematics, physics, etc.; tuition plus $1,800 single or married but without children, $2,500 married but with one child or more.

Solar Energy. Four fellowships for graduate students, candidates for the doctorate in chemistry, physics, or engineering or candidates for Master in Architecture, for study in a field which may lead to improved use of solar energy; tuition plus $1,400 single, $2,100 married; for two terms but renewable.

Gerard Swope. For students of exceptional ability and promise, as a mark of highest distinction.

United States Steel Foundation. For a U.S. citizen graduate student in the general area of industrial organization and management; tuition plus $1,500 single, $2,100 married.

Whitney. For an entering graduate student from other than M.I.T., in any department; tuition plus $1,400.

AERONAUTICAL ENGINEERING

American Bosch Arma Corporation. For a Master's (or under certain conditions for a doctoral) candidate in the Instrumentation Laboratory; tuition plus $1,600 single (or married but without dependents); or tuition plus $2,100 married and having dependents, status determined as of date of award.

AC Spark Plug. For a graduate student in instrumentation; tuition plus $2,100.

Aviation Week. For a male U.S. citizen enrolled for an advanced degree, renewable as long as satisfactory academic rating is maintained; tuition plus $1,600.

Douglas Aircraft Company. For a highly recommended graduate student; tuition plus $900.

Richard C. Du Pont. Memorial fellowship in aeronautical engineering, for a graduate student in any year of his work toward an advanced degree; tuition plus $1,400 single, $2,000 married.

Lester D. Gardner. For a graduate student; $2,000.

Goodyear Tire and Rubber Company and Goodyear Aircraft Corporation. For an American citizen graduate student; tuition plus $1,600.

Lockheed Leadership Fund. For a graduate student in the field of aerodynamics; tuition plus $1,400.

Reeves Instrument Corporation. For a highly recommended graduate student in the field of instrumentation and automatic control; tuition plus $1,600.

Sperry Gyroscope Company. Two fellowships, each for a graduate student in aeronautical engineering; tuition plus $1,600.

ARCHITECTURE

Grunsfeld Fund. For a distinguished advanced French student of the Ecole des Beaux Arts, for a year's study at M.I.T. and travel in the United States, to be selected from nominations presented to M.I.T. by the Ecole des Beaux Arts; tuition plus $1,500.

J. C. Nichols Foundation. Tuition plus $1,100.

Voorhees, Walker, Smith, and Smith. Tuition plus $1,600.

BIOCHEMISTRY

Karl Taylor Compton Fellowships of the Nutrition Foundation. Fellowships for graduate work in the field of biochemistry; each tuition plus $2,000.

General Foods Corporation. For an entering graduate student in biochemistry, whose research will be in the area of enzymology; tuition plus $1,400 renewable for each of two succeeding years.

CHEMICAL ENGINEERING

Allied Chemical and Dye Corporation. For an American citizen in the final year of graduate study; tuition plus $1,500 single, $2,000 married.

American Cyanamid Company. For several graduate students in chemical engineering for one semester each in the School of Chemical Engineering Practice; tuition plus $400.

American Oil Company. Two fellowships for students who attend either the School of Chemical Engineering Practice or the Engineering Practice School at Oak Ridge for one term; tuition plus $700.

American Viscose Corporation. For a student to attend the School of Chemical Engineering Practice for one term; tuition plus $750 single $1,050 married.

Union Carbide Chemicals Company. For a graduate student in chemical engineering; tuition plus $1,500 single or $2,100 married, for normal academic year or (at M.I.T.'s discretion) for calendar year.

Union Carbide Chemicals Company. For a student who attends either the School of Chemical Engineering Practice or the Engineering Practice School at Oak Ridge, for one, two, or three terms; tuition plus $1,400 single, $2,100 married, per twelve-month period.

R. M. Carpenter. Tuition plus $1,400.

Dow Chemical Company. For a graduate student, candidate for Master's degree or higher; tuition plus $1,400 single, $1,800 married.

E. I. Du Pont De Nemours and Company. For a graduate student in any year of work toward a doctorate; tuition plus $1,200 for first-year graduate student or $1,500 for later year if single; $1,800 or $2,100, respectively, if married.

Eastman Kodak Company. For a U.S. citizen in final year of Sc.D. research; tuition plus $1,400 single, $2,100 married with dependent children.

Eastman Kodak Company. For two M.S. students (preferably U.S. citizens) to attend the School of Chemical Engineering Practice at Oak Ridge; tuition for one term.

General Dynamics Corporation. For a graduate student in nuclear engineering; tuition plus $1,800 single, $2,200 married.

Humble Oil and Refining Company. For a student enrolled for S.M. or a doctorate; tuition plus $1,800.

Kimberly-Clark Corporation. For a graduate student whose research is in a subject of interest to the paper and pulp industry, for two regular terms and one summer term; tuition plus $1,600.

Arthur D. Little. Memorial fellowship for a candidate for a doctorate for two regular terms and one summer term; tuition plus $2,100.

Pittsburgh Consolidation Coal Company. For a candidate for a doctorate, for three terms; tuition plus $1,800.

Procter and Gamble Company. Two fellowships, each for a student in his first year of graduate study, for two terms; tuition plus $1,500.

Scientific Design Company. For a graduate student in chemical engineering; tuition plus $1,500 single, $2,100 married.

Standard Oil Foundation. For a graduate student whose thesis subject is in the field of basic research in chemical engineering; tuition plus $1,200.

CHEMISTRY

American Cyanamid Company. For a graduate student during his final academic year of residence in work toward the doctorate; tuition plus $1,800.

Consumers Union. For a graduate student in chemistry in the field of physical chemistry of surfaces; tuition plus $1,000.

General Electric Company. For a graduate student in chemistry; tuition plus $1,750 single, $2,100 married with no dependent children, $2,500 married with one or more dependent children; such status to be as of September 30, 1958.

Arthur D. Little. Memorial fellowship for a candidate for a doctorate in chemistry; tuition plus $1,400.

Monsanto Chemical Company. For a graduate student, preferably in his last year of a doctoral program, for two terms; tuition plus $1,750.

Forris Jewett Moore Memorial. For graduate study at M.I.T. or elsewhere, preference being given to the field of organic chemistry; tuition plus $1,400.

James Flack Norris Memorial. For a candidate for a doctorate; $2,500.

Union Carbide Chemicals Company. For a graduate student in his final year of predoctoral study; tuition plus $1,500 single, $2,100 married.

United States Rubber Company. For a male candidate for a doctorate; tuition plus $1,400 single, $2,100 married.

CITY PLANNING

F. W. Chandler. Awarded upon recommendation of the Head of the Department to a candidate for the M.C.P.; $1,200.

CIVIL ENGINEERING

McClintock Endowment. For a graduate student in civil engineering; tuition plus $1,300.

ECONOMICS

Economic Development. For a graduate student in the Department of Economics; tuition plus $1,400.

Goodyear Tire and Rubber Company. For a graduate student in the field of industrial economics or industrial relations; tuition plus $1,400.

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; up to $900.

Industrial Economics and Industrial Relations. For candidates for the doctorate in these fields; several, tuition plus $1,000.

Westinghouse Fellowship in Industrial Relations. For a graduate student in this field; tuition plus $1,400.

ELECTRICAL ENGINEERING

Bendix Aviation Corporation. For a U.S. citizen well advanced in a doctoral program whose field of study is of interest to the donor; tuition plus $1,600 single, $2,400 married.

General Dynamics Corporation. For a graduate student in the field of electronics; tuition plus $1,800 single, $2,200 married.

International Business Machines Corporation. For a graduate student in electronics, communications, and information handling; tuition plus $1,800 single or married with no children, $2,500 married with children.

Melpar, Incorporated. For a graduate student in electronics and communications; tuition plus $1,500 single, $2,100 married.

Minneapolis-Honeywell. For graduate work in feedback control; tuition plus $1,400.

Owens-Corning Fiberglas Corporation. For a graduate student in acoustics; tuition plus $1,600 single, $2,400 married.

Schlumberger Foundation. For a graduate student in electrical engineering; tuition plus $1,500.

FOOD TECHNOLOGY

American Chicle Company. Tuition plus $1,600.

Campbell Soup Company. For a graduate student in food technology; tuition plus $2,100 single, $2,400 married.

The Coffee Brewing Institute. Tuition plus $1,600.

Gerber Products Company. Tuition plus $1,600.

Procter and Gamble. For a graduate student in food technology; tuition plus $1,600–$2,200.

Roche Anniversary Foundation. Tuition plus $1,600.

GEOLOGY AND GEOPHYSICS

Gulf Research and Development Company. For a graduate student in geophysics, preferably but not necessarily to a doctoral candidate beyond his first year of graduate study, for two regular terms; tuition plus $2,000.

Standard Oil Company of California. For a graduate student in the field of earth science; tuition plus $1,500.

INDUSTRIAL MANAGEMENT

School of Industrial Management. For advanced study and research in industrial management, for college graduates whose major studies have been in science, engineering, and engineering administration. A number of fellowships; tuition plus up to $1,400 single, up to $2,100 married. Awards may be continued for second year of study if performance justifies.

Sloan. For training in executive development, for industrial executives of some experience who are nominated by their employers, a twelve months' program with grants.

MATHEMATICS

Mathematics. For graduate students who are studying in the Department of Mathematics for careers of research or teaching in the various fields; tuition plus $1,300.

MECHANICAL ENGINEERING

E. I. Du Pont De Nemours and Company. For a graduate student in any year of work toward a doctorate; tuition plus $1,200 for first-year graduate student or $1,500 for later year if single; $1,800 or $2,100, respectively, if married.

General Motors Corporation. For a graduate student in automotive engineering; tuition plus $1,200 single, $1,800 married.

Lasalle Steel Foundation. For a graduate student working either toward S.M. or Sc.D. in mechanical engineering, whose major field of interest including thesis is in the field of metal-cutting; tuition plus $1,400 single, $2,000 married.

Procter and Gamble. For a graduate student in mechanical engineering; tuition plus $1,400 single, up to $2,100 married.

Shell. For a graduate student, candidate for the S.M. or Sc.D., preference to be given to doctoral candidate in last year of work; tuition plus $1,800 single, $2,100 married with one or more children; renewable.

Visking. For a graduate student in the final year of a doctoral program; tuition plus $1,500 if single, $2,100 if married.

METALLURGY

Allegheny-Ludlum. Two fellowships for graduate students whose thesis research is on topics of interest to the alloy steel industry; tuition plus $1,800–$2,400.

Aluminum Company of America. Three fellowships for graduate students whose thesis research is on topics of interest to the aluminum industry; tuition plus $1,200–$1,800.

American Brake Shoe Company. For a graduate student; tuition plus $1,800.

American Lithium Institute. To encourage work on alloys containing lithium; tuition for calendar year plus $2,100.

Armco Foundation. To a graduate student for research in the general field of metallurgy; tuition plus $1,200–$2,200.

Crane Company. For a graduate student in the Department of Metallurgy whose major interest is in the field of foundry research, for two regular terms and one summer term; tuition plus $1,800.

General Electric. For a graduate student in metallurgy; tuition plus $1,750 single, $2,100 married with no dependent children; $2,500 married with one or more dependent children; such status to be as of September 30, 1958.

Horizons, Inc. For a graduate student in metallurgy, for two regular terms plus one summer term; tuition plus $2,100 for calendar year.

International Nickel Company. For a postgraduate student or postdoctoral fellow for fundamental studies in the field of corrosion; tuition plus $2,100 per calendar year.

Kennecott Copper Corporation. For a graduate student in metallurgy; $2,000 including tuition.

Muchnic Foundation. For a graduate student in metallurgy, for research in foundry; tuition plus $1,800.

National Steel Corporation. For a graduate student in metallurgy whose research is in the general field of the plastic behavior of steel; tuition plus $1,500 single, $2,100 married.

Nelco Metals. For a graduate student for research on cast iron; tuition plus $2,700 per calendar year of three academic terms.

Union Carbide Chemicals Company. For a graduate student in the general field of metallurgy; tuition plus $1,500 single, $2,100 married, for two regular terms.

Union Carbide Chemicals Company. For a graduate student in the field of mineral engineering; tuition plus $1,500 single, $2,100 married, for two regular terms.

Universal-Cyclops Steel Corporation. For a candidate working on tool steel; tuition plus $1,400.

Weirton Steel Company. For fundamental studies in corrosion; tuition plus $1,200.

PHYSICS

General Electric. For a graduate student in physics; tuition plus $1,750 single, $2,100 married with no dependent children; $2,500 married with one or more dependent children; such status as of September 30, 1958.

Eastman Kodak Company. For a U.S. citizen in his final year of Ph.D. research; tuition plus $1,400 single, $2,100 married with dependent children.

International Business Machines Corporation. For a graduate student in the field of physics; tuition plus $1,800 single or married but without children; $2,500 married but with one or more children.

Shell. For a candidate for the S.M. or Sc.D., preference to be given to doctoral candidate in last year of work; tuition plus $1,800 single, $2,100 married with one or more children.

SCHOLARSHIPS

UNRESTRICTED FUNDS

Graduate Scholarships totalling $120,000 are available for 1958–59.

REGIONAL AWARDS

Hebrew Institute of Technology, Haifa, Israel. For a staff member; tuition, in conjunction with an award by the Boston Stein Club.

Imperial College of Science and Technology, London, England. Tuition.

M.I.T. Clubs of Mexico. For a graduate student nominated by the alumni of the M.I.T. Clubs of Mexico City and Monterrey; tuition.

Theodore B. Parker Memorial. For graduates of colleges of the Tennessee Valley states; tuition.

Vermont Scholarship. Open to a native of Vermont or a graduate of Middlebury College or Norwich University. Undergraduate applications have preference; tuition.

Prizes and Awards for Graduate Students

To recognize outstanding teaching and research by graduate students, two awards have been established in memory of Dr. Harry Manley Goodwin, the first dean of the Graduate School, through a fund given by Mary B. and Richard H. Goodwin.

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 Goodwin Premium. In any year in which there is no qualified candidate for the Medal, a cash award not to exceed $500 may be granted to any graduate student in recognition of originality, ingenuity, thoroughness, and a scholarly written presentation of research embodied in a thesis of conspicuously unusual merit. As in the case of the Medal, nominations but not applications are receivable by the Dean of the Graduate School.

APPENDIX B: STUDENT HOUSING

The student residences at the Massachusetts Insititute of Technology have been planned to afford economical, comfortable living quarters, an environment conducive to study, and an opportunity to participate in those social and extracurricular activities which properly supplement scholastic work. Faculty Residents occupy quarters in each of the residential centers. Chosen for their understanding of students and student questions, these men welcome informal friendly discussions with their fellow residents.

The Institute believes that it is to the great advantage of all students who do not live at home to live in Institute Houses or in fraternities. As far as accommodations allow, such residence is required for all freshmen unless other special arrangements are approved by the Dean of Residence. Upperclassmen are free to make whatever living arrangements they choose.

THE UNDERGRADUATE HOUSES FOR MEN

The Everett Moore Baker House (West Campus), located on the river front at 362 Memorial Drive, Cambridge, west of Massachusetts Avenue, accommodates some 350 students in single, double, or triple rooms. The House has its own dining facilities, where residents are expected to take commons meals.

The Alfred Edgar Burton House (West Campus), also on the river front at 410–420 Memorial Drive, Cambridge, west of Baker House, consists of five units accommodating about 580 students. There are some single and double rooms, but most of the accommodations are suites of rooms designed for congenial groups. Residents of Burton House who choose to do so may arrange for commons meals served in a nearby campus dining room, where à la carte service is also available.

The Faculty Houses (East Campus)—Ware, Atkinson, Runkle, Holman, Nichols, and Crafts,—on Memorial Drive east of Walker Memorial and adjacent to the President's House, accommodate about 225 students.

The Alumni Houses (East Campus)—Munroe, Hayden, Wood, Goodale, Bemis, and Walcott,—near Walker Memorial, have accommodations for 430 men.

Dining facilities for residents of the East Campus Houses are in the Walker Memorial Building. This includes 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. 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 $10 a term the service supplies blankets for the term, with 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 when possible.

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 or a nuisance to others, and is regarded as a serious offense meriting the immediate and permanent exclusion of the offender from the Houses.

Rents. Rents in the undergraduate Houses range from $150 to $215 each person each term, and are subject to review and change at the end of each school year. 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 "Residence at M.I.T.," available from the Dean of Residence, Room 7–104.

Rooms are engaged for the full academic year. Reservations are automatically cancelled and proportionate refunds are made to students who cancel their registrations 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. Students resident in the undergraduate Houses who desire to move to recognized fraternities after Registration Day and prior to the end of the second week of the fall term or during the first two weeks of the spring term, and whose transfer is requested by authorized representatives of the fraternity, will be refunded the rental fee less a pro rata charge for occupancy.

Basic Regulations. In applying for a room in the Houses, a student is understood to agree to abide by the following basic regulations:

1. Only one room application form per student may be filed. Duplicate applications will not be considered.

2. Upperclassmen who are assigned rooms in the Houses in the spring will receive a card which must be signed and returned by August 1 in order to confirm acceptance of a room assignment. Students from whom no card is received will lose their assignment and be transferred to the bottom of the waiting list. Under special conditions approved by the Dean of Residence, students may be relieved of the responsibility for confirmed assignments up to, but not including, Registration Day in September.

3. Room changes within the dormitories will be made in special circumstances 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 dormitory rooms will be expected to live in the dormitories throughout the 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 may move from the dormitories to a fraternity only during the first two weeks of the fall term and during the first two weeks of the spring term.

6. The Institute reserves the right to move students within the dormitories 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 dormitories, instead of moving, provided they have the approval of the Dean of Residence.

7. Students who do move from the dormitories 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.

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.

11. Damage of Institute property in the dormitories is the responsibility of the residents. Each student is held accountable for any damages in his own room, the entire dormitory, or any part thereof as may be determined by student government.

12. All students electing to live in Baker House are required to register for commons meals. Students who for medical or other reasons require special diets should apply for residence in Burton House or the East Campus Houses.

13. Open house regulations and regulations for extracurricular activities in the dormitories are among the responsibilities of student government in the Houses. The Faculty and administration expect all students to abide by the regulations of student government.

14. 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, the minimum such action being permanent expulsion from the Houses.

Key Deposits. A deposit of $1 is required for a room key, subject to refund in full upon return of the key.

Parking and Automobile Regulations. Because of the acute shortage of on-campus parking space, the Institute cannot provide parking facilities for use of resident students. A limited number of spaces are provided, with the approval of the Dean of Residence, for residents with physical handicaps demanding use of an automobile.

Operators of motor vehicles should consult the Massachusetts Registry of Motor Vehicles regarding regulations and insurance of out-of-state motor vehicles. The registration and operating licenses of certain states are not honored in Massachusetts after thirty days.

RESIDENCE FOR WOMEN STUDENTS

The Women's Dormitory at 120 Bay State Road, Boston, accommodates 17 students. The current rate for room and board is $400 each person each term. Application forms and further information may be obtained from the Dean of Residence.

Apartment dormitory accommodations are available for upperclass and graduate women students in Bexley Hall, 52 Massachusetts Avenue, Cambridge, directly opposite the main Institute buildings. Apartments are for two or three occupants and are fully furnished and equipped except for blankets, linens, and draperies. The building—one unit of the Bexley Hall apartment house—has a separate entrance, is protected by a fire-sprinkler system on main and service staircases, contains a self-service machine laundry, and provides a basement storage space for each apartment. Rent, including gas and electricity, is $200 each person each term. Applications forms and further information may be obtained from the Dean of Residence.

THE GRADUATE HOUSE

The Graduate House is a center for the social life of the graduate student community. Rooms in the Graduate House are reserved exclusively for men graduate students.

Application forms for rooms are sent with notices of admission to new graduate students and with a circular issued during each spring term to students already living in the House. They should be filed with the Superintendent of the Graduate House. Priority in the assignment of rooms is granted to students already living in the House.

Notices of assignments will be forwarded to applicants as promptly as possible. Acceptances must be returned as requested; otherwise, the rooms may be reassigned. The assignment of rooms is in order of application; the right is reserved to reject any applicant for sufficient reason.

Rents in the Graduate House range from $140 to $215 each person each 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 cancelled 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 for the undergraduate Houses, given above.

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