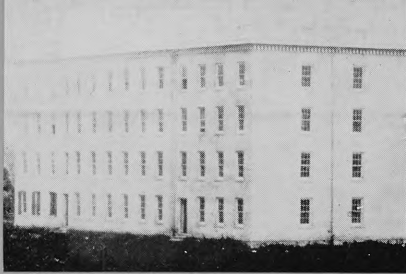

UNIVERSITY OF MICHIGAN

OFFICIAL PUBLICATION

Centennial of Engineering 1853 1953

COLLEGE OF

ENGINEERING

ANNOUNCEMENT

1953 - 1954

The University of Michigan campus in the late 1850's

Front cover, top: Old South Wing, in which Professors Alexander Winchell and De Volson Wood taught engineering

Front cover, bottom: Entrance to Denison Arch, West Engineering Building

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COLLEGE OF ENGINEERING

ANNOUNCEMENT

1953-1954

Ann Arbor, Michigan *Published by the University*

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September 16–19, Wednesday–Saturday .... Registration*
September 21, Monday .... First semester classes begin
November 25, Wednesday (evening) .... Thanksgiving recess begins
November 30, Monday (morning) .... Classes resume
December 18, Friday (evening) .... Christmas recess begins

1954

January 4, Monday (morning) .... Classes resume
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June 12, Saturday .... Commencement

This calendar is subject to change.
* For registration schedules see pages 168–69.

INTRODUCTION

1953–54 is the Centennial Year of Engineering Education at the University of Michigan. On January 20, 1854, Alexander Winchell, who had been appointed Professor of Physics and Civil Engineering in November, 1853, taught his first class in Parker's Aids. The occasion will be celebrated during the current academic year with a two-day convocation on October 23–24, and the dedication of the Cooley Research Laboratory on the new North Campus, followed by other appropriate events throughout the year.

The special character of the Engineering College today is a product of historical forces which shaped its development. The first of these is the relation of engineering to the liberal arts college, where engineering education began. There it evolved slowly, clinging to its origins at the same time that it was adapting itself to the needs and demands of a changing world.

The requirements for the degree of Civil Engineer, first stated in the *Catalogue* of 1855–56, included both classical and engineering subjects. By 1858 engineering had achieved the rank of a department within the Literary College, and a four-year curriculum in enginering was established under the guidance of DeVolson Wood, the real founder of engineering education at Michigan. During the sixties Wood, with occasional assistance, taught most of the engineering classes.

After his resignation in 1872, the engineering program was placed in the hands of Charles Ezra Greene, Joseph Baker Davis, and Charles Simeon Denison, a trio that guided the engineering instruction for more than thirty years. The splendid service of these men and of Wood is memorialized by plaques in the arch (the Denison Arch) of the West Engineering Building.

The formative years of engineering training at Michigan were dominated by scientists and publicists whose main purpose was to produce civil engineers to meet the problems of an era of rapid growth in population, especially in urban areas. After 1870, engineers took an increasingly active part in education, teaching became more practical, and laboratory instruction, a field in which American leadership has been especially marked, was developed.

The gradual acquisition of separate quarters accompanied these changes and emphasized the growing independence of engineering education. The original engineering building, a mechanical laboratory or shop, was constructed on the southeast corner of the campus in 1881.

Part of this building is shown in the right center of the illustration opposite page 8. Shortly afterward the building on the extreme right, a joiner shop, was added. The main structure shown in the picture was built in 1885. In 1890 this structure was enlarged to its present dimensions and the original shop was removed. In 1891 the old Dental College Building was converted to an engineering building and was so used until 1922, when it was removed to provide space for the Clements Library.

Engineering became an independent department of the University in 1895, thirty-four years after DeVolson Wood first recommended such a step, with Charles E. Greene as the first dean. A committee composed of Henry S. Carhart, Mortimer E. Cooley, and Greene was assigned the task of planning the organization of the new department. Greene and Cooley were reluctant to separate the Department of Engineering from the College of Literature, Science, and the Arts for fear of narrowing the engineer's education, which they thought should be as broad as possible.

Four-year programs were offered, leading to degrees in civil, mechanical, and electrical engineering. The 1896–97 *Announcement* of the Department also lists courses in marine engineering and naval architecture, metallurgy, and mining engineering. Alfred H. White, Professor Emeritus of Chemical Engineering, was listed as an instructor in chemical technology in 1898–99, and chemical engineering was offered as a degree program in that year. Courses in naval architecture, previously taught by Cooley, were considerably expanded in 1901–2 under H. C. Sadler, Junior Professor of Naval Architecture, and a degree program was instituted.

Cooley became dean of the College in 1904, and under his able guidance the school rose to a position of international respect. He had joined the staff in 1881 and in the same year directed the construction of the initial engineering laboratory. Dubbed "the scientific blacksmith," Cooley was then the only mechanical engineer in the state of Michigan. He taught blacksmithing, machine shop, and patternmaking. During his administration, the West Engineering Building was completed in 1904 and enlarged in 1909–10; East Hall was acquired from the Ann Arbor School Board in 1922 for the use of nontechnical classes; and the East Engineering Building was completed in 1923. The Departments of Engineering Mechanics and Aeronautical Engineering were organized during this period, and the expanding program in architecture culminated in the creation, in 1931, of the College of Architecture. Cooley retired in 1928, after forty-seven years as professor of mechanical engineering.

Although now completely weaned from its parent institution, the Engineering College never lost touch with liberal arts education. Engineering students still take physics, chemistry, and mathematics, as well as numerous electives such as foreign languages, economics, psychology, history, and philosophy in the College of Literature, Science, and the Arts. The fact that the Engineering College is part of a large University composed of a great range of humane and professional schools brings both students and faculty members into a variety of personal and cultural contacts which enrich their perspective as engineers.

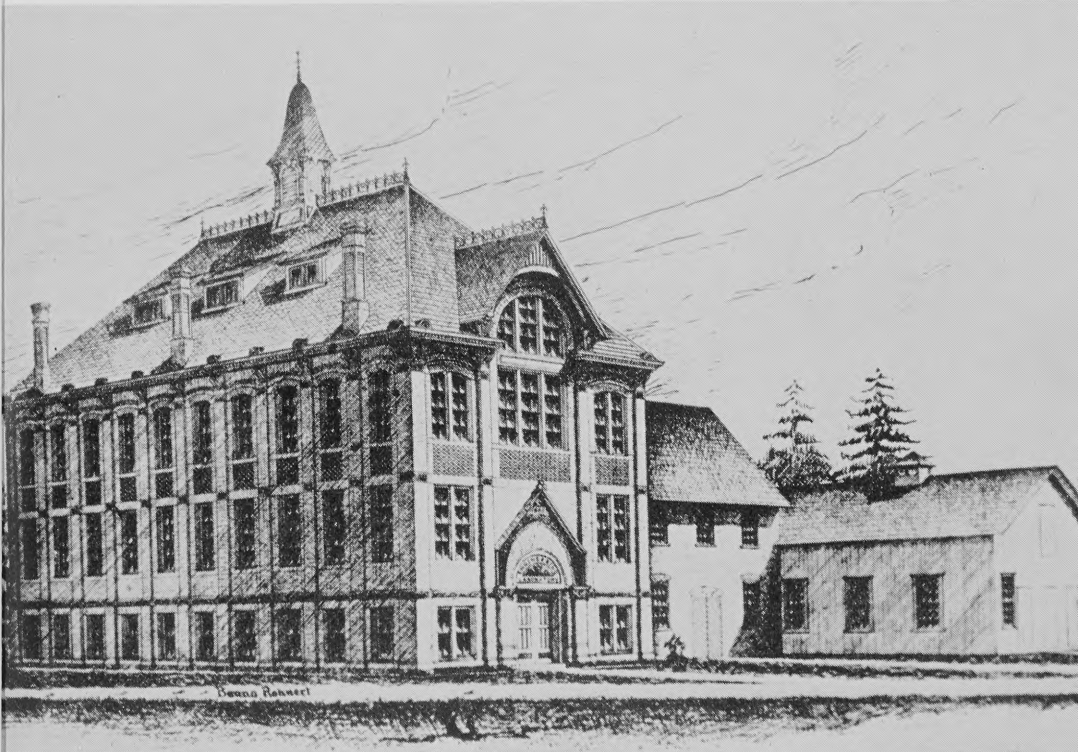
A second force that has helped to shape the present character of the College is that, from the outset, engineering instruction was regarded as an educational process. DeVolson Wood had a genius for teaching, the particular merit of which lay in his capacity to make men think for themselves. Joseph Baker Davis, for whom Camp Davis is named, was a gruff but kindly teacher who had a natural sympathy for students and gave of himself unsparingly. Charles Simeon Denison devoted his whole life to his students, and even his profound interest in art was secondary to his affection for the engineering undergraduates. It has been said of him, "His life work was helping to build men."

This concern for the individual student has endured throughout the growth of the College and the inevitable changes in staff and administration. It is evident in two outstanding institutions in the College today. The first is the Honor System, which is encouraged by the faculty but operated entirely by the students, and is dedicated to the development of a sense of personal integrity and honor. Under this system, or code, students take their examinations without proctors and are responsible for their own conduct. The second is the Mentor System, in which each freshman engineer is assigned to a faculty member who counsels him informally on his personal and academic problems.

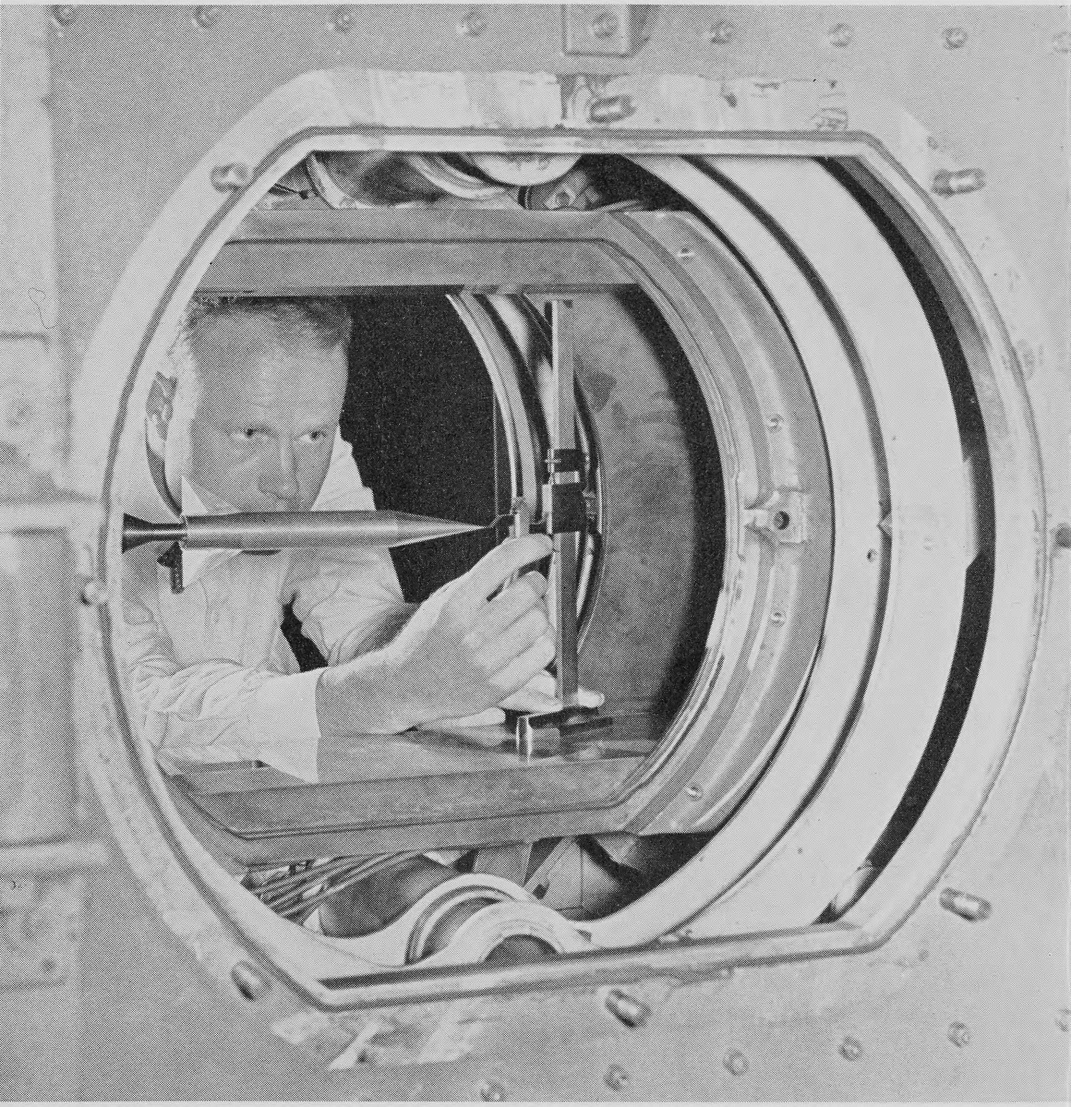
A third force that has helped to shape the College likewise goes back to the very beginnings. In 1855 Professor Winchell made a survey for a railroad which was to run from Ann Arbor to Jonesville and thereby began the policy of engaging in collateral practice which endures today. The policy was given official approval in 1910 by the Regents, who realized that such a plan would permit the University to attract men of superior abilities whose teaching would profit by the application of their knowledge. Such collateral work was often — and still is — in the nature of research which serves the public welfare. As early as 1860 the Regents approved a study of the best methods of constructing roads, a study that may be regarded as the remote beginnings of the Department of Engineering Research, established in 1920, and now called the Engineering Research Institute. This organization makes available to industry and to the government the special resources of the Engineering College for research and investigation. This service, which is financed by the clients, has developed to a point where the annual budget is in the millions, and the employed personnel is more than a thousand.

The emphasis upon research and the availability of splendid facilities have led to a tremendous development in postgraduate work at Michigan, a phase of education that looms increasingly significant as science opens new horizons.

Although the Engineering College has continued to grow and to expand in response to the changing needs of the modern world, it has never lost sight of the fact that education is its primary purpose. While providing a solid training in the practical application of knowledge, it has never forgotten that men are more than machines. It is fitting, therefore, that the celebration of the Centennial of Engineering Education at Michigan should include the dedication of the new Research Laboratory that honors the man, who more than any other, epitomizes these ideals—Mortimer E. Cooley.



Engineering laboratories as of 1885.



Adjusting apparatus in test chamber of supersonic wind tunnel for studies in wind streams up to 3,000 miles per hour, aeronautical engineering.

GENERAL INFORMATION

Engineering has been defined as "the art and science by which the properties of matter and the sources of power in nature are made useful to man in structures, machines, and manufactured products."

To produce the structures, machines, and products of industry requires the application of scientific knowledge, the management of men, and the utilization of natural resources. The engineer is a practitioner. He brings to bear on each problem all available science and experience or judgment to arrive at the best practical solution. He combines knowledge of what to do and how to do it with understanding of why he is doing it and of the significant results of his actions. He becomes not only an interpreter of science in terms of material human needs, but also a manager of men, money, and materials in satisfying these needs.

Only through continued practice or exercise of judgment can one acquire the stature of an engineer. The successful engineer must develop sound judgment by his willingness to try, to recognize failures, and to keep on trying until he arrives at a satisfactory solution.

The educational objective of the College of Engineering is to prepare its students to take positions of leadership commensurate with their abilities in a world where science, engineering, and human relations are of basic importance. The programs are specially planned to prepare them, according to their aptitudes and desires, to become practicing engineers, administrators, investigators, or teachers. But the useful knowledge and mental discipline gained from such educational programs are so broad and fundamental as to constitute excellent preparation for other careers. The undergraduate programs lay a sound foundation of science, sufficiently broad and deep to enable graduates to enter understandingly into scientific investigation in the several fields of engineering and, at the same time, to impart such knowledge of the usual engineering practice as will make graduates immediately useful in any subordinate position to which they may be called.

Doing is an essential phase of engineering education, and laboratory work under the supervision of those who have had professional experience as well as full scientific background has always been the practice at Michigan. The faculty are encouraged to be active in research and professional practice with the aim of improving their teaching and keeping informed on new developments in their fields of the profession.

Experience has clearly demonstrated that teaching, particularly in science and its applications, reaches its highest type only in an atmosphere of research and steady progress in more thorough understanding of the subjects taught. Such teaching is at its best when the student and teacher work together in developing new relationships of fundamental scientific nature or better and more economical ways of applying scientific knowledge to the problems of industry and the public welfare. Graduate and undergraduate students are given an excellent opportunity to take part in such activities in the well-equipped engineering laboratories, in the field, and in the Engineering Research Institute. This was established as the Department of Engineering Research in 1920, for the purpose of encouraging research in engineering and as an agency for stimulating co-operation with industry and for making the abilities of the staff and the facilities of the University more readily available for public service.

To profit satisfactorily by an engineering education, the student should have mental ability and alertness of a high order, good health, and perseverance. The plainest indication of such ability is evident in superior grades in high school, particularly in mathematics and science. A serious mistake is frequently made in regarding manual dexterity and ingenuity or an interest in mechanical things as an indication of engineering ability.

The choice of a career is a most important one and should be based on sound and complete information and on guidance.* The admissions officer of the University and the officers and program advisers of the College of Engineering will gladly be of any possible service in this connection.

* Such information may be obtained from the pamphlet, *Engineering as a Career,* prepared by the Engineers' Council for Professional Development, 29 West 39th Street, New York City, and through local engineering societies and high-school principals.

COLLEGE OF ENGINEERING

HARLAN HATCHER, Ph.D., Litt.D., LL.D., *President of the University*
MARVIN LEMMON NIEHUSS, A.B., LL.B., *Vice-President and Dean of Faculties*
GEORGE GRANGER BROWN, Ph.D., Ch.E., *Dean of the College of Engineering*
WALTER JOHNSON EMMONS, B.S., A.M., *Assistant Dean and Secretary of the College of Engineering*

Facilities

The physical facilities of the University for instruction, housing, health, recreation, physical education, and athletic activities are described in the bulletin entitled *General Information,* available upon request.

The WEST ENGINEERING BUILDING (1904) contains the offices of the College; one division of the engineering libraries; the hydraulic, sanitary, and structural laboratories of civil engineering; the general mechanical engineering laboratory which includes the engines, turbines, pumps, fans, compressors, and pertinent hydraulic machinery; the fluid mechanics and physical testing laboratories with their special equipment for engineering mechanics; drafting and computing rooms; and the 360-foot naval tank with dynamometers for testing ship models.

Directly across the street, the EAST ENGINEERING BUILDING (1923) houses the machine-tool laboratory of more than one hundred modern types of machine tools; the machinability laboratory fully equipped with dynamometers; the gaging and measuring laboratory; a complete foundry and melting laboratory; metal-working, welding, heat treating, spectrographic (mass, infrared, ultraviolet, etc.), and metallographic laboratories; the X-ray laboratory equipped for radiography and diffraction studies for metallurgical and production engineering; process operations laboratory; catalytic pilot plants; the petroleum, gas, electrochemical, high pressure, paper, paint and varnish, plastics, and measurements laboratories of chemical engineering; the transportation and other libraries; and the highway and soil mechanics laboratory. The EAST ENGINEERING ADDITION (1947) contains two subsonic wind tunnels, a supersonic jet, structures, propulsion, and instrumentation laboratories of aeronautical engineering; the electrical machinery, communications, photometric electronics, servomechanisms and other laboratories of electrical engineering.

The ENGINEERING ANNEX (1885; and additions) houses the automotive and internal combustion engine laboratories and the motion and time study laboratories.

Buildings at the WILLOW RUN AIRPORT contain the Lake Hydraulics Laboratory equipped with a large wave tank and wave-making machine and the instruments required for the study of problems arising from the action of water along shores; a supersonic wind tunnel capable of attaining a Mach number of 4.5; a propulsion laboratory equipped with stands for testing various types of jet and rocket motors and with auxiliary equipment.

The University of Michigan was the pioneer in the establishment and maintenance of a camp for field work in surveying. The camp was organized in 1874 under the supervision of the late Professor J. B. Davis. Several sites were occupied in Michigan until 1929, when the University purchased land in Jackson Hole, Wyoming, for the location of the present camp.

CAMP DAVIS is situated in the valley of the Hoback River, twenty miles southeast of the city of Jackson, Wyoming, and seventy-five miles south of Yellowstone National Park. The elevation of the camp — more than six thousand feet above sea level — the nature of the surrounding area, and the climate combine to make this location nearly ideal for summer instruction in surveying and geology.

An outline of the work covered at the camp, and other information, may be obtained upon application to the Camp Director, Professor Harry Bouchard, 209 West Engineering Building.

Honor Code

"Honesty, justice, and courtesy form a moral philosophy which, associated with mutual interest among men, constitutes the foundation of ethics. As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers, and clients, and with fairness and impartiality to all."

In 1916, thirty years before this statement was published by the Engineers' Council for Professional Development and adopted as part of the Canons of Ethics by the national professional engineering societies, the students of the College of Engineering, with the approval of the faculty, established and adopted the following procedure:

All examinations and written quizzes in the College are held under the Honor System, the object of which is to create that standard of honor which is essential to a successful engineer and a good citizen. Students are expected to uphold the system or declare their unwillingness to do so after having been duly instructed in all its rules. The instructor does not remain in the room during an examination. The students are placed upon their honor to refrain from all forms of cheating and to reprimand a fellow student who acts suspiciously and, in case he does not take heed, to report him to the Honor Committee. Every student must write and sign the following at the end of his examination paper, if he had not asked for an examination under a proctor:

"I have neither received nor given aid during this examination."

The Honor Code recognizes the joint responsibility of instructor and student. It is a highly successful and respected tradition which has proved its value in the development of character and the ability of the student to assume responsibility.

Combined Programs with Other Institutions

The College of Engineering has agreements with Alma College, Albion College, Emmanuel Missionary College, Kalamazoo College, Western Michigan College of Education, and Central Michigan College of Education under which a student who has been in residence at one of these institutions for three years, and who has completed with a good record a prearranged program including substantially the work of the first two years of the College of Engineering, may be admitted to the College of Engineering, and after two additional years may be graduated in engineering.

Under this agreement these colleges accept the first year at the College of Engineering, if the record is satisfactory, in lieu of the senior year and grant the student his degree at that time.

Combined curriculums are offered with the College of Literature, Science, and the Arts of the University in the fields of chemical engineering and civil engineering. Each of these programs requires five years and one summer session for completion and leads to baccalaureate degrees in both the College of Engineering and the College of Literature, Science, and the Arts. Requirements are set forth on pages 31 and 37.

Students may be admitted with advanced standing from junior colleges or other institutions (see pages 19–20).

Placement

The young graduate from an engineering school must continue his education by internship in industry or professional work before he can develop into a fully competent engineer. For this reason, his first professional experiences after leaving school are of the greatest importance in his continued development, and the College of Engineering considers the proper placement of its graduates an essential part of its functions. When classifying as a senior or soon thereafter, each student is requested to fill out or prepare a number of copies of a personnel record to be filed with his program adviser or an especially designated member of the faculty.

Most of the leading companies which employ engineers visit the College at least annually for the purpose of recruiting engineers for their training programs and operations. Senior students are usually notified well in advance of these visits and so are enabled to discuss the various opportunities with members of the faculty and to indicate their preference for interviews. The representatives of the employers make arrangements for interviews with all students through the Dean's Office and the secretaries of the various departments in co-operation with the program advisers.

The interest of the College in the proper employment of its graduates by no means ceases when the student leaves the campus. Graduates are invited to file more comprehensive records and to correspond with their program advisers or other members of the faculty whenever they feel the College can be of assistance in helping to find a more suitable position.

Extracurricular Opportunities

Students at the University of Michigan enjoy many privileges outside of their classes as indicated in the bulletin *General Information.* Living a full life is an art, acquired by practice. The *Michigan Technic,* debating societies, orchestras, bands, sport groups, glee clubs, and other organizations provide excellent opportunities, and engineering students are encouraged to take an active part in them. They constitute an important part of University life after the day's work is well done.

The following organizations, many of them related to scholastic or professional interests, are among those available to students of the College of Engineering:

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, student chapter
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, student chapter
AMERICAN INSTITUTE OF METALLURGICAL ENGINEERS, student chapter
AMERICAN MILITARY ENGINEERS (U. of M. Post)
AMERICAN SOCIETY OF CIVIL ENGINEERS, student branch
AMERICAN SOCIETY OF MECHANICAL ENGINEERS, student branch
CHI EPSILON, national civil engineering honor fraternity
ETA KAPPA NU, national electrical engineering honor society
INSTITUTE OF THE AERONAUTICAL SCIENCES, student branch
Michigan Technic, a monthly magazine containing articles on technical subjects and other matters of interest to the College, staffed by engineering students
SIGMA XI, a national society devoted to the encouragement of research
PHI ETA SIGMA, national honor society for freshman men
PHI KAPPA PHI, national honor society for seniors of all schools and colleges
PI TAU PI SIGMA, national honor Signal Corps fraternity
PI TAU SIGMA, national mechanical honor fraternity
QUARTERDECK SOCIETY, student branch of Society of Naval Architecture and Marine Engineering
SAILING CLUB, an organization for dinghy sailing, iceboating, intercollegiate competition
SCABBARD AND BLADE, national R.O.T.C. honor fraternity
STUMP SPEAKERS' SOCIETY OF SIGMA RHO TAU, intercollegiate engineering speakers' society
TAU BETA PI, national engineering honor society
TRIANGLES, junior honor society
VULCANS, senior honor society

Scholarships, Fellowships, Prizes, and Student Aid

Numerous scholarships, fellowships, and prizes, as well as adequate loan funds, are available to the engineering students. A list of these, with the conditions governing them, is given in the special bulletins, *University Scholarships, Fellowships, and Prizes,* and *Student Loan Funds,* which are available upon request.

The Committee on Scholarships of the College has under its jurisdiction those scholarships and loan funds which have been established for the special benefit of students in engineering. Applications may be addressed directly to this committee.

Graduate students are frequently given the opportunity to teach in the capacity of teaching fellows.

A number of student assistants are also appointed each semester and assigned to work in the several departments. For the most part, these assistants are graduate students and seniors who are proficient along certain lines.

Fees and Expenses

Detailed information regarding registration and payment of fees, also directions for classification, may be obtained from the Secretary of the College.

Semester fees:	Michigan students	$ 90
	Non-Michigan students	215

The semester fees must be paid before classification, and no student can enter upon his work until after such payment.

Students are urged to provide themselves with money orders or travelers' checks to cover semester fees. For the convenience of students, the Cashier's Office will cash or accept in payment of semester or other University fees, money orders or travelers' checks. Personal checks will not be cashed but will be accepted for the exact amount of fees.

Semester fees are the students' contribution to the cost of class instruction, use of libraries, physical education privileges, membership in the Michigan Union or Michigan League, and medical attention from the University Health Service in accordance with regulations of the Health Service as given in the bulletin of *General Information.*

Reduced program fees. The election of nine hours or fewer is considered a reduced program. Before a student may elect such a program he must obtain permission from the Assistant Dean. Those electing such a reduced program must pay each semester the appropriate fee as set forth in the bulletin of *General Information,* which should be consulted for further information.

A student room in one of the residence halls for men.

At the University of Michigan surveying camp in the Teton mountains, Wyoming.

ADMISSION

Applicants for admission must be at least sixteen years of age. They must present satisfactory evidence of good moral character. Freshmen must present, on a form to be obtained from the Director of Admissions, the record of work done in the preparatory school attended. The transcript of academic record presented by students transferring from other colleges usually includes a satisfactory statement concerning character. Applications should be addressed to the Assistant Dean, College of Engineering.

Admission as a Freshman

Requirements for admission are stated in units, a unit being defined as a course covering an academic year and including in the aggregate not less than the equivalent of 120 sixty-minute hours of classroom work. Two to three hours of laboratory, drawing, or shopwork are counted as equivalent to one hour of recitation.

Applicants for admission as freshmen without entrance deficiency must present a minimum of fifteen units which shall include at least three units each from Groups A and B, two units from Group C, and three units from Group D.

	UNITS
A. ENGLISH	
At least three units are required	3
B. MATHEMATICS GROUP	
At least three units are required, including algebra, one and one-half units, plane geometry, one unit, and solid geometry, one-half unit	3
(In addition, trigonometry, one-half unit, is urgently advised, because, if not offered for admission, it must be elected in the first year of college.)	
C. SCIENCE GROUP	
Two units are required. This should consist of one unit of physics and one unit of chemistry but botany, zoology, or biology may be offered ..	2
D. REQUIRED GROUP	
Three units are required from a group consisting of foreign languages, botany, zoology, biology, history, economics, or additional English, mathematics, or chemistry. If foreign language is offered it must be chosen from Greek, Latin, French, German, or Spanish. Not less than one full unit of a foreign language will be accepted......	3

The remaining units required to make up the necessary fifteen units may be elected from among the subjects listed above and any others which are counted toward graduation by the accredited school.............	4
Total	15

Four units of English and four units of mathematics, including one-half unit of trigonometry, and one unit of chemistry should be presented whenever possible.

College credit is not given for work done in the high-school course, but adjustments in the work required for graduation from the University are made in accordance with a student's preparation and ability. Some acceleration is possible as stated under "Studies of the First Year."

Applicants who do not meet the preceding requirements for admission without deficiency are advised to consult the Director of Admissions concerning their particular problems. Deficiencies may be removed before the anticipated date of entrance, or may be satisfied by examination. When conditions warrant such action, provisional admission may be granted if not more than two units are lacking.

Candidates for admission who have passed College Board, New York Regents, or Canadian Matriculation examinations with satisfactory grades will be excused from further examinations in the subjects covered. All applications for examination by the College Entrance Examination Board must be addressed to its secretary, Box 592, Princeton, New Jersey, and must be made on a blank form which may be obtained from its secretary.

ADMISSION BY CERTIFICATE

Only those applicants are admitted by certificate who are officially recommended graduates of high schools accredited to this University and who have completed in a standard high school a full four-year curriculum covering at least fifteen units of acceptable entrance credit.*

In the recommendation of graduates for admission to the University, it is expected that principals of secondary schools will take into consideration the character, scholarship interests and attainments, seriousness of purpose, and intellectual promise of the individuals concerned. A grade of work distinctly above passing is presupposed.

The principals of accredited schools are urged to send direct to the Director of Admissions, as soon as reasonable after the junior year, upon the blank furnished by the University, the application of each prospective

* A bulletin containing a list of the accredited schools in the state of Michigan will be sent upon request to the Bureau of School Services, University of Michigan.

graduate intending to enter the freshman class at the beginning of the ensuing year. The applicant will be given a tentative report concerning his eligibility for admission, and it will be confirmed when the principal's supplementary report of the student's final work is received by the Director of Admissions. If the applicant's credentials are satisfactory, he will receive a certificate of admission to the University without examination, contingent only upon his satisfactory completion of the secondary school program and the passing of a medical examination at the time of registration.

Advanced Standing

A student in another college or university who intends to enter the College of Engineering with advanced standing should examine carefully the program which he intends to elect and arrange his work accordingly. The applicant must present to the Assistant Dean evidence of honorable dismissal from an approved college, together with an official transcript of his college work and preparatory studies. The transcript must show a scholastic average corresponding to at least a C grade in this College, and, for admission without deficiencies, he must satisfy the requirements for admission from high school.

The student is usually able to complete the required work in English, mathematics, physics, chemistry, physical education, the nontechnical subjects, and the work in drawing and engineering mechanics if his institution offers adequate instruction in these fields. The remaining requirements for graduation may then be completed in two years.

The student is urged to write to the adviser in the program he wishes to elect for advice and for information not found in this *Announcement.* The Assistant Dean of the College of Engineering will be glad to give information concerning admission requirements or other matters of a general nature.

A graduate of the University or of an approved college is admitted without examination to advanced standing as a candidate for a degree in engineering. He should present to the Assistant Dean an official certificate of graduation—not a diploma—and an official transcript of his studies. If the course completed has covered substantially the equivalent of the required work in the first three years of the program he desires to follow at the University of Michigan, he may be admitted as a senior. The courses to be taken during residence at the University will depend on the program concerned. Upon the satisfactory completion of such courses, covering at least one year's residence and 30 hours of credit, the student will be recommended for the degree of Bachelor of Science in Engineering.

A student who has completed at least one year of work with a satisfactory grade average in an approved college may be admitted to advanced standing without examination.

A student who has not completed a year's college work in an approved college, but before entering the University has pursued studies beyond those required for admission, may be admitted to advanced standing. Entrance requirements in such cases may be satisfied by complying with the conditions stated on pages 17–18.

ADJUSTMENT OF ADVANCED CREDIT

At the time of admission, records of studies taken elsewhere are reviewed by representatives of the several teaching departments of the College, or by the Assistant Dean in the cases of certain nonengineering subjects. Advanced credit is allowed as appears justified but is granted upon a tentative basis, subject to review and revision if, at any time, it develops that the student is unable to continue successfully with more advanced studies because of inadequate preparation. In general, credit will not be allowed for courses with a D or other low grade.

Advanced credit is adjusted in terms of semester hours completed without scholastic grade being assigned to this credit. The student's scholastic average is determined by grades earned while he is enrolled in this College.

Credit for experience is generally not granted. When experience in industry closely parallels the content of a required course, however, the student may be excused from taking such course, thus gaining time for the election of courses in which he is interested.

Applicants for advanced credit should apply at the time of admission at Room 259, West Engineering Building. It is desirable that credentials should be submitted as far in advance of registration week as practicable. Students desiring advanced standing in drawing must bring all drawings completed previous to entrance.

Special Students

Students who are pursuing work in college, and who are not candidates for a degree, are designated special students.

Persons over twenty-one years of age who wish to pursue particular studies in engineering, and who show by examination or by the presentation of satisfactory certificates that they are prepared to do good work in the selected courses, may be admitted as special students on the recommendation of the adviser of the program in which they wish to study. The object of this rule is to enable young men who are beyond the high-school age to secure technical training along special lines when they are properly prepared for the work. Two or more years of successful experience as teacher, draftsman, surveyor, engineer, or operative in engineering work will be given considerable weight in determining the fitness of the candidate. In general, a good working knowledge of English, algebra, and geometry is required for success in engineering studies. Applicants for admission as special students should send as early as possible to the program adviser concerned letters of recommendation, certificates of scholarship, and an exact statement of the courses desired. They should state their age, education, and experience and should bring drawings to demonstrate their experience and ability.

College graduates are also admitted as special students and may take those courses for which their preparation is sufficient.

Special students pay the same fees as regular students. Their work is assigned and regulated by the adviser for the program in which they register.

A special student may become a candidate for a degree by fulfilling the regular requirements for admission. See pages 164–65.

A student who is a candidate for a degree cannot become a special student without the permission of the faculty.

Veterans

Veterans who have special admission problems are invited to write to the Assistant Dean for advice.

STUDIES OF THE FIRST YEAR

Work during the first year, as far as subjects are concerned, is the same for all students who enter without deficiencies. After the first year, each student indicates the field in which he expects to practice and is then enrolled in the appropriate program.

The variation among the several programs is not so pronounced as to make transfer difficult in the second year should the student decide that he wishes to do so. Subsequently, however, differences between the programs become increasingly apparent, and transfer from one to another becomes increasingly difficult and will generally delay graduation.

Programs leading to the several degrees and typical semester schedules for the second and succeeding years will be found in the following section.

The scholastic requirements for graduation are expressed in terms of the quality and level of attainment reached by the student and not in terms of the total number of credit hours acquired in college. *The basic level of attainment* required of all students in every program is demonstrated ability in English, drawing, mathematics, chemistry, physics, and materials equivalent, respectively, to the satisfactory completion of the following courses: English 11, 12, and 21, Drawing 1 and 2, Mathematics 54, Chemistry 5E, Physics 46, Chemical and Metallurgical Engineering 1. In addition, the student must complete the specific program of courses, or their equivalent, required in his elected degree program with an average of C (2.0) or more in all courses taken while enrolled in the College.

The schedule of studies for first-year students is usually as outlined below. Modifications are necessary for those who enter with deficiencies in admission requirements. Modifications are also permitted, and, in fact, are encouraged in accordance with the ability and preparation of the student.

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
Math. 13 (or 17)	4	Math. 14 (or 18)	4
English 11	3	English 12	2
English 21	1	English (Group II)	2
Drawing 1	3	Drawing 2	3
Chem. 5E (or 1 or 3)	5 or 4	Ch. and Met. 1	5
or Ch.–Met. 1	5	or Chem. 5E (or 4 or 6)	5 or 4
Assembly	0	Assembly	0
Phys. Ed.	0	Phys. Ed.	0
	16 or 15		16 or 15
Air. Sci.	2	Air. Sci.	2
Mil. Sci.	2	Mil. Sci.	2
Nav. Sci.	3	Nav. Sci.	3

This schedule assumes that at least 1½ units of algebra, solid geometry, and trigonometry have been taken in high school.

The tabulation on page 24 indicates the required courses at the University for those entering with various degrees of preparation in mathematics and chemistry.

As indicated, it is clearly to the advantage of the high-school student to elect, if available, a full 4-unit program in mathematics through college algebra, or at least a 3½-unit program including trigonometry. He should also elect one unit of chemistry and one of physics.

By carefully planning his high-school program, a superior student may materially decrease the time required to graduate from the University. Depending upon his preparation and ability, as indicated by high-school standing and orientation period examinations, he may save six credit hours in the mathematics sequence and three credit hours in chemistry. He would then be able to graduate with but 131 credit hours instead of the 140 credit hours required of the average entering freshman. This, alone, represents the saving of the equivalent of a summer session or a semester of half-time work. In addition, students who have attained a sufficiently high degree of proficiency in English composition and speech, drawing, and other subjects in which attainment levels are stated in the several degree programs may be able to save additional time in the completion of their degree requirements.

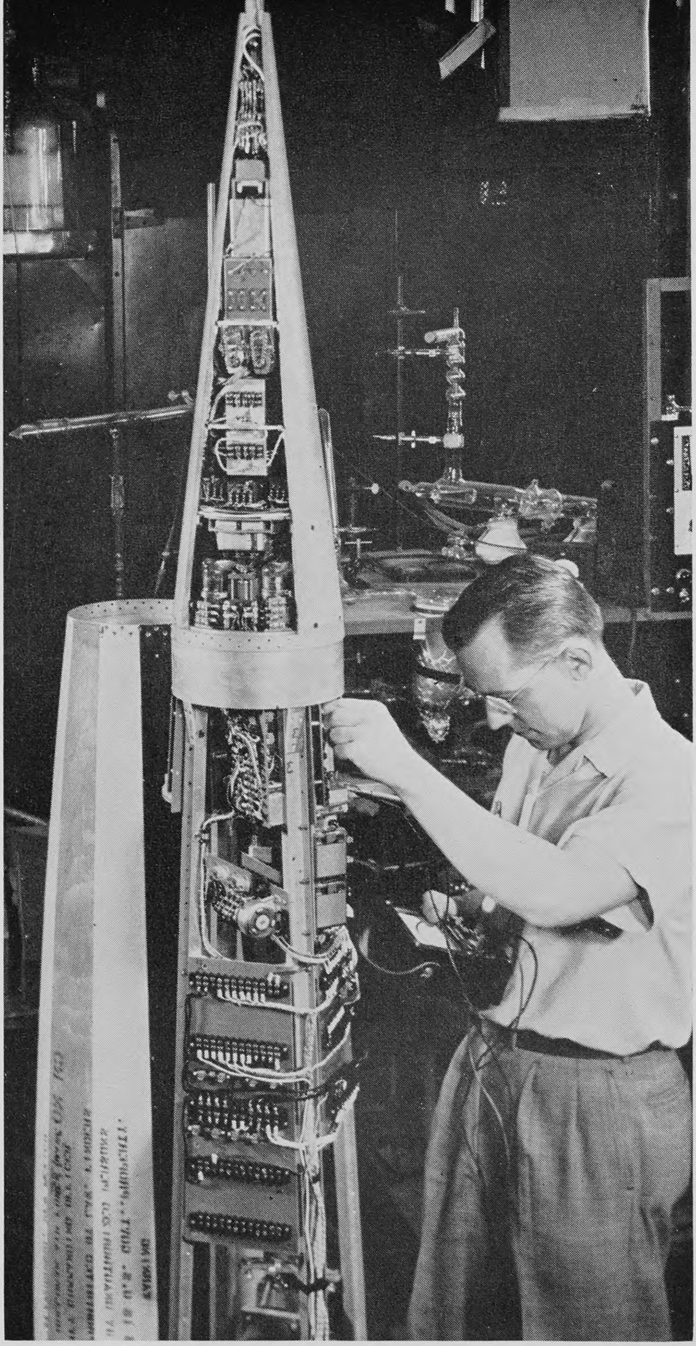
Students planning to take chemical, materials, or metallurgical engineering may facilitate their progress by electing Chemistry 5E, five hours, in the first semester and Chemistry 23, four hours, instead of English Group II in the second semester. They must then take, at a later time, English Group II. An alternate procedure is to elect Chemistry 11 and 12 during the first year for a total of eight hours. This program makes it possible to elect Chemistry 41 during the first semester of the second year and to elect subsequent courses marked "x" at an earlier semester than is indicated.

Physical education twice a week throughout the year (without credit in hours) is required of all first-year students, unless air or military science is elected as a substitute. Enrollment in air or military science is for a period of four semesters.

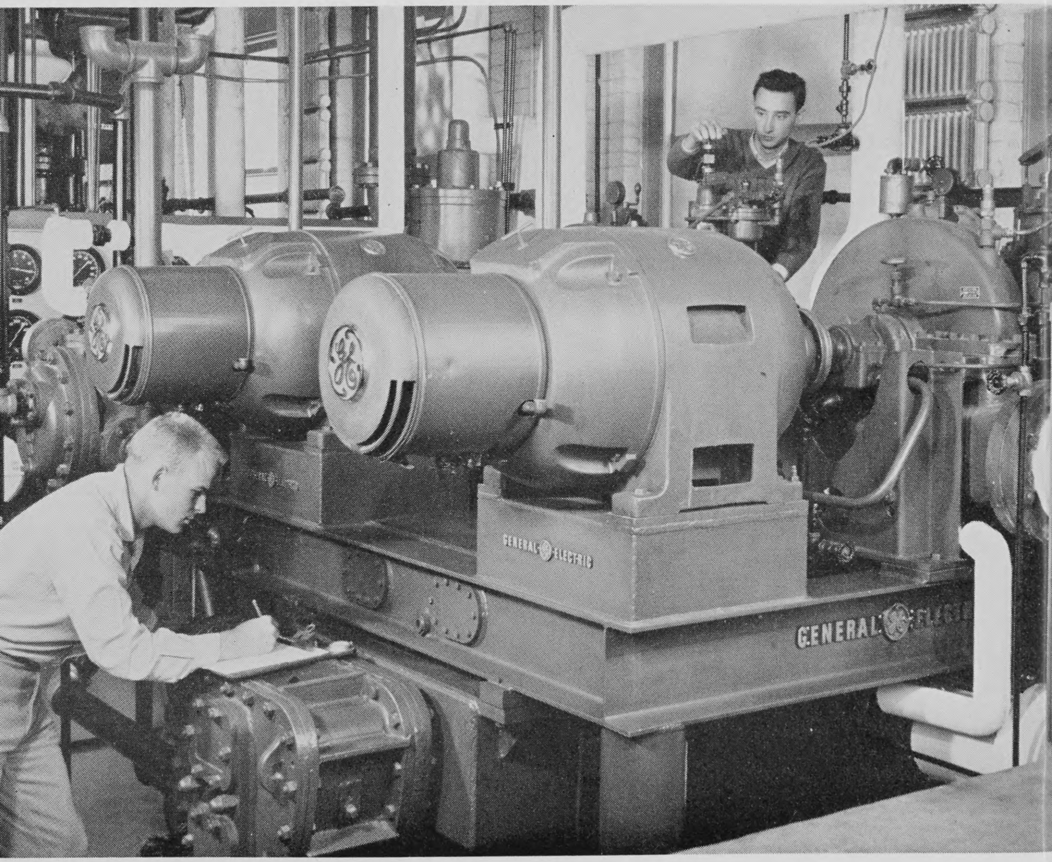
Enrollment in one of the ROTC programs is not required. If elected, hours of credit in air, military, and naval science will be recorded as stated above.

The classifier in consultation with the student will arrange a schedule intended to adjust irregularities as quickly as possible. Students are required to remove all admission deficiencies during their first year, unless granted an extension of time.

Units Presented			Comments	Student to Elect (See course descriptions)	Total Hours to Elect	Hours Saved
Alg.	Geom.	Trig.				
1	1	0	Minimum for admission	Math. 6, 7, 13, 14, 53, 54	22	–4
1	1½	0		Math. 7, 13, 14, 53, 54	20	–2
2	1	0		Math. 6, 8, 13, 14, 53, 54	20	–2
1½	1½	0	Meets admission requirements	Math. 8, 13, 14, 53, 54	18	0
2	1½	0		Math. 8, 13, 14, 53, 54	18	0
2	1	½		Math. 6, 13, 14, 53, 54	18	0
1½	1½	½		Math. 13, 14, 53, 54	16	+2
2	1½	½	Moderate ability	Math. 13, 14, 53, 54	16	+2
			Superior ability	Math. 17, 18, 54	12	+6
Chemistry not offered			Ability unknown	Chem. 1, followed by Chem. 4 or 6	8	0
Chemistry 1 unit			Moderate ability	Chem. 3, followed by Chem. 4 or 6	8	0
Chemistry 1 unit			Superior ability	Chem. 5E	5	+3



Internal mechanism of a meteorological rocket. These instruments and the electronic equipment provide automatic radio transmission of information to monitoring devices on the ground, aeronautical engineering.



Twin turbine unit, mechanical engineering.

UNDERGRADUATE DEGREE PROGRAMS

The programs in aeronautical, chemical, civil, electrical, mechanical, metallurgical engineering, engineering mechanics, industrial engineering, naval architecture, and marine engineering are accredited by the Engineers' Council for Professional Development. The program in materials engineering has been offered since 1951.

The degree programs in mathematics and physics emphasize basic sciences and include options in engineering to be selected by the student. A qualified student who wishes to broaden or extend his background is permitted to become a candidate for a degree in one of these programs in addition to that in the engineering program of his major interest. See Requirements for Graduation, page 164.

ATTAINMENT LEVELS AND PROFESSIONAL SUBJECTS. As stated under Studies of the First Year, graduation requirements are expressed in terms of attainment rather than in terms of a fixed number of credit hours. Attainment levels have been established in certain basic areas which are the same for all degree programs. Students entering with normal high-school preparation may expect to graduate with 140 credit hours. The degrees of attainment in the several subjects will be determined from a consideration of records of scholastic work supplemented, generally, by examinations given during the orientation week which precedes the opening of each semester.

Courses taken at other recognized colleges or universities, if passed with at least a "C" grade, will receive credit here if equivalent to courses required by the student's degree program.

GROUP OPTIONS AND ELECTIVE STUDIES. The system of group options and electives allows the student to follow his particular interests and aptitudes by electing certain optional studies within the degree program in which he is enrolled or to elect work for which he is qualified in other departments of engineering or in other colleges or schools of the University, subject to the approval of his classifier or program adviser. In this way the student may receive instruction from specialists and plan in advance for possible graduate studies in some special field, in cognate sciences, in economics, or in business administration. The plan permits the greatest freedom of choice of subjects consistent with the acquisition of a sound background and a desirable breadth of education in the chosen fields.

Aeronautical Engineering

Adviser: Professor Conlon

The program in aeronautical engineering has been arranged to cover all problems entering into the design, construction, and test of aircraft. It also includes a study of general aerodynamics, the determination of the strength of structures, and the general design of components of aircraft. Studies in the field of propulsion include the aerodynamic design of propellers, turbo and ram jet motors, and the design of rocket motors.

The program is arranged to cover the essentials of aerodynamics necessary for the proper understanding of the behavior of airfoils and propulsion devices and of problems connected with stability and maneuvering. The fundamentals thus developed constitute the basis of design, construction, and performance analysis of all types of aircraft.

By a proper choice of electives approved by the program adviser the student may emphasize aerodynamics, propulsion, structures and design, or instrumentation.

Studies in the field of instrumentation include principles of measurements, data transmission, automatic control, and systems analysis.

Courses in meteorology are offered in the Department of Geology. Courses in air navigation are offered in the departments of Astronomy and Mathematics.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Aeronautical Engineering) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or 2 four-hour courses	5–8
Draw. 1 and 2	6
Physics 45 and 46	10
Ch. and Met. 1 and Prod. Eng. 1	5
Total, normally	44–53

B. Professional subjects and electives:	HOURS
Drawing 3, Advanced Engineering Drawing	2
English, Group II and Group III	4
Econ. 53, 54, General Economics	6
*Math. 57, Differential Equations	2
Prod. Eng. 31, Machining I*a*	2
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Merh. 4, Fluid Mechanics	3
Mech. and Ind. Eng. 82, Elements of Machine Design	3
Mech. and Ind. Eng. 105, Thermodynamics I	3
Elec. Eng. 5, Direct- and Alternating-Current Apparatus and Circuits	4
Aero. Eng. 1, General Aeronautics	3
Aero. Eng. 101, Airplane Design	3
Aero. Eng. 110, Fundamentals of Aerodynamics	5
Aero. Eng. 111, Theory and Design of Propellers	3
Aero. Eng. 112, Experimental Aerodynamics	1
Aero. Eng. 113, Aircraft Performance	3
Aero. Eng. 130, Basic Airplane Structures	3
Aero. Eng. 132, Airplane Structures Laboratory	1
Nontechnical electives	6
Group options and electives	19
Total, professional subjects and electives	87

SUGGESTED SCHEDULE

For common first-year schedule see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Electives	3	Aero. Eng. 1	3
	17		17

* With special permission of the program adviser, students may elect an advanced technical course in place of Math. 57.

SUMMER SESSION	HOURS
Eng. Mech. 3	3
Elec. Eng. 5	4
	—
	7

FIFTH SEMESTER	
Math. 57	2
Aero. Eng. 130	3
Aero. Eng. 132	1
Aero. Eng. 111	3
Mech. and Ind. Eng. 105	3
Aero. Eng. 110	5
	—
	17

SIXTH SEMESTER	HOURS
Mech. and Ind. Eng. 82	3
Econ. 53	3
Eng. Mech. 4	3
Prod. Eng. 31	2
Electives	6
	—
	17

SEVENTH SEMESTER	
English (Group III)	2
Aero. Eng. 113	3
Econ. 54	3
Aero. Eng. 112	1
Group Option	3
Electives	5
	—
	17

EIGHTH SEMESTER	
Aero. Eng. 101	3
Electives	8
	—
	11

Chemical Engineering

Adviser: Professor Katz

Chemical engineering is concerned mainly with the development and application of manufacturing processes in which chemical or certain physical changes of materials are involved. The chemical engineer is essentially a process engineer and is concerned primarily with the design, construction, and operation of equipment and plants in which these processes take place.

Certain basic or unit operations such as fluid flow, heat transfer, evaporation, filtration, distillation, crushing, extracting, and drying are common to the processing of different materials in most industries. Any manufacturing process with which the chemical engineer deals is made up of a sequence of such operations. Knowledge of these unit operations and their commercial applications is one of his distinguishing characteristics.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Chemical Engineering) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two four-hour courses*	5–8
Draw. 1, 2	6
Physics 45, 46	10
Ch. and Met. 1	5
Total, normally	44–53

B. Professional subjects and electives:

Drawing 3	2
English, Group II and Group III	4
Economics 153, 173	6
Eng. Mech. 5, Statics, Strength, and Elasticity	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D. C. and A. C. Apparatus and Circuits	4
Mech. and Ind. Eng. 109, Heat, Power, and Refrigeration	3
Chemistry 23, 41, Introductory Analytical	4–8*
Chemistry 61, 161R, Organic	8
Chemistry 83E, Physical	4
Ch. and Met. 2, Engineering Calculations	3
Ch. and Met. 16, Measurements Laboratory	3
Ch. and Met. 111, Thermodynamics	3
Ch. and Met. 113, Unit Operations	4
Ch. and Met. 115, Unit Operations Design	3
Ch. and Met. 117, Metals and Alloys	3
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 121, Design of Process Equipment	2
Ch. and Met. 129, Engineering Operations Laboratory	3
Ch. and Met. 130, Chemical Process Design	3
Nontechnical electives	6
Group options and electives	5†
Total, professional subjects and electives	83–87

* Students who elect Chemistry 11 and 12 under (A) are not required to elect 23.

† Advanced courses in air, military, or naval science, approved by the program adviser, may be used as option electives but the basic courses (100 or 200 series) will not be accepted.

SUGGESTED SCHEDULE*

For common first-year schedule see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Draw. 3	2	Ch. and Met. 2	3
Physics 45	5	Physics 46	5
xChem. 23	4	xChem. 41	4
	15		16

SUMMER SESSION	
Eng. Mech. 5	4
Chem. 83E	4
	8

FIFTH SEMESTER		SIXTH SEMESTER	
xChem. 61	6	xChem. 161R	2
Ch. and Met. 16	3	Ch. and Met. 115	3
Ch. and Met. 111	3	Ch. and Met. 118	3
Ch. and Met. 113	4	Econ. 173	3
		Mech. and Ind. Eng. 109	3
	16	Eng. Mech. 3	3
			17

SEVENTH SEMESTER		EIGHTH SEMESTER	
Ch. and Met. 117	3	Ch. and Met. 121	2
Ch. and Met. 129	3	Ch. and Met. 130	3
Elec. Eng. 5	4	English, Group III	2
Econ. 153	3	Electives	8
Electives	3		15
	16		

COMBINED PROGRAMS

CHEMICAL ENGINEERING AND METALLURGICAL ENGINEERING

Degrees in both chemical and metallurgical engineering may be earned by taking the courses, or their alternates, required for both degrees. Students in the chemical engineering program who desire to earn a degree in metallurgy

* The program may be completed in eight semesters without a summer session if seventeen- to eighteen-hour semester schedules can be carried successfully and the sequences are carefully planned. Qualified students may elect the Math. 17, 18, 54 sequence to reduce the total hours. Also the election of Chem. 11 and 12 or Chem. 5E and 23 during the first year will permit advancing the courses marked x by one semester.

as well, will find that they must add Ch.-Met. 13, 119, and 124, and elect Ch.-Met. 127 and 128 rather than Ch.-Met. 117 for a total of eleven hours for additional courses. Students in the metallurgical program who desire to earn a degree in chemical engineering as well must elect Chem. 61 and 161R instead of 61R; Ch.-Met. 113 and 115 instead of Ch.-Met. 114; and Ch.-Met. 130 in addition for a total of ten extra hours.

CHEMICAL ENGINEERING AND CHEMISTRY

Advisers: College of Literature, Science, and the Arts, Associate Professor Hodges; College of Engineering, Professor Schneidewind.

Combined degrees are offered in chemistry (B.S., College of Literature, Science and the Arts) and in chemical engineering (B.S.E. [Chem.], College of Engineering).

This program aims to supply the demands of industry and of students for a strong curriculum in chemistry and in chemical engineering. It is also excellent preparation for further graduate study and for research or development.

During the first four semesters the student is under the complete jurisdiction of the College of Literature, Science, and the Arts. After completing the work of the first four semesters the student is under the complete jurisdiction of the College of Engineering. After satisfactorily completing all the course requirements listed below the student will be granted the two degrees, B.S., and B.S.E. (Chem.).

Candidates for the degrees of Bachelor of Science in Chemistry in the College of Literature, Science, and the Arts and Bachelor of Science in Engineering (Chemical Engineering) in the College of Engineering are required to complete the following program:

	HOURS	HOURS
HUMANITIES GROUP		18
English 1, 2	6	
German 1, 2, 35	12	
If any of this German is satisfied by entrance credits, an equivalent amount of work in foreign language must be substituted.		
MATHEMATICS AND SCIENCE GROUP		63 (or 71)
Chemistry 11, 12, (or 3, 4, 23), 41 (5 hrs.), 61, 141 (4 hrs.), 161, 182, 183, 184, 185, 186, 191	41 (or 45)	
Physics 45, 46	10	
Math. 13, 14, 53, 54; or 17, 18, 54	16 (or 12)	

	HOURS	HOURS
SOCIAL SCIENCES GROUP*		12
Econ. 53, 54, 173	9	
Electives	3	
ENGINEERING COURSES		54
Eng. Mech. 3, 5	7	
Mech. and Ind. Eng. 109	3	
Elec. Eng. 5	4	
Drawing 1, 2, 3	8	
Ch. and Met. Eng. 1, 2, 111, 113, 115, 117, 118, 121, 129, 130	32	
ELECTIVES†		9
Not more than 44 hours of courses in the Department of Chemistry may be counted toward the degree.		
Total		156 (or 164)

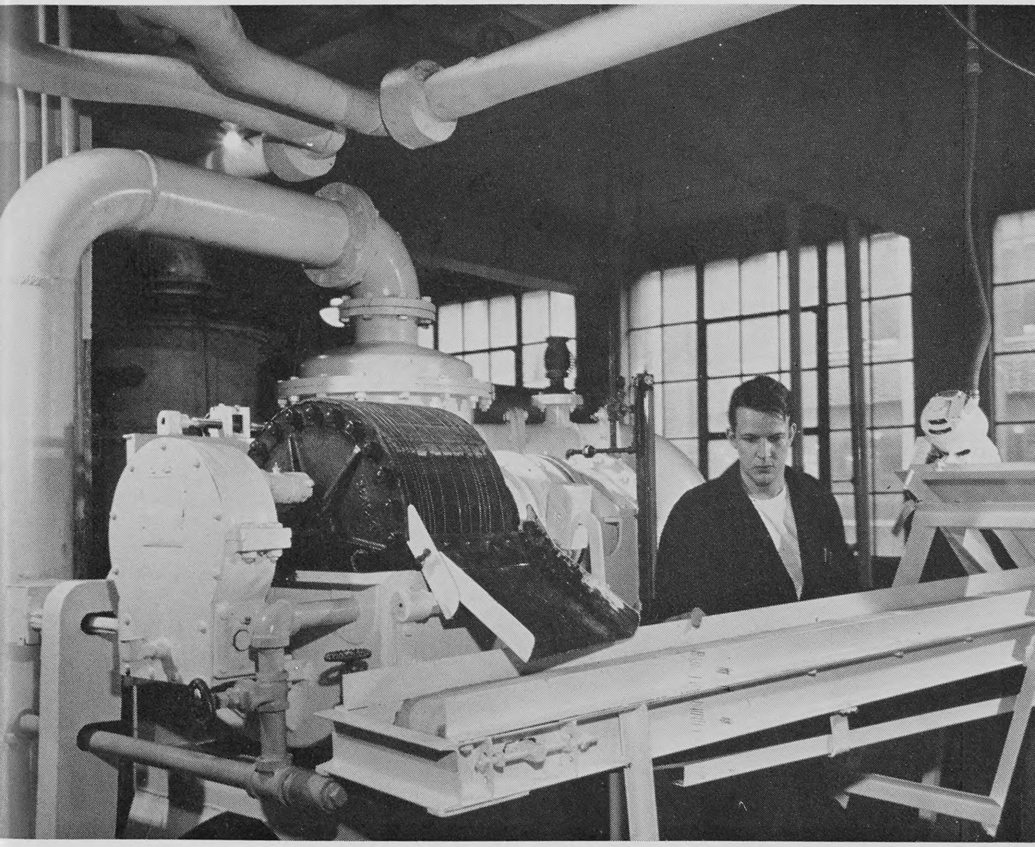
Civil Engineering

Adviser: Professor Boyce

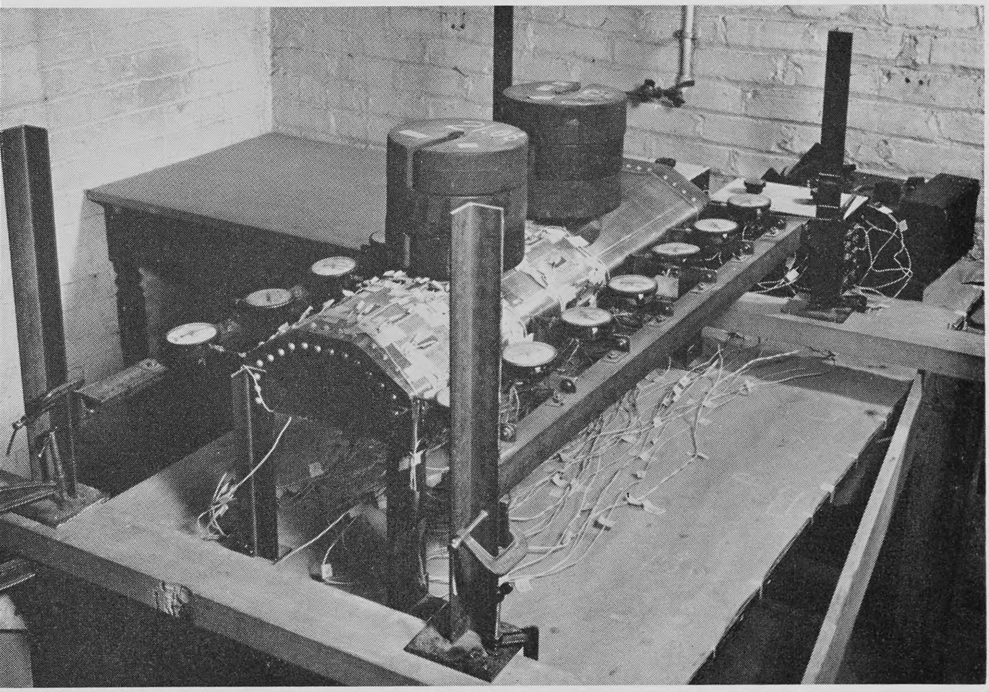
Civil engineers plan, design, and supervise the construction of roads, railroads, harbors, buildings, tunnels, waterways, bridges, dams, airfields, canals, water supply and sewerage systems, and the many other facilities necessary for public works and industrial development. They plan the conservation, utilization, and control of water resources. They operate in the field of surveying and mapping. The nature, size, and cost of such projects require that the civil engineer work either directly for city, state, or other governmental agencies, or indirectly for these agencies through engineering firms, or for utility or other companies large enough to finance such undertakings. The wide range of activities of the civil engineer requires a broad foundation in engineering sciences with a limited amount of specalization in the junior and senior years in one of the following fields:

* Econ. 173 and 153 may be substituted; in this case electives in social sciences will total six hours.

† Not more than five hours of free electives may be used for advanced ROTC work.



Rotary vacuum filter, chemical engineering.



Strain gage measurements of stresses in a scale model of a roof truss, civil engineering.

CONSTRUCTION ENGINEERING. The methods and techniques of modern construction. Fundamental principles of construction applicable to all types of engineering structures. Principles of business management as applied in the field of engineering contracting.

HIGHWAY ENGINEERING. Location, design, construction, and maintenance of various types of roads and streets, including materials, surveys, plans, specifications, economics, financing, and administration.

HIGHWAY TRAFFIC ENGINEERING. Methods of increasing the efficiency and safety of traffic movement. Traffic surveys, geometrical design of urban and rural highways, traffic control devices, and other means of regulating and controlling the use of highways.

HYDRAULIC ENGINEERING. The application of the fundamental principles of hydraulics and hydrology to the development of water power, flood control, drainage, the improvement of rivers and harbors, and other hydraulic structures. Laboratory facilities and instruction are offered for students who wish to engage in research work in hydrology and hydraulics that will lead to advanced degrees.

RAILROAD ENGINEERING The design, construction, and operation of railroad properties, including metropolitan terminals, statistical analysis of operating data, freight and passenger traffic, economics, financing, administration, and regulation.

SANITARY ENGINEERING. The planning, construction, and operation of waterworks, sewerage and drainage systems, water-purification plants, and works for the treatment and disposal of city sewage and industrial wastes; improvement and regulation of natural waters for purposes of sanitation; air sanitation; and principles and standards of ventilation.

STRUCTURAL ENGINEERING. The theory, design, and construction of structures, such as bridges, buildings, dams, retaining walls, and reservoirs, involving the use of steel, reinforced concrete, and lumber. The testing and utilization of soils in foundations and subsurface construction.

GROUP OPTIONS AND ELECTIVES. As early as practicable the student should select that division of civil engineering in which he may have a major interest and confer with the adviser for that option relative to the completion of his program.

REQUIREMENTS

Candidates for the degree of Bachelor of Science (Civil Engineering) are required to complete the following:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Draw. 1, 2	6
Physics 45, 46	10
Ch. and Met. 1 and Prod. Eng. 1	5
Total, normally	44–53

B. Professional subjects and electives:

Civ. Eng. 1, 2, 3, Surveying	11
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Elec. Eng. 5, Electrical Apparatus and Circuits	4
Mech. and Ind. Eng. 13, Heat Engines	4
Civ. Eng. 20, Structural Drafting	2
Civ. Eng. 22, Theory of Structures	3
Civ. Eng. 23, Elementary Design of Structures	3
Civ. Eng. 30, Concrete Mixtures	1
Civ. Eng. 50, Fundamentals of Sanitary Engineering	2
Civ. Eng. 60, Highway Engineering	2
Civ. Eng. 70, Railroad Engineering	2
Civ. Eng. 121, Reinforced Concrete	3
Civ. Eng. 140, Hydrology	3
Civ. Eng. 141, Hydraulics	2
Civ. Eng. 151, Water Supply and Sewerage	3
Civ. Eng. 180, Specifications and Contracts	2
Geol. 11 or 99	4
*Econ. 153, 173	6
Nontechnical electives, including one course each from English, Group 11 and Group III, and another nontechnical course	6
Group options and electives	10
Total, professional subjects and electives	87

* Econ. 53 and 54 may be elected instead of Econ. 153 and 173.

GROUP OPTIONS AND ELECTIVES

One of the following groups, each including a design course, should be selected by the student. Substitution for any other than the design course is subject to the approval of the program adviser.

CONSTRUCTION ENGINEERING

Adviser: Associate Professor Alt

	HOURS
Civ. Eng. 131, Cost Analysis and Estimating	2
Civ. Eng. 132, Construction Methods and Equipment	3
Choice of a civil engineering design course	3

HIGHWAY TRAFFIC ENGINEERING

Adviser: Associate Professor Kohl

Civ. Eng. 165, Highway Traffic Engineering	2
Civ. Eng. 166, Highway Traffic Surveys	2
Civ. Eng. 169, Highway Design	3

HIGHWAY ENGINEERING

Adviser: Professor Emmons

Civ. Eng. 161, Highway Materials	3
Civ. Eng. 167, Highway Economics	2
Civ. Eng. 169, Highway Design	3

HYDRAULIC ENGINEERING

Adviser: Professor Brater

Civ. Eng. 143, Advanced Hydraulics	3
Civ. Eng. 146, Hydraulic Engineering Design	3
Choice of either:	
Civ. Eng. 142, Water Power Engineering	2
Civ. Eng. 144, Hydraulic Structures	3

RAILROAD ENGINEERING

Adviser: Professor Sadler

Civ. Eng. 172, Railroad Maintenance	2
Civ. Eng. 173, Terminal Design	3
Civ. Eng. 176, Economics of Railroad Construction and Operation	2

SANITARY ENGINEERING

Adviser: Assistant Professor Borchardt

	HOURS
Bacteriology 51 or 111E	4
Civ. Eng. 154, Sanitary Engineering Design	3
Civ. Eng. 156, Sanitary Engineering Laboratory	2

STRUCTURAL ENGINEERING

Adviser: Professor Sherlock

Civ. Eng. 122, Advanced Theory of Structures	3
Civ. Eng. 123, Design of Structures	3
Choice of either:	
Civ. Eng. 124, Rigid Frame Structures	3
Civ. Eng. 135, Applied Soil Mechanics	3

The elective hours may be filled by suitable courses offered by any department in the University, subject to the approval of the program adviser.

SUGGESTED SCHEDULE

For common first-year schedule see page 22.

THIRD SEMESTER	HOURS
Math. 53	4
Physics 45	5
Civ. Eng. 1	3
Eng. Mech. 1	3
Civ. Eng. 20	2
	17

FOURTH SEMESTER	HOURS
Math. 54	4
Physics 46	5
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Civ. Eng. 2	4
	18

SUMMER SESSION (at Camp Davis)	
Civ. Eng. 3	4
Geol. 11 or 99	4
	8

FIFTH SEMESTER	
Civ. Eng. 30	1
Eng. Mech. 3	3
Eng. Mech. 4	3
Civ. Eng. 22	3
Civ. Eng. 60	2
Civ. Eng. 70	2
Electives	3
	17

SIXTH SEMESTER	
Civ. Eng. 50	2
Econ. 173	3
Civ. Eng. 121	3
Civ. Eng. 23	3
Civ. Eng. 140	3
Electives	3
	17

SEVENTH SEMESTER	HOURS
Civ. Eng. 151	3
Civ. Eng. 141	2
Elec. Eng. 5	4
Econ. 153	3
Electives	5
	17

EIGHTH SEMESTER	HOURS
Civ. Eng. 180	2
Mech. and Ind. Eng.	4
Engl. 136	2
Electives	6
	14

COMBINED PROGRAM WITH COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS

Advisers: College of Literature, Science, and the Arts, Assistant Dean Robertson; College of Engineering, Professor Sherlock.

The College of Engineering and the College of Literature, Science, and the Arts offer a combined program which leads to the degrees of Bachelor of Science in Engineering (Civil Engineering) and Bachelor of Arts.

The program includes those courses in languages, literature, fine arts, philosophy, and history which would normally be taken by a student receiving a Bachelor of Arts degree with science as his major. At the same time, his science elections are planned in such a manner as to satisfy the requirements for both degrees. Upon completion of the five-year program the student will have fulfilled all the requirements for the Bachelor of Science in Engineering (Civil Engineering) degree and for the Bachelor of Arts degree. The degrees will be granted on completion of the prescribed program, with the understanding that if military science is elected, it must be carried in addition to the 171 semester hours of the regular curriculum.

A student electing the five-year combined program will enroll in the College of Literature, Science, and the Arts for the first four semesters. He will then enroll in the College of Engineering for the remaining six semesters and summer session.

In addition to the courses required for the program in civil engineering, shown on page 34, the combined curriculum requires the successful completion of the following courses:

	HOURS
A foreign language group or literature group	16
Philosophy	6
Fine arts or history	5
American literature	3
Economics	3
History, geology, philosophy, fine arts, political science	3

Electrical Engineering

Adviser: Professor Lovell

The electrical engineer is concerned with electrical energy and its applications. In our homes we have electric refrigerators, electrically controlled heating and air conditioning units, phonographs, radios, and television sets. In our communities are electric power plants and power distribution lines, electric street cars, and communication systems. The modern automobile, and still more the modern passenger or military airplane, carries a bewildering array of electric controls, gages, and instruments without which our present automobile and airplane transportation would be impossible. Radar, electrically controlled gun batteries, guided missiles, robot airplanes, and scores of other such developments are all in the realm of electrical engineering.

The diversity of the work done by electrical engineers and the specialization required within the profession have led to the establishment of two options within the basic program: one centered in electrical power production and machinery, the other in electronics and communication. A student may achieve, by a careful selection of elective courses, a measure of specialization even within the basic undergraduate program. Extensive specialization, however, should be reserved for graduate study.

Course requirements are identical for the first three years, but before beginning his senior year, a student must decide which of the two options he wishes to select. Thereafter he may change his option only with the consent of the program adviser.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Electrical Engineering) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Physics 45, 46	10
Chem. 5E, or two 4-hour courses	5–8
Draw. 1, 2	6
Ch. and Met. Eng. 1 and Prod. Eng. 1	5
Total, normally	44–53

B. Professional subjects and electives:

	HOURS
Math. 57	2
English Group II, III	4
Draw. 3	2
Econ. 53, 54	6
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a,* Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. and Ind. Eng. 13, Heat Engines	4
Mech. and Ind. Eng. 82, Elements of Machine Design	3
Elec. Eng. 3, Circuits I	4
Elec. Eng. 4, D.C. Machinery	2
Elec. Eng. 10, Principles of Electricity and Magnetism	4
Elec. Eng. 100, Circuits II	4
Elec. Eng. 130, Electrical Measurements	3
Elec. Eng. 150, A.C. Apparatus	4
Elec. Eng. 160, Fundamentals of Electrical Design	4
Elec. Eng. 180, Electronics and Electron Tubes I	4
Nontechnical electives. Suggested courses from English Group III, Geography, History, Philosophy, Political Science, Sociology, Languages and Literature, Fine Arts, Psychology	6
Group options and electives	17
Total, professional subjects and electives	87

GROUP OPTIONS AND ELECTIVES

MACHINERY-POWER

Adviser: Professor Carey

Civ. Eng. 21, Theory of Structures	3
Mech. and Ind. Eng. 14, Laboratory	1
Elec. Eng. 140, Power Plants, Transmissions, and Distribution	5
Elec. Eng. 151, Electrical Machinery or 155, Industrial Electrical Engineering	3-4
Elec. Eng. 170, Illumination and Photometry	2
Electives	2–3
Total	17

ELECTRONICS-COMMUNICATION

Adviser: Professor Holland

	HOURS
Elec. Eng. 101, Networks and Lines	3
Elec. Eng. 120, Radio Communications I	4
Elec. Eng. 121, Radio Communications II or 126, Telephone Communication or 181, Industrial Electronics	4
Elec. Eng. 141, Economic Applications in Electrical Engineering	2
Electives	4
Total	17

SUGGESTED SCHEDULE

For common first-year schedule see page 22.

THIRD SEMESTER	HOURS
Math. 53	4
Physics 45	5
Drawing 3	2
Eng. Mech. 1	3
Electives	3
	17

FOURTH SEMESTER	HOURS
Math. 54	4
Physics 46	5
Elec. Eng. 3	4
Electives	3
	16

FIFTH SEMESTER	
Elec. Eng. 4	2
Elec. Eng. 10	4
Elec. Eng. 100	4
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Math. 57	2
	17

SIXTH SEMESTER	
Elec. Eng. 150	4
Elec. Eng. 180	4
Eng. Mech. 3	3
Mech. and Ind. Eng. 82	3
Eng. Mech. 4	3
	17

SUMMER SESSION	
Elec. Eng. 130	3
Mech. and Ind. Eng. 13	4
	7

MACHINERY-POWER

SEVENTH SEMESTER	
Elec. Eng. 151 or 155	3 or 4
Elec. Eng. 140	5
Mech. and Ind. Eng. 14	1
Engl. (Group III)	2
Econ. 53	3
Elective	3 or 2
	17

EIGHTH SEMESTER	
Elec. Eng. 160	4
Elec. Eng. 170	2
Civ. Eng. 21	3
Econ. 54	3
Elective	3
	15

Analog computer laboratory, electrical engineering.

Modern production engineering foundry.

ELECTRONICS-COMMUNICATION

SEVENTH SEMESTER	HOURS
Elec. Eng. 101	3
Elec. Eng. 120	4
Engl. (Group III)	2
Econ. 53	3
Elective	4
	16

EIGHTH SEMESTER	HOURS
Elec. Eng. 160	4
Elec. Eng. 141	2
Elec. Eng. 121, or 126 or 181	4
Econ. 54	3
	13

Engineering Mechanics

Adviser: Professor Eriksen

The object of the program in engineering mechanics is to prepare men for theoretical and research work in engineering fields. A great demand now exists for men with this training in the research and development laboratories of the large utilities, in automotive and aircraft industries, and in laboratories and the many projects of the federal government. Representative problems given to these men include analysis of stresses due to static or dynamic loading, thermal charges, or drawing of metals; studies in photoelasticity; problems in instrumentation; analysis of fluid motion as gas flow in internal combustion engines, liquid flow in shock absorbers or torque converters; vibration analysis and elimination; problems in heat conduction; and the thermodynamics of plastics, synthetic rubber, and other materials.

The major areas of study in engineering mechanics are strength of materials, elasticity and plasticity, dynamics and vibrations, and fluid mechanics and thermodynamics. Emphasis is placed on analysis as a means of solving problems and, consequently, advanced mathematics and advanced mechanics play an important part in this training. Every student is required to take a complete design sequence in some other department of the College of Engineering to enable him to correlate his theoretical training with the engineering practice in that field.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Engineering Mechanics) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Draw. 1, 2	6
Physics 45, 46	10
Ch. and Met. 1 and Prod. Eng. 1	5
Total, normally	44–53

B. Professional subjects and electives:

Draw. 3	2
Econ. 53, 54	6
Math. 103, Differential Equations	3
Math. 147, Modern Operational Mathematics	2
Math. 150, Advanced Mathematics for Engineers	4
Civ. Eng. 4, Surveying	2
Civ. Eng. 21, Theory of Structures	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Elec. Eng. 135, Methods of Instrumentation	3
Mech. and Ind. Eng. 13, Heat Engines	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, 2*a*, Strength and Elasticity	5
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 124, Theory of Elasticity I	3
Eng. Mech. 131, Fundamental Vibration Analysis	3
Eng. Mech. 141, Advanced Fluid Mechanics I	3
Eng. Mech., Approved advanced courses	7
Nontechnical electives, including one course each from English, Group II and Group III and another nontechnical course	6
Group option and electives	18
Total, professional subjects and electives	87

GROUP OPTIONS AND ELECTIVES

Students in engineering mechanics may elect one of the following groups of courses according to their interest. Substitutions within any group are subject to the approval of the program adviser.

AERODYNAMICS

	HOURS
Aero. Eng. 110, Fundamentals of Aerodynamics	3
Aero. Eng. 112, Experimental Aerodynamics	1
Aero. Eng. 114, Applied Aerodynamics	3
Aero. Eng. 116, Advanced Fluid Mechanics	3
Aero. Eng. 118, Advanced Experimental Aerodynamics	2

AEROMECHANICS

Aero. Eng. 101, Airplane Design	3
Aero. Eng. 110, Fundamentals of Aerodynamics	3
Aero. Eng. 111, Theory and Design of Propellors	3
Aero. Eng. 113, Aircraft Propellors	3
Aero. Eng. 130, Basic Airplane Structures	3

CHEMICAL ENGINEERING

Ch. and Met. 113, 115, Unit Operations	7
Ch. and Met. 121, Design of Process Equipment	2
Ch. and Met. 129, Engineering Operations Laboratory	3

ELECTRICAL POWER

Elec. Eng. 7, Motor Control and Electronics	4
Elec. Eng. 100, Circuits II	4
Elec. Eng. 150, Alternating-Current Machinery	4

ELECTRONICS

Elec. Eng. 100, Electromechanics	4
Elec. Eng. 120, Radio Communications	4
Elec. Eng. 180, Electronics and Electron Tubes	4

HYDRAULICS

Civ. Eng. 140, Hydrology	3
Civ. Eng. 141, Hydraulics	2
Civ. Eng. 143, Advanced Hydraulics	3
Civ. Eng. 144, Hydraulic Structures	3
Civ. Eng. 146, Hydraulic Engineering Design	3

INTERNAL COMBUSTION ENGINES

	HOURS
Mech. and Ind. Eng. 106, Thermodynamics	3
Mech. and Ind. Eng. 114, Internal Combustion Engines	3
Mech. and Ind. Eng. 116, Design of Internal Combustion Engines	3
Mech. and Ind. Eng. 164, Gas Turbines and Jet Propulsion	3

METALLURGY

Ch. and Met. 117, Metals and Alloys	3
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 127, 128, Physical Metallurgy	6

NAVAL ARCHITECTURE

Nav. Arch. 11, Introduction to Practice	2
Nav. Arch. 12, Form Calculations I	3
Nav. Arch. 21, Structural Design I	3
Nav. Arch. 22, Structural Design II	2
Nav. Arch. 131, Ship Design I	3

STRUCTURES

Civ. Eng. 23, Elementary Design of Structures	3
Civ. Eng. 121, Reinforced Concrete	3
Civ. Eng. 122, Advanced Theory of Structures	3
Civ. Eng. 123, Design of Structures	3

Industrial Engineering

Adviser: Professor Vincent

The industrial engineer is primarily interested in the operating efficiency of a manufacturing organization. His principal task is the establishment of a smooth uninterrupted flow of production at the lowest possible cost. He may be called upon to devise entire plans of production, including plant layout, or to decide between methods of processing an individual item. He may be asked to set up methods of inspection and to devise means which will ensure the quality of the product. The evaluation of jobs for establishing wage rates, determination of production standards satisfactory to labor, the adoption of economical methods of handling materials and of packaging products for shipment are examples of the many responsibilities of the industrial engineer. Proper preparaton for such duties involves familiarity with the fundamentals of engineering as applied to the manufacturing industries and with the principles of business and personnel management.

Option A is intended to meet the needs of those students who wish to prepare themselves for staff and administrative work in manufacturing enterprises by a study of the principles and practices involved in organizing and controlling the functions of such enterprises. It is concerned with the establishment of standards for these functions and with the comparison of operating results with such standards. Basic engineering training is combined with the following subjects related to management: factory organization, cost and production control, motion and time study, job analysis and wage incentives, materials handling and plant layout, engineering economy, personnel administration, and statistical quality control.

Option B is intended to meet the needs of those students primarily interested in the methods and operations of manufacture. It includes the development, operation, and control of processes such as casting, forging, rolling, die-casting, stamping, molding, and machining; and it is concerned with such functions as production planning, factory layout, routing, and methods of manufacture; with jig, fixture, tool, and die design; and with technical estimating and inspection. The objective is to acquaint engineering students with principles and methods of fabricating materials.

The two options follow a common program for the first two years but begin to differ immediately thereafter. Each student should consult the option advisers before electing any courses following the fourth semester.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Industrial Engineering) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Draw. 1, 2	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Physics 45, 46	10
Ch. and Met. Eng. 1 and Prod. Eng. 1, Engineering Materials	5
Total, normally	44–53

B. Professional subjects and electives:

	HOURS
Draw. 3	3
*Econ. 153	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 3, Dynamics	3
Ch. and Met. Eng. 107, Metals and Alloys	2
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Mech. and Ind. Eng. 80, Mechanism	2
Mech. and Ind. Eng. 82, Machine Design	3
Mech. and Ind. Eng. 86, Advanced Machine Design	3
Mech. and Ind. Eng. 135, Industrial Management	3
Mech. and Ind. Eng. 139, Engineering Economy	2
Prod. Eng. 32, Machining I	3
Prod. Eng. 131, Machining II	3
Bus. Ad. 13, 14, Cost Accounting	6
Bus. Ad. 124, or Mathematics 161, Statistical Methods for Engineers	3
Bus. Ad. 142, Personnel Administration	3
Nontechnical electives, including one course each from English, Group II and Group III and another nontechnical course	6
*Group options and electives	29
Total, professional subjects and electives	87

GROUP OPTIONS AND ELECTIVES

OPTION A—MANAGEMENT

Adviser: Professor Gordy

Prod. Eng. 11, Casting	2
Mech. and Ind. Eng. 13, Heat Engines	4
Mech. and Ind. Eng. 17, Laboratory	2
Mech. and Ind. Eng. 104, Hydraulic Machinery	3
Mech. and Ind. Eng. 130, Plant Layout and Materials Handling	3
Mech. and Ind. Eng. 136, Motion and Time Study	3
Mech. and Ind. Eng. 137, Wage Incentives and Job Evaluation	2
Mech. and Ind. Eng. 138, Production Control	2
Electives	8
Total	29

* Students planning to enroll in the School of Business Administration as candidates for the M.B.A. may elect Econ. 53 and 54 and Bus. Ad. 11 and 12. The electives may be chosen to apply to the 60-hour requirement for the M.B.A. Some of the engineering courses may be accepted by the School of Business Administration to apply to this 60-hour requirement.

OPTION B—PRODUCTION

Adviser: Professor Boston

	HOURS
Math. 103, Differential Equations	3
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 142, Thermodynamics	2
Ch. and Met. Eng. 102, Structure of Metals	2
Ch. and Met. Eng. 219, Metallurgical Operations	3
Prod. Eng. 12, Casting	3
Prod. Eng. 107*a*, Metals and Alloys Laboratory	1
Prod. Eng. 141, Design for Production	2
Prod. Eng. 151, Process Instrumentation	2
Electives	8
Total	29

SUGGESTED SCHEDULES

For common first-year schedule, see page 22.

THIRD SEMESTER	HOURS
Math. 53	4
Phys. 45	5
Draw. 3	2
Eng. Mech. 1	3
Elective	2
	16

FOURTH SEMESTER	HOURS
Math. 54	4
Phys. 46	5
Mech. and Ind. Eng. 80	2
Eng. Mech. 2	4
	15

OPTION A—MANAGEMENT

SUMMER SESSION	
Mech. and Ind. Eng. 13	4
Elec. Eng. 5	4
	8

FIFTH SEMESTER	
Mech. and Ind. Eng. 82	3
Mech. and Ind. Eng. 17	2
Eng. Mech. 3	3
Bus. Ad. 13	3
Mech. and Ind. Eng. 135	3
Prod. Eng. 32	3
	17

SIXTH SEMESTER	
Mech. and Ind. Eng. 86	3
Bus. Ad. 14	3
Mech. and Ind. Eng. 130	3
Mech. and Ind. Eng. 136	3
Mech. and Ind. Eng. 104	3
Prod. Eng. 11	2
	17

SEVENTH SEMESTER	HOURS
Bus. Ad. 124 or Math. 161	3
Econ. 153	3
Prod. Eng. 131	3
Mech. and Ind. Eng. 137	2
Ch. and Met. Eng. 107	2
Electives	3
	16

EIGHTH SEMESTER	HOURS
Engl., Gr. III	2
Mech. and Ind. Eng. 138	2
Mech. and Ind. Eng. 139	2
Bus. Ad. 142	3
Electives	6
	15

OPTION B—PRODUCTION

SUMMER SESSION	
Ch. and Met. Eng. 107	2
Prod. Eng. 107*a*	1
Prod. Eng. 12 (or 32)	3
	6

FIFTH SEMESTER	
Math. 103	3
Eng. Mech. 3	3
Mech. and Ind. Eng. 82	3
Bus. Ad. 13	3
Prod. Eng. 102	2
Prod. Eng. 32 (or 12)	3
	17

SIXTH SEMESTER	
Mech. and Ind. Eng. 135	3
Eng. Mech. 142	2
Mech. and Ind. Eng. 86	3
Bus. Ad. 14	3
Prod. Eng. 131	3
Ch. and Met. Eng. 219	3
	17

SEVENTH SEMESTER	
Econ. 153	3
Engl., Gr. III	2
Elec. Eng. 5	4
Eng. Mech. 4	3
Math. 161	3
Electives	3
	18

EIGHTH SEMESTER	
Bus. Ad. 142	3
Prod. Eng. 141	2
Prod. Eng. 151	2
Mech. and Ind. Eng. 139	2
Electives	6
	15

Materials Engineering

Adviser: Professor Schneidewind

With the rapid development of new and better materials to meet the more exacting demands of industry and government agencies there has developed a demand for engineers with a sound understanding of materials and the factors that determine their various properties. Materials engineers must have a sound foundation in physics and chemistry, as well as in engineering and in the materials used and manufactured by industry. They must also understand the utility, properties, and applications of materials such as metals, alloys, cements, plastics, ceramics, and protective coatings. They are particularly valuable in manufacturing plants where it frequently is desirable to replace present materials for the purpose of improving the product, reducing costs, reducing service failures, or because of shortages of specific raw materials. They find opportunities in the development of new products, specification of new materials or combinations of these for existing products, development of new applications, or in the sales field. This program as designed also offers work in specifications, methods of fabrication, corrosion, high temperature properties of metals, and stress analysis.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Materials Engineering) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Draw. 1, 2	6
Physics 45, 46	10
Ch. and Met. 1	5
Total, normally	44–53

B. Professional subjects and electives:

English, Groups II and III	4
Econ. 153 and 173	6
Eng. Mech. 5, Statics, Strength, and Elasticity	4
Eng. Mech. 3, Dynamics	3
Eng. Mech. 126, Advanced Stress Analysis	2
Elec. Eng. 5, D. C. and A. C. Apparatus and Circuits	4
Mech. and Ind. Eng. 82, Machine Design	3
Chemistry 23, Introductory Analytical	0–4*
Chemistry 61R, Organic	4

* Students who elect Chemistry 11 and 12 under (A) are not required to elect 23.

	HOURS
Chemistry 83E, Physical	4
Prod. Eng. 31, Machining	2
Ch. and Met. 2, Engineering Calculations	3
Ch. and Met. 13, Casting	2
Ch. and Met. 16, Measurements Laboratory	3
Ch. and Met. 111, Thermodynamics	3
Ch. and Met. 114, Unit Operations	4
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 121, Design of Process Equipment	2
Ch. and Met. 124, X-ray Studies of Engineering Materials	2
Ch. and Met. 125, Organic Materials	3
Ch. and Met. 126, Glass and Ceramic Materials	2
Ch. and Met. 127, Physical Metallurgy I	3
Ch. and Met. 136, Protective Coatings	3
Ch. and Met. 217, Corrosion and High Temperature Resistance of Metals	3
Ch. and Met. 219, Metallurgical Operations	3
Nontechnical electives	5
Group options and electives	3*
Total, professional subjects and electives	83–87

SUGGESTED SCHEDULE†

For common first-year schedule, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Phys. 45	5	Phys. 46	5
xChem. 23	4	xChem. 61R	4
Electives	3	xCh. and Met. 2	3
	16		16

SUMMER SESSION	
‡xChem. 83E	4
xEng. Mech. 5	4
	8

* Advanced courses in air, military, or naval science approved by the program adviser may be used as free electives but the basic courses (100 or 200 series) will not be accepted.

† The program may be completed in 8 semesters without a summer session if 17 to 18 hour semester schedules can be carried successfully and the sequences are carefully planned. Chemistry 5E should be taken in the first semester and followed by Chemistry 23 in the second semester, postponing English Group II, and advancing the courses marked x in the above schedule.

‡ Chem. 182, 183, 184, total 8 hours credit, may be substituted for Ch. and Met. 111 and Chem. 83E totalling 7 hours credit.

FIFTH SEMESTER	HOURS
Eng. Mech. 3	3
Ch. and Met. 16	3
Ch. and Met. 111	3
Ch. and Met. 114	4
Elec. Eng. 5	4
	17

SIXTH SEMESTER	HOURS
Eng. Mech. 126	2
Econ. 173	3
Ch. and Met. 118	3
Mech. and Ind. Eng. 82	3
Prod. Eng. 31	2
Electives	2
	15

SEVENTH SEMESTER	
English, Group III	2
Econ. 153	3
Ch. and Met. 13	2
Ch. and Met. 125	5
Ch. and Met. 127	3
	15

EIGHTH SEMESTER	
Ch. and Met. 121	2
Ch. and Met. 124	2
Ch. and Met. 136	3
Ch. and Met. 217	3
Ch. and Met. 219	3
Electives	3
	16

Mathematics

Adviser: Associate Professor Hay

With the widespread advance in science and its application in development engineering and research, engineers so engaged find it necessary to rely to an increasing extent upon higher mathematics. Frequently these positions may be filled by men trained primarily in mathematics. The mathematics program in the College of Engineering provides the student an opportunity to become acquainted with engineering language and methods. Many students who are candidates for degrees in engineering programs elect additional courses and qualify for the award of a degree in mathematics as well. See Requirements for Graduation, pages 164–65.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Mathematics) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Draw. 1, 2	6
Physics 45, 46	10
Ch. and Met. 1 and Prod. Eng. 1	5
Total, normally	44–53

B. Professional subjects and electives:

English, Groups II and III	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D. C. and A. C. Apparatus and Circuits	4
Mech. and Ind. Eng. 13, Heat Engines, or approved equivalent	4
Electives in mathematics, including a course in differential equations and Math. 150 or 151	12
Electives in engineering	10
Electives from astronomy, chemistry, economics, engineering, drawing, mathematics, production engineering, natural sciences, physics, surveying	20
Nontechnical electives	6
Electives	17
Total, professional subjects and electives	87

Students in chemical engineering or in metallurgical engineering who become candidates for degrees in chemical engineering and mathematics or in metallurgical engineering and mathematics are permitted to substitute three hours of chemistry (beyond 5E) for Eng. Mech. 1, and Eng. Mech. 5 for Eng. Mech. 2.

All students who are candidates for the degree in mathematics must consult with and have their elections approved by the program adviser.

Mechanical Engineering

Adviser: Professor Vincent

Machinery, manufacturing, and power are the principal concern of mechanical engineers. They design, manufacture, and erect machinery and equipment for all industries, for handling materials and transporting people, and for refrigeration, heating, and air-conditioning. Many mechanical appliances in the modern home, the washing machine, oil burner, vacuum cleaner, as well as industrial equipment, are contributions of mechanical engineering. The automotive and public utilities industries are representative of the mechanical engineers' development of power application.

By use of the group options and electives the student may prepare himself for work in any of the major fields and industries in which he is interested.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Mechanical Engineering) are required to complete the following:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Draw. 1, 2	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Physics 45, 46	10
Ch. and Met. Eng. 1 and Prod. Eng. 1, Engineering Materials	5
Total, normally	44–53

B. Professional subjects and electives:

Draw. 3	2
Prod. Eng. 11, Casting	2
Prod. Eng. 31, Machining I*a*	2
Econ. 53, 54	6
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. and Ind. Eng. 1, Introduction to Mech. Eng.	1
Mech. and Ind. Eng. 17, Laboratory, First Course	2
Mech. and Ind. Eng. 80, Mechanism	2
Mech. and Ind. Eng. 82, Machine Design	3
Mech. and Ind. Eng. 86, Advanced Machine Design	3
Mech. and Ind. Eng. 104, Hydraulic Machinery	3
Mech. and Ind. Eng. 105, Thermodynamics I	3
Mech. and Ind. Eng. 106, Thermodynamics II	3
Mech. and Ind. Eng. 107, Applied Energy Conversion	3
Mech. and Ind. Eng. 108, Laboratory, Second Course	3
Mech. and Ind. Eng. 114, Internal Combustion Engines	3
Mech. and Ind. Eng. 125, Heating and Air Conditioning	3

	HOURS
Civ. Eng. 21, Theory of Structures	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Elec. Eng. 7, Motor Control and Electronics	4
Ch. and Met. Eng. 10, Utilization of Fuels	1
Ch. and Met. Eng. 107, Metals and Alloys	2
Nontechnical electives, including one course each from English, Group II and Group III and another nontechnical course	6
Group options and electives	9
Total	87

SUGGESTED SCHEDULE

For common first-year schedule, see page 22.

THIRD SEMESTER	HOURS
Math. 53	4
Physics 45	5
Drawing 3	2
Eng. Mech. 1	3
Mech. and Ind. Eng. 1	1
	15

FOURTH SEMESTER	HOURS
Math. 54	4
Physics 46	5
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Mech. and Ind. 80	2
	16

SUMMER SESSION	
Elec. Eng. 5	4
Mech. and Ind. Eng. 105	3
	7

FIFTH SEMESTER	
Mech. and Ind. Eng. 17 and Ch. and Met. Eng. 10	3
Mech. and Ind. Eng. 106	3
Econ. 53	3
Elec. Eng. 7	4
Eng. Mech. 3	3
Prod. Eng. 11	2
	18

SIXTH SEMESTER	
Mech. and Ind. Eng. 82	3
Mech. and Ind. Eng. 104	3
Econ. 54	3
Eng. Mech. 4	3
Ch. and Met. Eng. 107	2
Elective	2
	16

SEVENTH SEMESTER	
Mech. and Ind. Eng. 86	3
Mech. and Ind. Eng. 125	3
Civ. Eng. 21	3
Prod. Eng. 31	2
Electives	6
	17

EIGHTH SEMESTER	
Mech. and Ind. Eng. 107	3
Mech. and Ind. Eng. 108	3
Mech. and Ind. Eng. 114	3
Engl., Group III	2
Electives	4
	15

Metallurgical Engineering

Adviser: Professor Wood

The metallurgical engineer practices mainly in three fields, (1) the extraction of metals from their ores, (2) the melting and alloying of metals and the production of cast and wrought shapes, and (3) the selection and the adaptation by mechanical or by thermal treatment of these metal shapes to their final use.

His education has as its primary purpose the development of an understanding of the science of metals and the engineering involved in the production of metals and alloys and their conversion to a useful state.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Metallurgical Engineering) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses*	5–8
Draw. 1, 2	6
Physics 45, 46	10
Ch. and Met. 1	5
Total, normally	44–53

B. Professional subjects and electives:

Drawing 3	2
English, Group II and Group III	4
Economics 153, 173	6
Eng. Mech. 5, Statics, Strength, and Elasticity	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Mech. and Ind. Eng. 109, Heat, Power, and Refrigeration	3
Chemistry 23, 41, General and Analytical	4–8*
Chemistry 61R, Organic	4

* Students who elect Chemistry 11 and 12 under (A) are not required to elect 23.

	HOURS
Chemistry 83E, Physical	4
Ch. and Met. 2, Engineering Calculations	3
Ch. and Met. 13, Casting	2
Ch. and Met. 16, Measurements Laboratory	3
Ch. and Met. 111, Thermodynamics	3
Ch. and Met. 114, Unit Operations	4
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 119, Metallurgical Process Design	4
Ch. and Met. 121, Design of Process Equipment	2
Ch. and Met. 124, X-ray Studies of Engineering Material	2
Ch. and Met. 127, Physical Metallurgy I	3
Ch. and Met. 128, Physical Metallurgy II	3
Ch. and Met. 129, Engineering Operations Laboratory	3
Nontechnical electives	6
Group options and electives	4*
Total, professional subjects and electives	83–87

SUGGESTED SCHEDULE†

For common first-year schedule, see page 22.

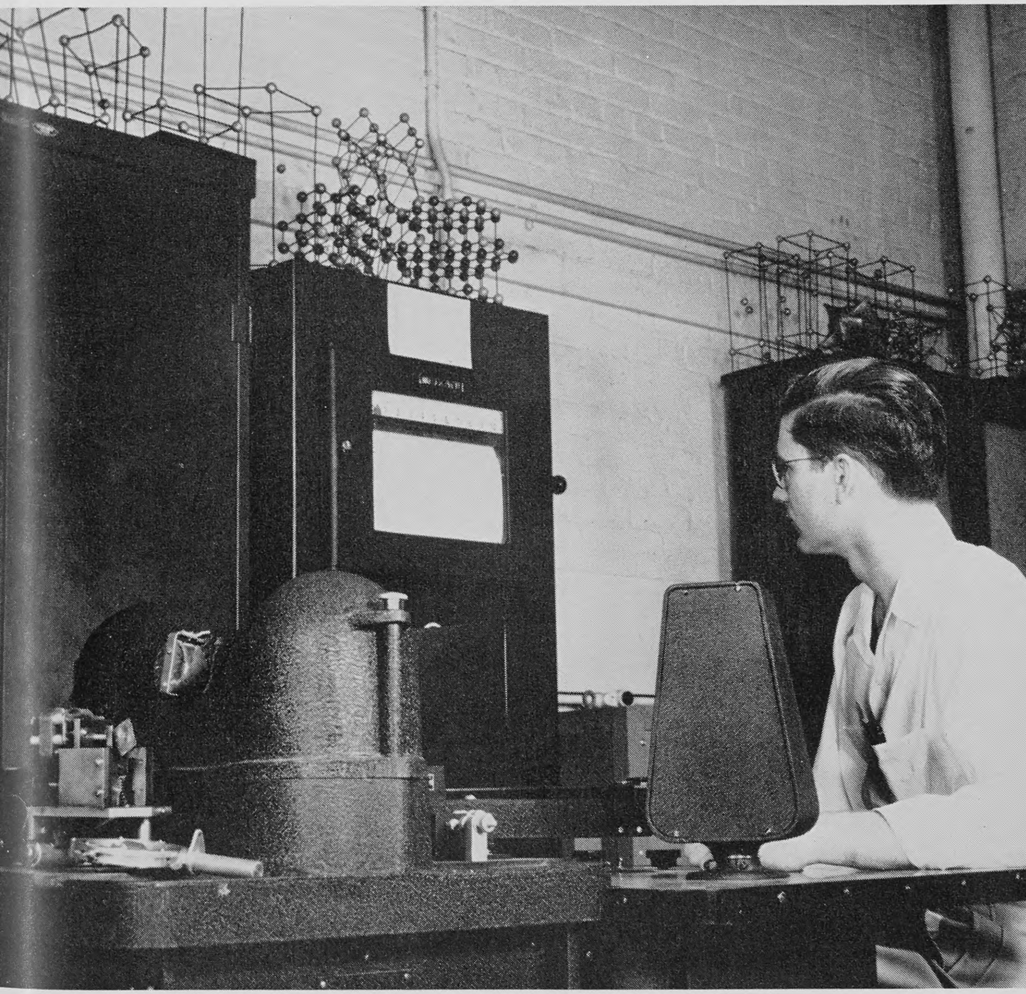
THIRD SEMESTER	HOURS
Math. 53	4
Draw. 3	2
Physics 45	5
xChem. 23	4
	15

FOURTH SEMESTER	HOURS
Math. 54	4
Ch. and Met. 2	3
Physics 46	5
xChem. 41	4
	16

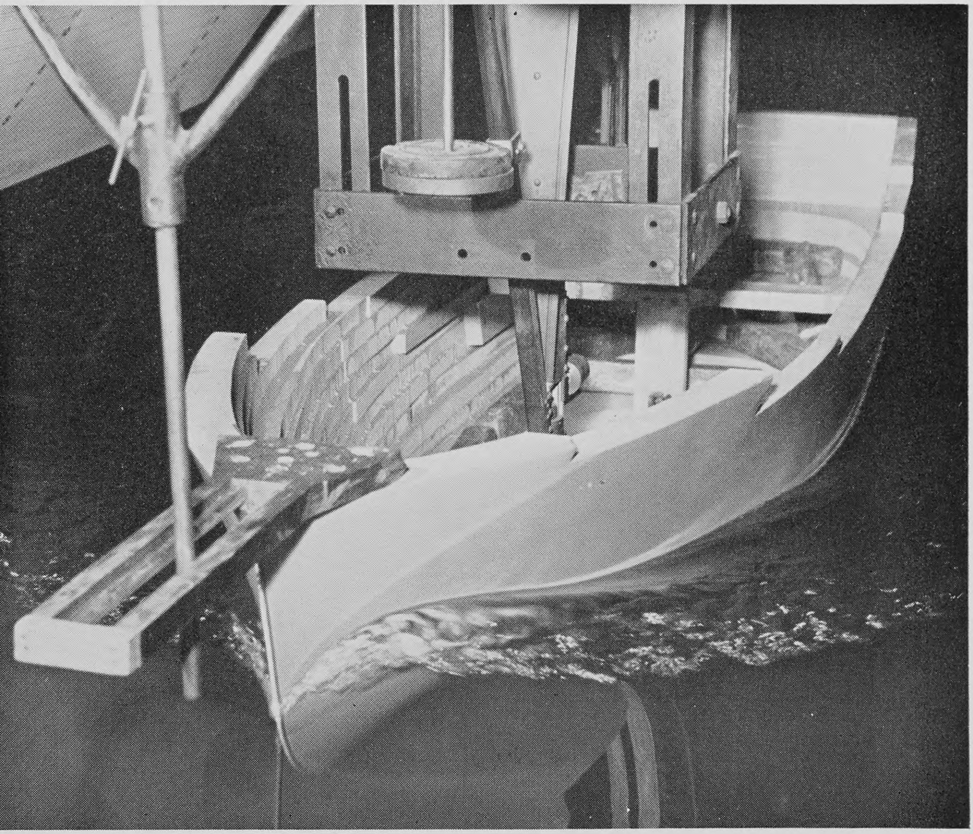
SUMMER SESSION	
Eng. Mech. 5	4
Chem. 83E	4
	8

* Advanced courses in air, military, or naval science approved by the program adviser may be used as option electives, but the basic courses (100 or 200 series) will not be accepted.

† The program may be completed in eight semesters if 17–18 hour semester schedules can be carried successfully and the sequences are carefully planned. Qualified students may elect the Math. 17, 18, 54 sequence to reduce the total hours. Also the election of Chem. 11 and 12 or Chem. 5E and 23 during the first year will permit advancing the courses marked x by one semester.



X-ray diffraction unit, metallurgical engineering.



A model attached to the tow car and to automatic recording devices in the 360-foot naval tank, naval architecture and marine engineering.

FIFTH SEMESTER	HOURS
xChem. 61R	4
Ch. and Met. 16	3
Ch. and Met. 111	3
Ch. and Met. 13	2
Eng. Mech. 3	3
	15

SIXTH SEMESTER	HOURS
xCh. and Met. 114	4
xCh. and Met 118	3
Ch. and Met. 127	3
Econ. 173	3
Elec. Eng. 5	4
	17

SEVENTH SEMESTER	
Ch. and Met. 128	3
Ch. and Met. 119	4
Mech. and Ind. Eng. 109	3
Econ. 153	3
Electives	3
	16

EIGHTH SEMESTER	
Ch. and Met. 121	2
Ch. and Met. 129	3
Ch. and Met. 124	2
English, Group III	2
Electives	7
	16

COMBINED PROGRAMS

For combined program leading to a degree also in chemical engineering, see Combined Programs, pages 31–33.

Naval Architecture and Marine Engineering

Adviser: Professor Baier

This program has for its object the training of students in the design and construction of ships, their propelling machinery, and auxiliaries. The program ultimately is directed to the following two divisions:

NAVAL ARCHITECTURE, Option I relates to the design and construction of ship hulls and includes such topics as form, strength, structural details, resistance, powering, stability, weight and cost estimating, and the methods available for solving the general problems of preliminary and final ship design.

MARINE ENGINEERING, Option II includes those subjects dealing more particularly with the design and construction of the various types of propelling machinery, such as steam-reciprocating, turbine, and oil engines; boilers of different types; auxiliaries; propellers; and the general problem of heat transference.

In addition to these two fields of activity, graduates frequently become connected with the operating divisions of transportation companies.

Others have entered the Coast Guard service or other governmental maritime agencies. Some prefer to work with and specialize in the design, construction, and brokerage of both power and sail yachts. The prescribed courses are therefore designed to give a student a thorough training in the fundamental problems relating to marine engineering, with certain of them open to elective work in any group which may give him a more specific training in the particular line of work he may wish to follow.

In planning the program, it has been recognized that the basic work is similar to that in mechanical engineering, with the differentiation largely in the third and, particularly, the fourth year. As a ship represents a floating power plant, fundamental courses in civil, electrical, and chemical engineering also are included. Although it is true, in the shipbuilding and shipping industry, that men are eventually segregated into the divisions mentioned above, it has been thought advisable to devote more time to the essentials of the subject rather than to undue specialization in any one, and to give the student as broad a background as possible. If, however, further specialization is desired, it is recommended that the student return for a fifth year for graduate study. Facilities for research work are provided in the naval tank or experimental model basin, which is unique in this institution.

The department is in constant touch with all the shipbuilding and shipping establishments, not only in this district, but throughout the country, and is able to aid its graduates in obtaining positions in the various lines mentioned.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Naval Architecture and Marine Engineering) are required to complete the following:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Draw. 1, 2	6
Physics 45 and 46	10
Ch. and Met. 1 and Prod. Eng. 1	5
Total, normally	44–53

B. Professional subjects and electives:

	HOURS
Draw. 3	2
Econ. 53 and 54 or 153 and 173	6
Civ. Eng. 4, Surveying	2
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials	4
Eng. Mech. 2*a*, Laboratory — Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. and Ind. Eng. 17, Mechanical Engineering Laboratory	2
Mech. and Ind. Eng. 80, Mechanism	2
Mech. and Ind. Eng. 82, Machine Design	3
Mech. and Ind. Eng. 105, Thermodynamics I	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Nav. Arch. 11, Introduction to Practice	2
Nav. Arch. 12, Form Calculations I	3
Nav. Arch. 21, Structural Design I	3
Nav. Arch. 141, Marine Machinery	4
Nav. Arch. 151, Resistance, Power, and Propellers	3
Nontechnical electives, including one course each from English, Group II and Group III and another nontechnical course	6
Group options and free electives	28
Total, professional subjects and electives	87

GROUP OPTIONS

I. NAVAL ARCHITECTURE

Adviser: Associate Professor Adams

For those principally interested in ship design and hull construction:

	HOURS
Eng. Mech. 127, Theory of Structures in Ship Design	4
Nav. Arch. 13, Form Calculations II	3
Nav. Arch. 22, Structural Design II	2
Nav. Arch. 131, Ship Design I	3
Nav. Arch. 132, Ship Design II	4
Nav. Arch. 137, Contracts, Specifications, and General Arrangements of Vessels	3
Nav. Arch. 152, Naval Tank	2
Electives	7
Total	28

II. MARINE ENGINEERING

Adviser: Professor Baier

For those principally interested in the design of propelling and other ship machinery:

	HOURS
Civ. Eng. 21, Theory of Structures	3
Mech. and Ind. Eng. 104, Hydraulic Machinery	3
Mech. and Ind. Eng. 106, Thermodynamics II	3
Mech. and Ind. Eng. 108, Mechanical Engineering Laboratory	3
Mech. and Ind. Eng. 113, Steam Turbines	3
Mech. and Ind. Eng. 114, Internal-Combustion Engines	3
Nav. Arch. 142, Steam Generators; or Nav. Arch. 143, Marine Propulsion Machinery; or Nav. Arch. 144, Heat Balance	3
Electives	7
Total	28

SUGGESTED SCHEDULE

For common first-year program, see page 22.

THIRD SEMESTER	HOURS
Math. 53	4
Eng. Mech. 1	3
Physics 45	5
Nav. Arch. 11	2
Draw. 3	2
	16

FOURTH SEMESTER	HOURS
Math. 54	4
Physics 46	5
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Nav. Arch. 12	3
	17

SUMMER SESSION	
Ch. and Met. Eng. 1 (Prod. Eng. 1)	5
Mech. and Ind. Eng. 80	2
	7

FIFTH SEMESTER	*Option* I	II
Mech. and Ind. 105	3	3
Eng. Mech. 127	4	–
Civ. Eng. 21	–	3
Eng. Mech. 3	3	3
Nav. Arch. 21	3	3
Civ. Eng. 4	2	2
Electives	2	2
	17	16

SIXTH SEMESTER	*Option* I	II
Mech. and Ind. 17	2	2
Nav. Arch. 141	4	4
Nav. Arch. 22	2	–
Mech. and Ind. 106	–	3
Mech. and Ind. 82	3	3
Nav. Arch. 13	3	–
Mech. and Ind. 104	–	3
Eng. Mech. 4	3	3
	17	18

SEVENTH SEMESTER	HOURS Option I	II
Econ. 53	3	3
Nav. Arch. 131	3	–
Mech. and Ind. 114	–	3
Nav. Arch. 137	3	–
Mech. and Ind. 113	–	3
Nav. Arch. 152	2	–
Mech. and Ind. 108	–	3
Elec. Eng. 5	4	4
Electives	3	2
	18	18

EIGHTH SEMESTER	HOURS Option I	II
Econ. 54	3	3
Nav. Arch. 132	4	–
Nav. Arch. 142, 143, or 144	–	3
Nav. Arch. 151	3	3
Electives	4	5
English, Group III	2	2
	16	16

Physics

Adviser: Professor Wolfe

The rapid advance in physics and its applications in industry have developed increasing demands for applied physicists. This program is intended to meet the demand and usually leads to activities in research, development, or teaching.

Students who are candidates for degrees in engineering programs often elect additional courses in this program and qualify for graduation with a degree in physics as well. See Requirements for Graduation, pages 164–65.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Physics) are required to complete the following program:

A. Subjects to be elected or equivalent attainment levels to be demonstrated:

	HOURS
English 11, 12, 21	6
Math. 8, 13, 14, 53, 54	12–18
Chem. 5E, or two 4-hour courses	5–8
Draw. 1, 2	6
Physics 45, 46	10
Ch. and Met. 1 and Prod. Eng. 1	5
Total, normally	44–53

B. Professional subjects and electives:

English, one course each from Group II and Group III	4
Modern language (preferably German or French)	8
Chem. 23, General and Analytical	4
Chem. 188, Physical	4
Math. 103, Differential Equations	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Elec. Eng. 3, Circuits I	4
Elec. Eng. 100, Circuits II	4
Physics 147, Electrical Measurements	4
Physics 165, Electron Tubes	3
Physics 196, Atomic and Molecular Structure	3
Group options and electives	39
Total, professional subjects and electives	87

GROUP OPTIONS AND ELECTIVES

Physics	13
Chemistry	3
Mathematics	3
Engineering	10
From economics, geography, history, philosophy, political science, sociology	6
Electives	4
	39

SPECIAL FIELDS

New developments in science and in the art of engineering are reflected in new courses offered by an alert faculty. Such courses may be elected under the system of group options and electives in the undergraduate program or in a program of advanced work in the Graduate School. Some of these special fields have been specifically mentioned under the various degree programs, but many of them are not formally recognized in this manner and are listed below as a matter of convenience. Program advisers will assist any student in preparing a program to fit his particular desires.

Nuclear Engineering

The new developments in atomic or nuclear energy have required engineers to design, construct, and operate the required facilities. After careful study, this College decided that the implications and effects of atomic energy demand the attention of engineers in all fields and that a special program leading to a degree in this field was not necessary at this time. Accordingly, a committee on nuclear engineering was formed to represent the different fields concerned: Chairman, Assistant Professor Gomberg (Electrical), Assistant Professor Borchardt (Civil), Associate Professor Brownell (Chemical), Associate Professor Rauch (Aeronautical), and Professor Schwartz (Mechanical). This committee has supervised arrangements for the following courses and field work.

COURSES IN NUCLEAR ENGINEERING

AERO. ENG. 190 OR ELEC. ENG. 190. INTRODUCTION TO NUCLEAR ENGINEERING.
ELEC. ENG. 192. MEASUREMENT IN NUCLEAR ENGINEERING.
CH. AND MET. ENG. 193. PROCEDURES AND DESIGN IN HANDLING OF RADIOACTIVE MATERIAL.
ELEC. ENG. 291. INTERACTION OF RADIATION AND MATTER.
ELEC. ENG. 294. WAVE MECHANICS IN NUCLEAR ENGINEERING.
AERO. ENG. 295. THEORY OF NUCLEAR REACTORS.
ELEC. ENG. 298. PRACTICE OF NUCLEAR ENGINEERING.

FIELD WORK

For those students who wish to pursue work with nuclear reactors at the practical level, arrangements are being made with the Argonne National Laboratory and the Oak Ridge National Laboratory for student training and experience with reactors. Work at the National Laboratories is restricted to United States citizens who have security clearance for work in the Atomic Energy Program. Arrangements for the clearance will be made through the Nuclear Engineering Committee. For students with other interests and for those not eligible for clearance, thesis problems in tracers, instrumentation, radiation effects, etc., utilizing the facilities available at the University, will be offered.

Opportunities for Specialization

THE ENGINEERING RESEARCH INSTITUTE offers excellent opportunity for the student to assist in research and development work and to gain actual research experience in one of a wide variety of special fields. The Institute offers no courses for instruction but conducts a large volume of research in many branches of applied science under contract with government agencies and industrial organizations. These projects are supervised by experienced faculty members or full-time research engineers and research scientists. Part-time employment may be obtained by advanced students who are thereby afforded an excellent opportunity to gain valuable experience while earning.

In AERONAUTICAL ENGINEERING the following three group options are suggested: aerodynamics, structures and design, and aircraft propulsion. A special program in guided missiles, at the graduate level, has also been developed at the request of the Air Force. Many of the courses in this program are open to civilian students.

CHEMICAL ENGINEERING is particularly well equipped to offer work in the following special fields: process design, petroleum refinery engineering, petroleum production engineering, protective coatings, plastics, and pulp and paper.

CIVIL ENGINEERING is well equipped to offer special work in soil mechanics and surveying, and in the following seven options: construction, highway, highway traffic, hydraulic, railroad, sanitary, and structural engineering.

ELECTRICAL ENGINEERING offers two main options: one in machinery and power and the other in electronics and communication, and suggests well-rounded programs in illumination, design, measurement, industrial electronics, electron tubes, and industrial-electrical engineering.

Within the MECHANICAL ENGINEERING program students may follow their special interests in automotive, aircraft power, air-conditioning, heat-power, refrigeration, or machine design.

In METALLURGICAL ENGINEERING the two main fields of physical metallurgy and process metallurgy are provided.

In INDUSTRIAL ENGINEERING two options are incorporated in the program which are related mainly to the mechanical industries. By the proper choice of electives, students in electrical, chemical, or metallurgical engineering may also prepare themselves for positions in production and management in these industries.

Reserve Officers' Training Corps

Units of Air, Army, and Naval ROTC are established at the University. Students enrolled in these corps receive uniforms and, under certain conditions, pay and allowances. Under the Selective Service Act (Public Law 759, 80th Congress) such students may be deferred from the draft until they have completed their ROTC training and four years of college if they agree to serve two years on active duty as an officer upon completion of their training, if ordered to do so. Students regularly enrolled in engineering are particularly well qualified to enter many of the technical branches of the several services, and all such physically qualified male citizens of the United States who meet the age requirements may apply for enrollment in one of the following programs in addition to their degree programs. Upon the successful completion of one of these programs and graduation from the College, the student will be commissioned in the appropriate reserve corps. For additional information consult the professor in the department concerned, or members of his staff.

AIR SCIENCE AND TACTICS

Professor Todd; Assistant Professors Beckley, Callow, Davis, Gane, Gould, Jordon, Maxam, Nixon, Reilly, Van Nest, and Winslow; Instructors Campbell, Cass, Gates, Jenks, J. Miller, R. Miller, Morton, Russell, Smith, and Vavrek.

The Department of Air Science and Tactics offers four specialized fields of instruction: communications, administration and logistics, flight operations, and general technical. Throughout the program both the theoretical and the practical phases of modern air power are emphasized. The student receives training in strategical and tactical air power, air operations, aerodynamics and propulsion, aerial navigation and meteorology, administration and logistics, industrial and personnel management, radio, radar, and electronics. After graduation special priority for selection to become flying officers is granted to Air Force ROTC Cadets, especially those enrolled in flight operations.

SUMMER CAMP. Attendance is required at summer camp between the third and fourth years of the Air Force ROTC program. Summer camps are of six weeks' duration and are held at selected Air Force bases.

SOCIETIES AND RIFLE TEAM. The Department of Air Science and Tactics sponsors a rifle team, an Air Force band, and a chapter of the National Arnold Air Society. Qualified members of the unit may participate in the Scabbard and Blade and Pershing Rifles.

COURSES OFFERED IN AIR SCIENCE

101. INTRODUCTION TO AVIATION, FUNDAMENTALS OF GLOBAL GEOGRAPHY, LEADERSHIP. I. (*2*).
102. SECURITY ORGANIZATIONS AND MILITARY SECURITY, LEADERSHIP. II. (*2*).
203. ELEMENTS OF AERIAL WARFARE, LEADERSHIP. I. (*2*).
204. CAREERS IN USAF, LEADERSHIP. II. (*2*).
311. APPLIED AIR SCIENCE AND TECHNIQUES, LEADERSHIP. I. (*3*).
312. APPLIED AIR SCIENCE AND TECHNIQUES, LEADERSHIP. II. (*3*).
411. PRINCIPLES OF LEADERSHIP AND MANAGEMENT. I. (*3*).
412. MILITARY ASPECTS OF WORLD POLITICAL GEOGRAPHY, LEADERSHIP LABORATORY. II. (*3*).

MILITARY SCIENCE AND TACTICS

Professor Miller; Assistant Professors Alling, Johnson, Langworthy, Nienhuis, Pabst, Picard, and Rippey.

GENERAL OBJECTIVE. The general objective is to produce junior officers who by their education, training, and inherent qualities are suitable for continued development in the Officers Reserve Corps of the Army of the United States, and in the Regular Army. Training in military leadership is emphasized. Instruction is given in subjects common to all branches of the Army.

COURSE OF INSTRUCTION FOR UNDERGRADUATES. Complete course of instruction comprises four years, with not less than ninety hours of instruction in each year of the basic course, and one hundred and fifty hours of instruction in each year of the advanced course. The complete course of instruction is organized into four major subdivisions as shown below. The subdivisions are concerned with four broad and distinct areas of military knowledge and skill. Every effort is made, in presenting the large number of individual subjects contained in the complete course, to inform students of the nature of the broad areas of military knowledge and skill and the relationship of the individual subjects to those areas.

		NUMBER OF HOURS				
COMMITTEE		MS I	MS II	MS III	MS IV	TOTAL
History	History of the Army, its Mission and Organization	15	15	7	23	60
	Military Personnel Management	5		5	29	39
History	First Aid and Individual Hygiene	(5)				
History	Unit Hygiene and Field Sanitation			(5)		
History	Uniform Code of Military Justice				(14)	
History	Military Administration				(15)	
	Operations, Tactics, and Techniques	65	42	114	92	313
	OPERATIONS					
Tactics	Military Intelligence			(8)		
Tactics	Estimate of the Situation and Combat Orders.............			(8)		
Tactics	The Military Team.........				(26)	
History	Command and Staff.........				(12)	
History	Organizations and Functions of Technical and Administrative Services				(25)	
	TACTICS					
Tactics	Small Unit Tactics..........	(18)		(20)		
Tactics	Mine Warfare			(4)		
Tactics	Guerilla Warfare				(2)	
	TECHNIQUES					
Weapons	Marksmanship	(10)		(7)		
Maps	Map and Aerial Photograph Reading	(10)	(15)			
Tactics	Field Fortifications and Camouflage			(6)		
Tactics	Gunnery			(24)		
History	Military Teaching Methods..			(10)		
Drill	School of the Soldier.........	(27)	(27)			

COMMITTEE		MS I	MS II	MS III	MS IV	TOTAL
		NUMBER OF HOURS				
Drill	Exercise of Command.......			(27)	(27)	
	Logistics and Material.......	5	33	24	6	68
	LOGISTICS					
Commun.	Signal Communications		(10)	(10)		
Weapons	Motor Transportation		(5)			
History	Supply and Evacuation				(6)	
	MATERIAL					
Weapons	Individual Weapons	(5)				
Weapons	Light Crew-Served Weapons..		(18)			
Weapons	Heavy Crew-Served Weapons.			(14)		
	TOTAL	90	90	150	150	480

The objective of the major subdivision entitled "History of the Army, its Mission and Organization" is: to motivate the student to achieve an understanding and appreciation of his obligation and privilege to serve his country as an officer of the Army; to integrate the subject material of the ROTC course into a whole which is meaningful to the student; to accomplish the foregoing by a historical orientation of the course so as to take advantage of the inspirational nature of the Army's illustrious past and present; to impress upon the student that the purpose of the ROTC program is to develop leadership in the students who elect these courses.

QUALIFICATION AND CLASSIFICATION. Regularly enrolled students, who are physically qualified male citizens of the United States, are offered instruction in the ROTC program. Upon successful completion of the course, the student is offered a commission as second lieutenant in the branch or service for which his training has fitted him. In the Medical and Dental Corps students are offered commissions as first lieutenants. Distinguished Military Graduates of the ROTC are offered direct commissions in the Regular Army.

CLASSIFICATION PROCEDURES IN THE BRANCH GENERAL PROGRAM. A classification board will be appointed composed of both ROTC and college staff members which will be responsible for the classification of cadets early in the junior year. Each cadet will be classified into that branch for which he is best adapted by talents and training. The following Arms and Services are available:

Arms: Armor, Artillery, Infantry, Corps of Engineers, and Signal Corps.

Services: Adjutant General's Corps, Quartermaster Corps, Finance Corps, Ordnance Corps, Chemical Corps, Transportation Corps, and Military Police Corps.

Medical Corps and Dental Corps are not open to undergraduates.

DEFERMENT. The Selective Service Act (Public Law 759, 80th Congress) authorizes the Secretary of the Army to defer selected ROTC students from the draft until they have completed their ROTC training and four years of college. The number of deferments granted each ROTC unit is based on quotas assigned by the respective secretaries. Selection based on competitive examinations is made by the Professor of Military Science and Tactics. A student certified for deferment under this law must agree in writing to serve two years on active duty as an officer upon completion of his college training if ordered to do so by the Secretary of the Army. Except for this provision, a reserve officer is not subject to active duty without his consent, except in time of national emergency. He may, however, increase his military knowledge and qualify for promotion through Army extension courses or active duty training.

PAY AND ALLOWANCES — SUMMER CAMP. Pay and allowances begin at the time of enrollment in the third year of the military science course and amount to approximately $230 for each of the last two years. In addition, the student receives approximately $112.50 plus all expenses for the six-week summer camp held between the third and fourth years of the military science course.

UNIFORMS. All ROTC students are furnished uniforms without charge.

CREDIT FOR PREVIOUS MILITARY TRAINING OR SERVICE. For information concerning credit allowed for previous military training or service, students should consult the Department of Military Science and Tactics.

EXTRACURRICULAR ACTIVITIES. The Department of Military Science sponsors a rifle team and offers facilities for photography and amateur radio. There are campus chapters of the American Ordnance Association, and of the national honorary military societies, Pi Tau Pi Sigma, Scabbard and Blade, and Pershing Rifles.

NAVAL SCIENCE

Professor McKean; Associate Professor Smith; Assistant Professors Williams, Slaymaker, Davis, Price, and Snyder.

THE MISSION of the Naval Reserve Officers' Training Corps is to provide a source, by a permanent system of training and instruction in essential naval subjects at civil educational institutions, from which qualified officers may be obtained for the Navy, the Marine Corps, the Naval Reserve, and the Marine Corps Reserve.

THE OBJECTIVES of the Department of Naval Science in carrying out the above mission at the University of Michigan follow:

1. To provide the student with a well-rounded course in basic naval subjects, which, in conjunction with a baccalaureate degree, will qualify him for a commission in the United States Naval Service.

2. To develop an interest in the naval service and a knowledge of naval practice.

3. By precept, example, and instruction to develop the psychology and technique of leadership in order that the young officer may be able to inspire others to their best efforts.

4. To supplement the academic work of the school year by summer cruises, aviation training, and/or Marine Corps encampments.

5. To provide certain selected groups of students with such specific training, differentiated in the last part of the course, as will qualify them for commissions in the United States Marine Corps, or the United States Navy (Supply Corps).

OFFICER CANDIDATES in the NROTC are of two types: (*a*) Regular NROTC students. These students, after selection by nation-wide competitive examinations, are appointed Midshipmen, USNR, and are granted a retainer pay at the rate of $600 a year, with tuition, nonrefundable fees, and books provided by the Navy for a maximum period of four years while under instruction at the NROTC institution or during summer training cruises. Regular students are obligated to serve at least fifteen months or, at the discretion of the Secretary of the Navy, three years on active duty after commissioning as ensigns, United States Navy, or second lieutenants, United States Marine Corps, unless sooner released by the Secretary of the Navy. They may apply for retention as career officers in the Regular Navy or Marine Corps. (*b*) Contract NROTC students. The contract NROTC students have the status of civilians who have entered into a mutual contract with the Navy. For administrative purposes they are referred to as Reserve Midshipmen. They are not entitled to the compensation or benefits paid Regular NROTC students except that they are entitled to issue of a uniform, textbooks, and equipment for the naval science courses, and payment of commutation of subsistence (currently about $30 a month) during their last two years of NROTC training. Under this plan students must agree to accept a commission in the Naval or Marine Corps Reserve on graduation and, while undergraduates, to engage in one summer practice cruise of approximately three weeks' duration between the junior and senior years. After commissioning, however, if they so desire and their services are required, they may elect to be commissioned as ensigns, United States Navy, or second lieutenants, United States Marine Corps, and serve for two years on active duty. They may then apply, if they desire, for retention in the Service.

They must pass the Navy physical examination before being accepted for a commission. Physical requirements are high. Vision must be 20/20 uncorrected by glasses; height must be between 66 and 76 inches; and students must be between 17 and 21 years of age. Officer candidates must remain unmarried until commissioned.

Regular NROTC students participate in three summer cruises of six to eight weeks' duration; Contract NROTC students participate in one three-week summer cruise. Marine candidates spend the third cruise period at the Marine Corps Schools, Quantico, Virginia.

All candidates must have completed a sequence in mathematics through solid geometry and trigonometry in high school or by the end of their sophomore year in college. Regular NROTC students must complete one year of college physics by the end of their sophomore college year. Physical training as prescribed by the University must also be taken.

Options. All students are required to complete eight semesters of naval science subjects. Candidates for Marine Corps commissions complete four semesters of general naval science subjects and four semesters of Marine Corps specialty courses. Candidates for commissions in the Supply Corps complete four semesters of general naval science subjects and four semesters of naval supply corps subjects.

COURSES OFFERED IN NAVAL SCIENCE

Each of the following subjects requires attendance at three one-hour recitations and a two-hour laboratory period each week.

101. Naval Orientation. I. *(3)*.
A preliminary course presenting naval history, concepts of sea power, and customs and traditions of the Navy.

102. Naval Orientation. II. *(3)*.
A general indoctrination in the various components of the United States Navy; shipboard organization and duties.

201. Naval Weapons. I. *(3)*.
A familiarization course in modern naval weapons and the purpose of each.

202. Naval Weapons. II. *(3)*.
Instruction in the general nature, basic principles of employment, and control of naval weapons, including radar and sonar. Employment of the Combat Center in ship organization. Fundamental operation and principles of guided missiles.

301. Navigation. I. *(3)*.
Provides an understanding of the theory and technique of surface navigation. Practical use of the dead reckoning and piloting methods of navigation.

301S. Navy Supply. I. *(3)*.
A study of naval finance and naval accounting methods. For Naval Supply Corps candidates only.

301M. History of the Art of War. I. *(3)*.
The development of tactics and materials by a study of specific European battles. For Marine Corps candidates only.

302. Navigation. II. *(3)*.
Thoroughly acquaints the student with the theory of celestial navigation. Practical problem solution is emphasized during summer cruises.

302S. Navy Supply. II. *(3)*.
For Naval Supply Corps candidates only. A study of supply organization and administration afloat.

302M. U. S. Military History and Policy. II. *(3)*.
For Marine Corps candidates only. The development of the United States military policy. Individual battles analyzed.

401. Naval Machinery and Diesel Engines. I. (*3*).
Provides a broad general conception of the fundamentals of naval engineering installations including steam, diesel, and auxiliary plants.

401S. Navy Supply. I. (*3*).
For Naval Supply Corps candidates only. Procurement, distribution, and storage with emphasis on ships' store and commissary problems.

401M. Amphibious Warfare. I. (*3*).
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare.

402. Ship Stability, Naval Justice, and Leadership. II. (*3*).
Principles of ship stability and buoyancy. Procedures for administration of naval justice. An understanding of the psychology of leadership.

402S. Navy Supply. II. (*3*).
For Naval Supply Corps candidates only. Procurement, distribution, and storage of Navy clothing. Fifteen sessions only; remaining thirty sessions combined with NS402 in study of Naval Justice and Leadership.

402M. Amphibious Warfare. II. (*3*).
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare. Fifteen sessions only; remaining thirty sessions combined with NS402 in study of Naval Justice and Leadership.

GRADUATE STUDIES

The undergraduate program in engineering offers only a limited opportunity for advanced or special studies. Many students find continued study for at least one additional year a decided advantage. It offers an attractive opportunity to pursue their special interests and to acquire a more thorough preparation for their first employment. Michigan has always maintained a leading position in postgraduate engineering education and offers excellent facilities in many fields.

All students who are candidates for graduate degrees are enrolled in the Horace H. Rackham School of Graduate Studies. The *Announcement* of the Graduate School should be consulted for complete information.

Master of Science in Engineering

A student who has received a bachelor's degree from the College of Engineering of this University, or has completed an equivalent program of studies elsewhere with sufficient evidence that he can meet the requirement of an average grade of B in his graduate studies, may enroll in the Graduate School for the degree of Master of Science in Engineering. The general requirements include the completion of at least thirty credit hours of graduate work approved by the program adviser or advisory committee with an average grade of at least B covering all courses elected as a graduate student.

A superior student who is well prepared may complete the requirements for a master's degree in two semesters. If his preparation is not adequate, the student will be required to take the necessary preparatory courses without graduate credit. A grade below B will not be accepted for graduate credit, unless, after review of the circumstances, the acceptance of the credit is recommended by the program adviser or the advisory committee.

Graduate credit is not allowed for work taken in an undergraduate college. But double registration in the College of Engineering and the Graduate School is permitted in the case of those students who require not more than six hours credit for completing the graduation requirements at the beginning of a given semester, or not more than four hours at the beginning of a summer session. Students contemplating graduate work should consult with the program adviser or the advisory committee for the desired program.

AERONAUTICAL ENGINEERING

Advisory Committee: Professors Kuethe, Nichols, and Sellars

A candidate for this degree may, through suitable selection of courses, specialize in any of the following fields: aerodynamics, structures, propulsion, design, and instrumentation. Ordinarily the candidate may include three to four hours of nontechnical studies and should not include more than five hours of laboratory research courses.

Students undertaking graduate work with a bachelor's degree in engineering but no previous work in aeronautical engineering will be required to complete the equivalent of the undergraduate aeronautical courses in addition to the graduate requirements.

CHEMICAL ENGINEERING

Advisory Committee: Professors Williams, Flinn, Churchill, Siebert, and York.

The requirements for this degree include Chemical and Metallurgical Engineering 211, 213, 215, and such other courses as are approved by the advisory committee. Each student is encouraged to develop a program to fit his professional objectives and should consult with the advisory committee in this matter.

CIVIL ENGINEERING

All applicants for the degree of Master of Science in Engineering (Civil) must present the equivalent of the undergraduate civil engineering program as preparation and in addition must complete a minimum of fifteen hours of graduate work in civil engineering courses and such other courses as are approved by the adviser. Graduate study programs leading to this degree may be arranged in the special fields as follows:

Special Fields	*Adviser*
Construction	Professor Alt
Geodesy and Surveying	Professor Bouchard
Highway and Highway Traffic	Professor Kohl
Hydraulics	Professor Brater
Municipal	Professor Boyce
Railway	Professor Sadler
Sanitary	Professor Borchardt

CONSTRUCTION ENGINEERING

Program Adviser: Professor Alt

This program is available to students interested in construction who meet the requirements for admission to master's degree work in civil engineering. The requirements for this degree include Civil Engineering 131, 132, 181, 235, and such other courses in engineering, economics, business administration, and other fields as may be approved by the program adviser.

ELECTRICAL ENGINEERING

Program Adviser: Professor Holland

A candidate for this degree is usually required to complete Electrical Engineering 210 and two courses in advanced mathematics. By suitable selection of his remaining courses he may specialize in any of the following fields: electrical power engineering, illumination, electrical engineering design, communication, general theory and measurement, industrial electronics, electron tubes, or industrial electrical engineering.

ENGINEERING MECHANICS

Advisory Committee: Professors Eriksen and Dodge

The following courses are prerequisite to all courses in engineering mechanics numbered 100 or above: Engineering Mechanics 1, 2, 3, and 4, Physics 45 and 46, and Mathematics 103.

The master's degree program must include Engineering Mechanics 124, 129, 131, 132, 141, 142 and Mathematics 152, 155, and 157, or their equivalents as approved by the advisory committee. If so approved, a master's thesis may be substituted for part of the course work.

INDUSTRIAL ENGINEERING

Advisory Committee: Professors Williams, Flinn, Churchill, Siebert, and York

Program Adviser: Professor Gordy

The degree of Master of Science in Engineering (Industrial) is available to those students whose interest is in industrial production or management rather than in professional technical engineering. The program of studies must be approved by the advisory committee or the program adviser. For those men who plan to enter industry in such management areas as production standards, incentive determination, methods and plant layout, the following courses are usually required: Mathematics 172, Business Administration 211, Mechanical and Industrial Engineering 237, Production Engineering 182 and a minimum of twelve hours from among the following courses: Mechanical and Industrial Engineering 123, 131, 238, and 240; Business Administration 143, 163, 244, 252; Electrical Engineering 170; Psychology 194; and Mathematics 162.

INSTRUMENTATION

Advisory Committee: Professors Rauch, Kaplan, Macnee, and Williams.

The program in instrumentation covers the field of measurements, communication, and control, as involved in modern control devices for the operation and control of equipment and processes. The program leading to the degree of Master of Science in Engineering (Instrumentation) is available to students who meet the requirements for the degree of Bachelor of Science in Engineering at this University. A candidate for the degree in instrumentation must complete a total of thirty hours of graduate credit including the following courses or their equivalent: Mathematics 148, Aeronautical Engineering 171 and 172, and Electrical Engineering 108.

MECHANICAL ENGINEERING

Advisory Committee: Professors Gordy, Schwartz, Edmonson, VanWylen, and Vines.

The course selections necessary for this degree are rather flexible but it is expected that approximately fifteen hours of course study will be in one of the areas such as heat-power, automotive, heating, air-conditioning and refrigeration, hydromechanical or machine design, and most of the remaining hours in well-selected subjects of a cognate character. At least one course in advanced design and one course in mechanical engineering laboratory must be included, and at least two advanced courses in engineering mechanics, production engineering, electrical engineering, or in some other branch of engineering are required.

METALLURGICAL ENGINEERING

Advisory Committee: Professors Williams, Flinn, Churchill, Siebert, and York

The requirements for this degree include Chemical and Metallurgical Engineering 211, 216, and 228, and such other courses as are approved by the advisory committee. Each student is encouraged to design his program to satisfy his special interest.

MUNICIPAL ENGINEERING ADMINISTRATION

Program Adviser: Professor Boyce

The program in municipal engineering and public administration is conducted in co-operation with the Institute of Public Administration. The program is available to students interested in the administrative problems of municipal engineering and city management who meet the requirements for admission to master's work in civil engineering.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Program Adviser: Professor Adams

A candidate for this degree must have completed the fundamental engineering courses of the degree Bachelor of Science in Engineering (Naval Architecture and Marine Engineering) or, if he has had practical experience in the subject matter covered by these courses, pass an examination in them. The requirements for a Master of Science in Engineering (Naval Architecture and Marine Engineering) degree usually include Naval Architecture 123, 135, 153, and 145 or 154.

NUCLEAR ENGINEERING

Advisory Committee: Professors Gomberg, Borchardt, Brownell, Rauch, and Schwartz

Candidates may be admitted to the degree program from any of the undergraduate engineering curriculums if accepted by the advisory committee. The requirements for the degree include Electrical Engineering 190, 192, Chemical and Metallurgical Engineering 193, Electrical Engineering 291, 298 or equivalent, and either Electrical Engineering 294 or 295 or other courses approved by the advisory committee.

SANITARY ENGINEERING

Advisory Committee: Professors Boyce and Borchardt

The program leading to the degree Master of Science in Engineering (Sanitary) is generally open to graduates in civil, chemical, and mechanical engineering. A student is expected to elect at least fifteen hours in the field of sanitary engineering and a number of courses in environmental health and public health statistics offered by the School of Public Health.

Professional Degrees

The following professional degrees may be awarded to qualified candidates:

AERONAUTICAL ENGINEER — Ae. E.
CHEMICAL ENGINEER — Ch. E.
CIVIL ENGINEER — C. E.
ELECTRICAL ENGINEER — E. E.
MARINE ENGINEER — Mar. E.
MECHANICAL ENGINEER — M. E.
METALLURGICAL ENGINEER — Met. E.
PUBLIC HEALTH ENGINEER — P. H. E.
NAVAL ARCHITECT — Nav. Arch.

These advanced degrees will be conferred upon persons who have proved their ability to plan and direct professional work or to conduct original investigation in applied science.

Graduates of the University of Michigan will be required to register during the semester in which they obtain their degrees. Such applicants may register *in absentia.*

Graduates from other institutions of recognized standing who have not been in residence at any time at the University of Michigan must satisfy the standard residence requirement of two semesters of full-time work before receiving the degree.

An applicant for any of these degrees must have received a bachelor's degree from an approved college at least seven years before registration for the advanced degree. He must have been engaged in professional work for a period of seven years, in responsible charge of the same for at least three years, and must present at the time of registration a detailed account of his professional experience up to that time.

Upon admission to candidacy for the degree, a committee will be appointed to supervise the preparation of a thesis, which, with the candidate's professional record, must demonstrate beyond doubt that he is a competent professional engineer capable of taking responsible charge of important engineering work. This thesis may not be a mere description of engineering work of a usual character nor a digest of existing literature, but should be a distinct contribution to engineering science. If the thesis has been previously completed it must be approved by the committee in charge.

Doctor's Degrees

DOCTOR OF PHILOSOPHY — Ph. D.

DOCTOR OF SCIENCE — Sc. D.

The doctor's degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly announced graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in some subdivision of the selected field and must present the results of his investigation in the form of a dissertation.

APPLICANT FOR THE DOCTORATE. A student becomes an applicant for the doctorate when he has been admitted to the Graduate School and has been accepted in a field of specialization. No assurance is given that he may become a candidate for the doctorate until he has given evidence of superior scholarship and ability as an original investigator.

There is no general course or credit requirement for the doctorate. In most departments a student must pass a comprehensive examination in his major field of specialization, which tests his knowledge in that field and in the supporting fields, before he will be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

A reading knowledge of German and French is required. A student must meet the language requirements for the doctorate before he can be accepted as a candidate for the degree. He should consult the Examiner in Foreign Languages, Professor Hootkins, 3028 Rackham Building, at his earliest convenience after becoming an applicant. In special cases a student may present a written request to the committee in charge of his doctoral work or to the departmental committee for a substitution of another language for French or German. English may be accepted as a substitute in the case of a student whose native language is other than English. The written request, together with the approval of the committee, should be transmitted to the Dean of the Graduate School with a complete statement of the reasons for requesting the change. The Dean will then pass upon the desirability of modifying the requirement. A student's native language cannot be accepted as a substitute, and the language approved as a substitute must be one that the student expects to use in connection with his dissertation. A student who completes French 12, German 12, Spanish 12, or Russian 12 with a grade of B or better will be recorded as having met the language requirement in the respective language.

A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School office upon request.

DEPARTMENTS OF INSTRUCTION

The College of Engineering is organized for administrative purposes to include ten departments of instruction which, with certain closely associated departments of other units of the University, provide the courses which constitute the several degree programs. This section lists these departments in alphabetical order, with the teaching staff of each and the courses which are offered.

The semester in which the course is offered is indicated as follows: the first semester — I, the second semester — II, summer session — S.S. The italic numeral or other information enclosed in parentheses indicates the hours of credit for the course: *(3)* denotes three hours credit, or *(To be arranged)*.

Aeronautical Engineering

1. GENERAL AERONAUTICS. *Prerequisite: Math. 53 and Phys. 45.* I and II. *(3)*.
Essentials of aeronautics as applied to the airplane and other modern means of flight. Lectures and recitations.

101. AIRPLANE DESIGN. *Prerequisite: preceded or accompanied by Aero. Eng. 113 and 130.* I and II. *(3)*.
Design procedure, including layouts and preliminary structural design; stress analysis and detail design. Lectures and drawing.

102. ADVANCED DESIGN. I and II. *(To be arranged)*.
Primarily for graduates. Continuation of Aero. Eng. 101, with more complex or special problems.

103. AIRPLANE DESIGN PRACTICE II. *Prerequisite: Aero. Eng. 113.* I and II. *(2)*.
Preliminary design of an airplane from the aerodynamic and structural standpoints, including three-view layout, weight and balance calculations, and preliminary performance estimations. Lectures and drawing.

104. AIRCRAFT VIBRATIONS. *Prerequisite: Aero. Eng. 109 or 110 and 130.* I and II. *(2)*.
Vibrations and other dynamic problems occurring in aircraft structures.

105. DYNAMICS OF THE AIRPLANE. *Prerequisite: Aero. Eng. 110 and 113.* *(2)*.
Theory of dynamic stability of the airplane as a rigid body compared with experience. Stability criteria and current requirements for stick-fixed as well as stick-free flight.

106. AEROELASTIC LOADS. *Prerequisite: Aero. Eng. 114 and preceded or accompanied by Aero. Eng. 113 and 172, or Eng. Mech. 131 or equivalent.* (*3*).
Loads on an airplane considered as a rigid body and as an elastic body. Maneuvering and gust loads, elementary flutter theory, landing loads, and other dynamic loading conditions.

109. FUNDAMENTALS OF AERODYNAMICS. *Prerequisite: preceded or accompanied by Math. 150 and Eng. Mech. 4.* (*3*).
Development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Lectures and recitations. (Differs from Aero. Eng. 110 in that an adequate background in mathematics is assumed.)

110. FUNDAMENTALS OF AERODYNAMICS. *Prerequisite: Math. 54, preceded or accompanied by Eng. Mech. 4.* I and II. (*5*).
Development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Lectures and recitations.

111. THEORY AND DESIGN OF PROPELLERS. *Prerequisite: preceded by Eng. Mech. 2 and Aero. Eng. 1.* I and II. (*3*).
Aerodynamic theories of the propeller and its strength; the selection of propellers for specific condition. Lectures and recitations.

112. EXPERIMENTAL AERODYNAMICS. *Prerequisite: Aero. Eng. 109 or 110.* I and II. (*1*).
Open only to seniors and graduates. Modern methods for obtaining experimental aerodynamic data. Lectures and laboratory.

113. AIRCRAFT PERFORMANCE. *Prerequisite: Aero. Eng. 109 or 110 and 111.* I and II. (*3*).
Methods for estimating performance, stability, and maneuverability as required for airplane design; relationships between engine and airplane, and between control and stability.

114. APPLIED AERODYNAMICS. *Prerequisite: Aero. Eng. 109 or 110.* I and II. (*3*).
Applies theoretical aerodynamics and modifications based on experiment to the calculation of actual air loads on the airplane.

115. THEORETICAL AERODYNAMICS. *Prerequisite: Aero. Eng. 109 or 110.* (*3*).
Summary of fundamentals of mathematical theory of hydrodynamics and its application to modern aerodynamics; application of complex variables to the two-dimensional airfoil.

116. ADVANCED FLUID MECHANICS. *Prerequisite: Aero. Eng. 109 or 110 or equivalent.* (*3*).
Advanced course in fluid mechanics dealing mainly with the physical aspects of various problems of viscosity and compressibility and their application in aeronautical as well as other branches of engineering.

117. ADVANCED THEORY OF PROPELLERS AND FANS. *Prerequisite: Aero. Eng. 109 or 110, 111, and Mech. and Ind. Eng. 105.* (*2*).
Critical study of the fundamental aerodynamic and strength theories of the propeller; viscosity and compressibility effects; theory and performance of axial

and centrifugal blowers, with application to superchargers and jet propulsion systems.

118. ADVANCED EXPERIMENTAL AERODYNAMICS. *Prerequisite: preceded or accompanied by Aero. Eng. 116.* (*2*).

Covers the work presented in Aero. Eng. 112 but with more attention to detail and more elaborate discussion of the advanced theories and methods used in this field. Lectures and laboratory.

119. MECHANICS AND FLUID RESISTANCE. *Prerequisite: Aero. Eng. 115.* (*2*).

Problems of resistance in fluid motion broadly treated, consideration given to viscous fluid resistance, wave resistance, and resistance due to fluid compressibility.

120. FANS AND DUCT SYSTEMS. *Prerequisite: Eng. Mech. 4, Mech. and Ind. Eng. 105.* (*2*).

Airfoil theory applied to fan design; theoretical performance, fan losses and dimensions; viscosity and compressibility effects; experimental results; losses in straight pipes, nozzles, diffusers, and around corners.

121. TURBULENCE AND DIFFUSION. *Prerequisite: Eng. Mech. 4 and Math. 60, or their equivalents.* (*To be arranged*).

Gives a physical picture of turbulence in boundary layers, wakes, jets, and behind a grid. The basic equations are derived, isotropic and locally isotropic turbulent fields are described, and applications to practical problems such as transfer and diffusion of heat and mass are treated.

130. BASIC AIRPLANE STRUCTURES. *Prerequisite: preceded or accompanied by Aero. Eng. 1 and preceded by Eng. Mech. 2.* I and II. (*3*).

Introduction to the elementary problems of airplane stress analysis. Lectures and recitations on the applications of the topics covered in mechanics and strength of materials to airplane structures, such as beam deflection, moment distribution, unsymmetrical bending, combined stresses, and tension field beams.

131. AIRPLANE STRUCTURES. *Prerequisite: Aero. Eng. 130 or by special arrangement for students from other departments.* I and II. (*3*).

The investigation and development of methods of analysis for stressed-skin airplane structures, the behavior of thin sheet and stiffened panels at and above the critical buckling stresses, and an introduction to the solution of indeterminate structures.

132. AIRPLANE STRUCTURES LABORATORY. *Prerequisite: preceded or accompanied by Aero. Eng. 130.* (*1*).

Lectures and experiments cover tests on columns, tubes, shear webs, torsion of open and closed sections, combined loadings, compression of flat plates, and other special topics.

133. ADVANCED AIRPLANE STRUCTURE. *Prerequisite: Aero. Eng. 131.* (*3*).

Special airplane stress analysis problems of an advanced nature. Shear lag, rigid frame analyses, torsional bending, the analysis of circular shell supported frames, and the general relaxation theory, with a complete discussion of various recent publications.

134. MATERIALS AND STRUCTURES. *Prerequisite: Aero. Eng. 130.* (*To be arranged*).
Materials likely to be used in the construction of pilotless aircraft, with particular reference to their physical properties at normal and elevated temperatures. Analysis of monocoque structures is reviewed and the effect of dynamic loads considered.

150. ROTARY WING AIRCRAFT. *Prerequisite: Aero. Eng. 109 or 110, 111.* (*3*).
Rotating-wing aircraft development. Performance analysis, rotor blade stall, stability, vibration.

160. SEMINAR. I and II. (*To be arranged*).
Open only to graduates and seniors who receive special permission. Reading and reports on selected aerodynamical and aeronautical problems. A reading knowledge of French and German is desirable.

161. RESEARCH. *Prerequisite: Aero. Eng. 112.* I and II. (*To be arranged*).
Continuation of Aero. Eng. 112. Offers an opportunity for students to pursue experimental investigations.

162. ANALYTICAL RESEARCH. (*To be arranged*).
Theoretical investigation of problems in aeronautical engineering particularly suited to treatment by analytical and mathematical methods.

165. AIRCRAFT PROPULSION I. *Prerequisite: Mech. and Ind. Eng. 105, 106, or equivalent.* (*3*).
Review of those phases of thermodynamics used in the analysis of compressible flow and propulsion systems; turbo jet, ram jet; and aeropulse.

165*a*. REVIEW OF THERMODYNAMICS AND INTRODUCTION TO AIRCRAFT PROPULSION. *Prerequisite: Mech. and Ind. Eng. 105.* (*3*).
Fundamental principles of thermodynamics and their general application to propulsion problems.

166. AIRCRAFT PROPULSION LABORATORY. *Prerequisite: preceded by Aero. Eng. 165.* (*2*).
Series of experiments designed to illustrate the general principles of propulsion and to introduce the student to certain experimental techniques in the study of actual propulsive devices, using full-scale or reduced models of the aeropulse, turbo-jet, and rocket motors.

171. PRINCIPLES OF AUTOMATIC CONTROL. *Prerequisite: Aero. Eng. 172 and Math. 148.* (*3*).
General aspects of systems, as they apply to control and guidance; steady and transient states of second order systems; characteristics and methods of damping and linear and nonlinear controls; transfer function analysis and general stability considerations.

172. ENGINEERING MEASUREMENTS AND PHYSICAL SYSTEMS. *Prerequisite: Eng. Mech. 3, Elec. Eng. 3 or 5.* (*3*).
Treatment of instrument response and errors; static, transient, and steady state behavior together with the statistical basis of measurement; altimeters, gyros, thermocouples, seismic instruments, strain gages, and vibration isolation;

the concept of the general response of a linear system with simple types of nonlinear damping; use of the electronic differential analyzer to solve and illustrate various physical systems over a wide range of parameters. Lectures and laboratory.

173. Fundamentals of Aeronautical Instruments and Research Techniques. *Prerequisite: Aero. Eng. 172. (3).*

Continuation of Aero. Eng. 172 including a study of the role of schlieren, shadow, X-ray, and interferometric techniques in aerodynamic research and a comparison of their relative accuracy and effect in data reduction; temperature measurement in combustion chambers and jets; wind tunnel balances; analysis of problems encountered in flight research, including methods of data multiplexing and data recovery; comparison of wind tunnels versus instrumental flight in aerodynamic and systems research.

175. Engineering Applications of the Differential Analyzer. *Prerequisite: Math. 54 or equivalent. (2).*

Basic theory and principles of operation of differential analyzers. Material treated will include heat flow, wave propagation, static and dynamic structural problems, automatic control systems, simulation of physical systems. One lecture and one three-hour laboratory a week. Laboratory consists of the solution of problems on the electronic differential analyzers of the Department of Aeronautical Engineering.

176. Flight Testing. *Prerequisite: Aero. Eng. 113 or equivalent. (2).*

Theory and practice of obtaining flight test data on performance and stability of airplanes from actual flight tests. No laboratory fee will be charged, but a deposit covering student insurance and operating expense of the airplane will be required.

179. Gyrokinetics. *Prerequisite: Math. 104 or equivalent. (3).*

Dynamics of rigid bodies, review of elementary mechanics, energy integral, Lagrangian and Hamiltonian methods, Euler's equations. Theory and application of gyroscopes for control and guidance.

190. Introduction to Nuclear Engineering. I and II. *(3).*

Open to seniors and graduate students. Introductory treatment of the application of theoretical physics in the production of nuclear energy to develop a broad background in atomic and nuclear science. Constitutes the basis for more specialized engineering studies of the applications of nuclear engineering. Elementary particles, electromagnetic radiation, waves, quantization and energy levels, radioactivity, measurement of nuclear phenomena, nuclear disintegration and fission, nuclear reactors, biological effects of radiation, and the application of nuclear reactors in power generation.

The attention of interested students is directed also to various pertinent offerings of the Department of Physics.

201. Dynamics of Viscous Fluids. *Prerequisite: Aero. Eng. 116. (3).*

Effect of viscosity in fluid flows. Laminar and turbulent boundary layers in theory and experiment; flow through tubes; flow separation; turbulence theories.

202. DYNAMICS OF COMPRESSIBLE FLUIDS. *Prerequisite: Aero. Eng. 116. (3).*

Advanced study of the mechanics of high-speed flows; subsonic and supersonic flow through nozzles and diffusers, normal and oblique shock waves, effects of viscosity, flow past wedges, cones, and around corners, transsonic and supersonic airfoil theory.

203. DYNAMICS OF PERFECT FLUIDS. *Prerequisite: Aero. Eng. 115, Math. 110 and 176 or equivalent. (3).*

Continuation of Aero. Eng. 115, in which theoretical methods are applied to three-dimensional flow and to unsteady flows of frictionless incompressible fluids. Forces and moments on an oscillating airfoil as they apply to the flutter of aircraft are derived and discussed.

204. AIRCRAFT PROPULSION II. *Prerequisite: Aero. Eng. 165. (3).*

Analysis of various propulsion systems, including ram jets and rocket motors, with special emphasis on the characteristics which govern the selection of a propulsion system for a specific installation.

210. ADVANCED ENGINEERING MEASUREMENTS. *Prerequisite: Aero. Eng. 172, Elec. Eng. 100 and 180, Math. 148. (3).*

Transfer functions and impulse response characteristics of linear systems; synthesis and analysis by the Fourier transform; power spectra and correlation functions of signal and noise; effects of nonlinear components; modern information theory used in analyzing instrumentation and the design of experiments; the role of calculating machines in the treatment of experimental data. Lectures and problems.

212. CONTROL AND GUIDANCE OF PILOTLESS AIRCRAFT. *Prerequisite: Aero. Eng. 171 or Elec. Eng. 255, Elec. Eng. 120 and 220, Math. 148. (3).*

General analysis of the stability of linear closed-loop systems; relations between control and propulsion and guidance and fuel consumption; beam rider, command guidance, and homing methods together with their relation to collision courses. Demonstrations are made with the electronic differential analyzer and missile simulator. Lectures, problems, and laboratory.

214. TELEMETRY AND REMOTE CONTROL OF AIRCRAFT. *Prerequisite: Aero. Eng. 172, Elec. Eng. 120, Math. 148. (3).*

Role and characteristics of transmission links; modulation and multiplex theory in the light of signal-to-noise improvement, crosstalk, and improvement thresholds. Modulation and multiplex methods include amplitude, frequency, phase, subcarrier, pulse-amplitude, pulse-width, pulse-position, and pulse-code. Information efficiencies of the above methods; end instruments and various methods of data recording. Lectures, problems, and laboratory.

248. ADVANCED FEEDBACK CONTROL. *Prerequisite: Aero. Eng. 171 or equivalent.* I. *(3).*

Review of linear system theory, analysis of multiple loop systems, response to pulse input signals. Behavior of linear systems in the presence of noise, introduction to autocorrelation methods. Analysis and synthesis of elementary nonlinear systems. Lectures and laboratory.

250. THEORY OF OSCILLATION OF NONLINEAR SYSTEMS. *Prerequisite: Math. 104 and a knowledge of elementary matrix theory.* (2).

Principally considered are autonomous (unforced) systems with large nonlinearities and a finite number of degrees of freedom as represented by systems of nonlinear ordinary differential equations without explicit appearance of the independent variable. The concept of phase space is introduced by redevelopment of linear ordinary differential equations in this framework. Conservative nonlinear systems are treated although the main emphasis is on nonconservative nonlinear systems with detailed treatment of second order systems including many physical examples. Use of the electronic differential analyzer for the solution of problems is demonstrated.

251. THEORY OF NONLINEAR SYSTEM RESPONSE. *Prerequisite: Aero. Eng. 250* (2).

Principally considered are forced systems with large nonlinearities and a finite number of degrees of freedom as represented by systems of nonlinear ordinary differential equations containing functions of the independent variable. Harmonic and subharmonic synchronization and entrainment of oscillatory systems are considered. The response of dynamical systems with nonlinear elements to functions of time is treated with particular reference to the improvement of feedback control system performance by the use of nonlinear elements. Use of the electronic differential analyzer for the solution of problems is demonstrated.

252. SEMINAR ON SIMULATION AND SOLUTION OF NONLINEAR SYSTEMS. *Prerequisite: Aero. Eng. 175 and 250, or permission of instructor.* (1).

Supervised work on assigned problems and problems of interest to the student of the types treated in Aero. Eng. 250 and 251. The principal tool used is the electronic differential analyzer.

295. THEORY OF NUCLEAR REACTORS. *Prerequisite: Elec. Eng. 294.* (3).

Derivation of neutron flux equations for monoenergetic neutrons with uniform or varied emission time. Analysis of homogeneous reactor configurations and study of heterogeneous reactor structure. Analysis of requirements for reactor control systems.

Business Administration*

Professors Stevenson, Griffin, Paton, Woodworth, Jamison, Blackett, Riegel, Waterman, Dixon, Schlatter, Schmidt, Dykstra, and others.

The courses listed below are of special interest to engineering students. In the election of such courses attention is called to the administrative rules of the School of Business Administration which affect elections as follows:

* School of Business Administration.

1. No student shall elect courses in the School of Business Administration who does not have at least third-year standing.

2. Juniors may elect courses numbered 1 to 99, inclusive, and seniors may elect any course numbered 1 to 199, inclusive, provided they have satisfied particular course prerequisites.

3. Courses numbered above 200 may be elected only by properly qualified graduate students and are *not* open to juniors and seniors.

For a description of courses in business administration, see the *Announcement* of the School of Business Administration. A supplement will be issued indicating the course offerings for each semester.

The following are courses of particular interest to engineering students:

11. Principles of Accounting. *(4)*.
12. Principles of Accounting. *(4)*.
13. Fundamentals of Accounting. *(3)*.
14. Industrial Cost Accounting. *(3)*.
51. Principles of Marketing. *(3)*.
61. Money and Banking. *(3)*.
62. Financial Principles. *(3)*.
105. Business Law. *(3)*.
106. Business Law. *(3)*.
124. Industrial Statistics. *(3)*.
141. Production Management. *(3)*.
142. Personnel Administration. *(3)*.

Chemical and Metallurgical Engineering

1. ENGINEERING MATERIALS AND PROCESSES. *Prerequisite: an acceptable high-school course in chemistry or Chem. 3. (5)*.

Metals, alloys, cement, clay products, protective coatings, plastics, fuels, and water. An introductory course. Two lectures, three recitations, and three hours of laboratory.

2. ENGINEERING CALCULATIONS. *Prerequisite: general chemistry and Phys. 45 (3)*.

Material and energy balances and their application to chemical and metallurgical problems.

10. FUELS. *(1)*.

Laboratory testing of fuels, gases, oils, and water, and interpretation of results. Scheduled with Mech. and Ind. Eng. 17.

13. PROCESSING OF CAST METALS. *Prerequisite: Ch. and Met. Eng. 118 and Chem. 83E. (2)*.

Quantitative study of the operations of melting, molding, pouring, cleaning, and inspection, as well as exercises in quality control. Melting experiments emphasize the application of physical chemistry to liquid metals. Operation and critical evaluation of cupola, induction, and arc furnaces are included. Molding experiments correlate the principles of gating and risering with heat transfer from liquid metal. Radiographic, magnaflux, metallographic, and rapid chemical control procedures are surveyed. One lecture and one three-hour laboratory period a week. For metallurgical engineers.

16. MEASUREMENTS LABORATORY. *Prerequisite: Chem. 41, preceded or accompanied by Chem. 83E (3).*

Physical-chemical measurements and determination of properties. Laboratory, computation, and reports.

100. PLANT WORK. *(1).*

Credit is given for a satisfactory report on some phase of work done in a plant. The nature of a problem must be approved before entering upon the work.

101. CHEMICAL PLANT DESIGN PROBLEM.

The American Institute of Chemical Engineers holds an annual competition for the solution of a problem open to all undergraduate students. A credit of one hour will be granted to any student who submits a solution of this problem which is satisfactory to the staff of the department.

102. STRUCTURE OF METALS. *Prerequisite: Ch. and Met. 107. (2).*

Survey of fundamental mechanisms controlling the properties of metallic solids; their crystallography; elastic and plastic properties; electrical, thermal, and mechanical properties.

105. JET AND ROCKET MOTOR FUELS. *Prerequisite: Ch. and Met. Eng. 2 or permission of instructor. (3).*

Preparation, supply, handling, and properties of materials used or usable for rocket propellants.

107. METALS AND ALLOYS. *Prerequisite: Ch. and Met. Eng. 1 and preceded or accompanied by Mech. and Ind. Eng. 82. (2).*

Structures and properties as affected by composition and mechanical and thermal treatment, with special emphasis on the utilization of common metals and alloys and their behavior in service.

107*a*. METALS AND ALLOYS LABORATORY. *(1).*

May be elected only in conjunction with Ch. and Met. Eng. 107. One laboratory period of three hours.

111. THERMODYNAMICS. *Prerequisite: Ch. and Met. Eng. 2 and Math. 54. (3).*

Laws of energy applied to continuous or flow processes, chemical equilibria, properties of materials and solutions, heat, work, and the concept of availability.

113. UNIT OPERATIONS I. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 111. (4).*

Equipment and theory of unit operations and their application.

114. UNIT OPERATIONS. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 111. (4).*

Unit operations in the field of metallurgical engineering.

115. Unit Operations II. *Prerequisite: Ch. and Met. Eng. 113. (3).*
Theories of heat and mass transfer operations and their application in calculations for equipment design.

117. Metals and Alloys. *Prerequisite: Ch. and Met. Eng. 118. (3).*
Structures of metals as affected by composition and thermal and mechanical treatment; their resultant physical properties and behavior in service. Lectures, recitations, and laboratory.

118. Structure of Solids. *Prerequisite: Chem. 83E. (3).*
Atomic structure; amorphous and crystalline solids covering fundamental crystallographic concepts, types of solids, ionic crystals, free electron theory of metals and semiconductors, specific heats, electric, magnetic, and optical properties, cohesive forces, crystal growth, work hardening and recrystallization, and surface properties of solids.

119. Metallurgical Process Design. *Prerequisite: Ch. and Met. Eng. 113 or 114. (4).*
Application of principles involved in the extraction of metals from ores and scrap, the production of alloys and their commercial shapes or forms.

121. Design of Process Equipment. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 115 or 119. (2).*
The student designs and estimates cost of selected equipment. Lectures, reports, and design.

124. X-ray Studies of Engineering Material. *Prerequisite: Ch. and Met. Eng. 16 and 118. (2).*
Radiography, investigation of welds and castings; diffraction studies of metals and alloys. Lectures, recitations, and laboratory.

125. Organic Materials. *Prerequisite: organic and physical chemistry, preceded or accompanied by Ch. and Met. Eng. 118. (3).*
Properties, structures, and engineering applications of organic materials. Lectures, recitations, and laboratory.

126. Glass and Ceramic Materials. *Prerequisite: physical chemistry and Ch. and Met. Eng. 118. (2).*
Structures and properties of glasses and ceramics as related to composition and thermal treatment.

127. Physical Metallurgy I. *Prerequisite: Ch. and Met. Eng. 2, 16, and 118. (3).*
Structures and properties of metals as related to composition and thermal and mechanical treatment. Lectures, recitations, and laboratory.

128. Physical Metallurgy II. *Prerequisite: Ch. and Met. Eng. 127. (3).*
Surface hardening, hardenability, hardening, tempering, isothermal transformation, related properties of iron and steel.

129. Engineering Operations Laboratory. *Prerequisite: Ch. and Met. Eng. 16 and 115 or 119. (3).*
Laboratory determination of actual operating data of equipment for chemical and metallurgical operations. Laboratory, conferences, and reports.

130. Chemical Process Design. *Prerequisite: Ch. and Met. Eng. 115 and 117* (*3*).
Application of chemistry and the unit operations to the design of chemical processes.

136. Protective Coatings—Pigments. *Prerequisite: Chem. 61R and 83.* II. (*3*).
Pigments, stains, and dyes, their manufacture, properties, and uses in protective coatings.

137. Protective Coatings—Vehicles and Dryers. *Prerequisite: Chem. 61 and 83.* I. (*3*).
Production, properties, and uses of natural and synthetic oils, thinners, and diluents.

193. Procedures and Design in the Handling of Radioactive Materials. *Prerequisite: Elec. Eng. 190, 192, or permission of instructor.* I. (*2*).
Procedures in the safe handling of radioactive materials, hazard evaluations, design of laboratories and waste disposal facilities. One hour lecture, three hours laboratory demonstrations, and experiments with high level sources.

202. Advanced Chemical Engineering Calculations. *Prerequisite: Ch. and Met. Eng. 115 and a course in differential equations.* II. (*3*).
Chemical engineering calculations on unsteady state heat and mass transfer, stagewise or column-plate operations, chemical reactions, fluid flow, and thermodynamics.

207. Metals at High Temperatures. *Prerequisite: Ch. and Met. Eng. 107, 117, or 127.* (*3*).
Fundamental principles determining the behavior of metals at high temperatures and the selection and performance of alloys in such applications as jet-propulsion engines, gas turbines, chemical industries, and steam power plants.

208. Rheological Engineering Materials. *Prerequisite: Ch. and Met. Eng. 118.* II. (*3*).
Structure and properties of materials whose behavior is intermediate between that of subcooled liquids and distinctly crystalline solids, such as plastics, paints and varnishes, leather, rubber, and ceramics.

210. Special Research and Design. (*To be arranged*).
Laboratory and conferences. Provides an opportunity for individual or group work in a particular field or on a problem of special interest to the student. The program of work is arranged at the beginning of each semester by mutual agreement between the student and a member of the staff. Any problem in the field of chemical and metallurgical engineering may be selected; current elections include problems in the following fields: fluid flow, heat transfer, distillation, filtration, catalysis, petroleum, plastics, paint, varnish, ferrous metallurgy, metals at high temperature, nonferrous metallurgy, foundry and cast metals, X-ray applications, electrodeposition, and nuclear energy. The student writes a final report on his project.

211. Engineering Thermodynamics. *Prerequisite: Ch. and Met. Eng. 111.* (*3*).
Principles of the laws of energy as applied to chemical and metallurgical engineering problems.

212. Advanced Process Design. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 211.* II. (*3*).

Process design calculation, with primary emphasis on application of rate data for homogeneous and heterogeneous reaction.

213. Advanced Unit Operations. *Prerequisite: Ch. and Met. Eng. 115.* (*4*).

Fluid flow, heat transfer, evaporation, filtration, and sedimentation.

215. Mass Transfer Operations. *Prerequisite: Ch. and Met. Eng. 115.* (*4*).

Advanced study of distillation, absorption, extraction, leaching, and allied operations.

216. Pyrometry and Furnace Control. *Prerequisite: Ch. and Met. Eng. 16.* (*3*).

Theory, construction, calibration, and use of commercial pyrometers; the methods of thermal analysis and the means of temperature control in furnaces. Recitation and laboratory.

217. Corrosion and High-Temperature Resistance of Metals. *Prerequisite: Ch. and Met. Eng. 107 or 117.* (*3*).

Fundamentals involved in choosing a metal for use in oxidizing or corroding media or at elevated temperatures.

219. Metallurgical Operations. *Prerequisite: Ch. and Met. Eng. 119 and 127.* (*3*).

Rolling, forging, extrusion, piercing, drawing, and straightening.

220. Operation and Management of Chemical Plants. *Prerequisite: Ch. and Met. Eng. 130.* (*3*).

221. Advanced Design of Process Equipment. *Prerequisite: Ch. and Met. Eng. 121.* (*3*).

The student selects some piece of chemical machinery and makes a complete set of drawings that would be required for its actual construction. Conferences and design.

224. X-ray Studies of Engineering Materials. *Prerequisite: Ch. and Met. Eng. 124.* II. (*3*).

Application of X-ray methods to the study of age hardening, cold working, and phase changes.

228. Nonferrous Metals. *Prerequisite: Ch. and Met. Eng. 128.* (*3*).

Ternary systems, solution and precipitation, plastic deformation, recrystallization, grain growth. Lectures, recitations, and laboratory.

229. Engineering Laboratory. *Prerequisite: Ch. and Met. Eng. 129.* (*4*).

Students work in small groups on development projects involving the design, construction, and operation of pilot plant scale equipment. Laboratory, conferences, and reports.

230. Process Design. *Prerequisite: Ch. and Met. Eng. 213.* II. (*3*).

Working in small teams, the students develop the process flow sheet and determine the capacities and operating conditions of the equipment and the instrumentation for a process such as the manufacture of acetylene, ethylene, magnesium, or fatty acids and their derivatives. An operational analysis is made to assure the operability of the process during the starting on-stream and shut-down periods.

231. Explosives. *Prerequisite: Chem. 169E and Ch. and Met. Eng. 130.* (*3*).

Manufacture of commercial and military explosives and pyrotechnic materials, their properties and uses.

232. Cellulose Industries. *Prerequisite: Chem. 83E and 169E.* II. (*3*).

Manufacture of pulp and paper, cellulose fibers, and plastics; their properties and uses.

235. Petroleum Refining. *Prerequisite: Ch. and Met. Eng. 115.* I. (*4*).

Design of process and plant used in the manufacture of petroleum products and natural gasoline.

237. Synthetic Resins and Emulsions. *Prerequisite: Ch. and Met. Eng. 137.* (*4*).

Manufacture, properties, and uses.

238. Fermentation Processes. *Prerequisite: Bact. 111E or permission of instructor.* (*3*).

Detailed study of the processes, operations, and equipment involved in selected industrial fermentation processes directed towards the production of pharmaceuticals, industrial chemicals, and industrial waste disposal. Lectures, seminars, and field trips.

239. Food Processing. *Prerequisite: organic chemistry and Ch. and Met. Eng. 115 or permission of instructor.* (*3*).

Chemistry of food and food processing methods. Lectures, seminars, and field trips.

240. Reactions of Steel Making. *Prerequisite: Ch. and Met. Eng. 119.* (*3*).

Design and operation of the blast furnace and steel-making processes.

241. Cast Iron and Steel. *Prerequisite: Ch. and Met. Eng. 107, 117 or 127.* (*3*).

Solidification, structures, and properties of cast ferrous metals; influence of composition, section size, and other variables on the rate of malleabilization; influence of variables on the properties and structures of grey irons; selection of cast metals for specific purposes.

242. Steels. *Prerequisite: Ch. and Met. Eng. 128.* (*3*).

Theory and practice of alloy additions to steel and the effect of alloying elements on properties of steel. Lecture and recitations.

243. Powder Metallurgy. *Prerequisite: Ch. and Met. Eng. 107, 117, or 127.* I. (*2*).

Metal powders, compacting, sintering, products utilization.

244 (Prod. Eng. 244). Cast Metals in Engineering Design. *Prerequisite: Prod. Eng. 11, 12 or Ch. Met. 13, 107, 117 or 127.* (*2*).

An understanding of the properties of the important cast metals is obtained by melting, casting, and testing. In addition to measurement of mechanical properties, resistance to heat, wear, and corrosion is discussed. The application of these properties in the design of critical parts in the aircraft, automotive, chemical, mining, and railroad industries is presented by case histories and examination of castings. One lecture and one three-hour laboratory period a week.

251. FURNACE DESIGN AND CONSTRUCTION. *Prerequisite: Ch. and Met. Eng. 114 or 115. (3).*

Furnace atmosphere, refractory materials, and their application in the design of furnaces.

254. HEAVY CHEMICALS. *Prerequisite: Ch. and Met. Eng. 129 and 130.* I. *(3).*

Design study of selected heavy chemical manufacturing processes and the design of major equipment.

258. ELECTROCHEMICAL OPERATIONS. *Prerequisite: Chem. 83E and Ch. and Met. Eng. 111.* I. *(4).*

The principles and industrial applications of electrochemistry. Lectures, recitation, and laboratory.

266. PAINT, VARNISH, AND LACQUER LABORATORY. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 136 or 137.* I. *(4).*

Analysis, physical testing, and manufacture. Conferences and laboratory.

311. APPLIED THERMODYNAMICS. *Prerequisite: Ch. and Met. Eng. 211. (3).*

Advanced analytical study of chemical engineering processes from the standpoint of quantitative thermodynamics.

315. AZEOTROPIC AND EXTRACTIVE DISTILLATION. *Prerequisite: Ch. and Met. Eng. 215. (3).*

Design and processes used in operation involving nonideal solutions.

316. SEPARATION OF ISOTOPES. *Prerequisite: Ch. and Met. Eng. 211 and 215. (2).*

Analysis of processes used in the separation of isotopes including mass diffusion, thermal diffusion, barrier diffusion, chemical exchange, and distillation.

328. PHYSICAL METALLURGY SEMINAR. *Prerequisite: Ch. and Met. Eng. 228. (2).*

333. HIGH MOLECULAR WEIGHT POLYMERS. *Prerequisite: Ch. and Met. Eng. 225. (3).*

335. PETROLEUM REFINERY ENGINEERING. *Prerequisite: Ch. and Met. Eng. 235. (4).*

Selected petroleum refining processes.

336. PAINT, VARNISH, AND LACQUER FORMULATION. *Prerequisite: Ch. and Met. Eng. 237. (5).*

Economic formulation, manufacture, and uses.

337. VARNISH. *Prerequisite: Ch. and Met. Eng. 237.* I. *(3).*

Formulation, manufacture, and uses of natural and synthetic resin, varnish, and wax.

340. METALLURGICAL REACTIONS. *Prerequisite: Ch. and Met. Eng. 211 and 240. (2).*

342. APPLIED PHYSICAL METALLURGY. *Prerequisite: Ch. and Met. Eng. 242.* I. *(3).*

Processing and service failures.

355. PETROLEUM PRODUCTION ENGINEERING. *Prerequisite: Ch. and Met. Eng. 235. (4).*

Petroleum gases and liquids under high pressure, the production of natural gases and crude oil, and process design of separation plants.

363. HEAT TRANSFER SEMINAR. *Prerequisite: Ch. and Met. Eng. 213. (To be arranged).*

365. MASS TRANSFER SEMINAR. *Prerequisite: Ch. and Met. Eng. 215. (To be arranged).*

Chemistry*

Professors Anderson, Brockway, Elderfield, Elving, Fajans, Ferguson, and Halford; Associate Professors Case, Hodges, Soule, and Westrum; Assistant Professors Meinke, Meloche, Parry, Rondestvedt, Rulfs, Smith, Vaughan, and Weatherill; Dr. Taylor.

1. GENERAL AND INORGANIC CHEMISTRY. I and II. *(4).*

Elementary course for students who have not studied chemistry in high school. Two lectures, three recitations, and one three-hour laboratory period.

3. GENERAL AND INORGANIC CHEMISTRY. *Prerequisite: one year of high-school chemistry.* I and II. *(4).*

Elementary course for students who have studied chemistry in high school. Two lectures, two recitations, and four hours of laboratory work.

4. GENERAL AND INORGANIC CHEMISTRY. *Prerequisite: Chem. 1 or 3.* I and II. *(4).*

Continuation of Chem. 1 or 3 designed for students who are planning to take additional work in chemistry. Students in engineering who are not planning to enter the curriculum in chemical and metallurgical engineering should elect Chem. 6 rather than Chem. 4. In Chem. 1 or 3 and Chem. 4, the fundamental principles of chemistry are studied, accompanied by the descriptive chemistry of most of the nonmetallic elements (Chem. 1 or 3) and of the important metallic elements (Chem. 4). Two lectures, two recitations, and four hours of laboratory.

5E. GENERAL AND INORGANIC CHEMISTRY. *Prerequisite: one year of high-school chemistry validated by a satisfactory grade on the placement test given during the Orientation period. All other students should elect Chem. 1 or 3, credit for which will be counted as a nontechnical elective, followed by Chem. 4 or 6.* I and II. *(5).*

Fundamental principles of chemistry and a study of the more important elements and compounds, omitting the common nonmetallic elements. Two lectures, two recitations, and six hours of laboratory work.

6. GENERAL CHEMISTRY. *Prerequisite: Chem. 1 or 3.* II. *(4).*

Continuation of Chem. 1 or 3 for students who are planning to take no further courses in chemistry. Includes all engineering students except those

* College of Literature, Science, and the Arts.

planning to enter the curriculum in chemical and metallurgical engineering, who should elect Chem. 4 *Chem. 6 will not be accepted as a prerequisite for more advanced courses in chemistry.* Two lectures, two recitations, and four hours of laboratory work.

11. GENERAL AND INORGANIC CHEMISTRY. *Prerequisite: high school algebra and chemistry and a satisfactory grade in the placement test.* I. (*4*).
Deposit, $10. Two lectures, two recitations, and four hours of laboratory.

12. INORGANIC CHEMISTRY AND QUALITATIVE ANALYSIS. *Prerequisite: Chem. 11.* II. (*4*).
Deposit, $10. Three lecture-recitations and six hours of laboratory.

23. INTRODUCTORY ANALYTICAL CHEMISTRY. *Prerequisite: Chem. 4 or 5E.* I and II. (*4*).
Ionic equilibria; an introduction to analytical chemistry. Approximately half the laboratory work deals with qualitative analysis and half with quantitative, the latter covering introductory work in both gravimetric and volumetric techniques.

41. QUANTITATIVE ANALYSIS. *Prerequisite: Chem. 23.* I and II. (*4 required, may be taken for 5*).
Study of gravimetric, volumetric, and electrolytic methods, and the analysis of limestone and brass. Solution of stoichiometric problems is emphasized. Three lectures or recitations and two four-hour laboratory periods.

61. ORGANIC CHEMISTRY. *Prerequisite: Chem. 3 and 4, or 5E and 23.* I and II. (*6*).
Survey of the whole field of organic chemistry. Four lectures, one recitation, and seven hours of laboratory.

61R. ORGANIC CHEMISTRY. *Prerequisite: Chem. 3 and 4, or 5E and 23.* I and II. (*4*).
Same as 61 but without laboratory work.

83E. ELEMENTARY PHYSICAL CHEMISTRY. *Prerequisite: Chem. 23, Phys. 46, and a knowledge of calculus.* I and II. (*4*).
Fundamentals of physical chemistry including an elementary exposition of the states of matter, solutions, chemical equilibrium, the phase rule, chemical kinetics, thermochemistry and electrochemistry, atomic theory, and molecular structure. Three lectures and two recitations.

141. ADVANCED QUANTITATIVE ANALYSIS. *Prerequisite: Chem. 41 and Phys. 46.* I and II. (*4–5*).
Analysis of natural and synthetic materials. Chemistry of the more important rarer elements. Discussion of techniques and physicochemical methods not covered in Chem. 41. Lectures and quiz, twice a week; laboratory, two or three periods a week.

161. ORGANIC CHEMISTRY. *Prerequisite: Chem. 61.* I and II. (*4*).
Special topics in organic chemistry not taken up in detail in Chem. 61. Two lectures, one discussion, seven hours of laboratory.

161R. ORGANIC CHEMISTRY. *Prerequisite: Chem. 61.* I and II. (*2*).
Same as Chem. 161 but without laboratory work.

171. ELECTROCHEMISTRY. *Prerequisite: Chem. 83E.* I. (*2*).
Elementary treatment of the fundamentals of the subject. Two lectures.

185, 186. PHYSICOCHEMICAL MEASUREMENTS. *Prerequisite: preceded or accompanied by Chem. 41 and 83E.* 185, I and II; 186, I and II. (*2 each*).
Measurements of molecular weights, properties of pure liquids and solutions, thermochemical data, equilibria, kinetics, atomic and molecular properties, and electrochemical data.

188. PHYSICAL CHEMISTRY. *Prerequisite: Chem. 4 or 5E, 23 and calculus.* I and II. (*4*).
Fundamentals of physical chemistry particularly for students enrolled in the curriculum in physics, others by special permission. Four lectures.

234. PHYSICOCHEMICAL METHODS IN QUANTITATIVE ANALYSIS. *Prerequisite: Chem. 83E and 141.* II. (*2*).
Lectures and laboratory work.

256. ORGANIC CHEMISTRY OF SYNTHETIC POLYMERS. *Prerequisite: Chem. 161.* II. (*2*).
Chemistry of synthetic polymers, including the preparation of the intermediates for resins and rubber substitutes of commercial importance. Two lectures and reading.

Civil Engineering

1. SURVEYING. *Prerequisite: Math. 14.* I and II. (*3*).
Care and use of surveying instruments and equipment; differential and profile leveling, establishing grade, vertical curves, traverse surveys and computations; circular curves. Theory, problems, and field exercises.

2. SURVEYING. *Prerequisite: Civ. Eng. 1.* I and II. (*4*).
Principles of triangulation, topographic mapping, use of plane table and stadia; U.S. land subdivision, property surveys; map projections and co-ordinate systems; earth-work computations including mass diagram; controlled planimetric map from aerial photographs; map making; theory of instrument adjustment. Problems and field exercises.

3. SURVEYING. *Prerequisite: Civ. Eng. 1 and 2.* Camp Davis. S.S. (*4*).
Field adjustment of instruments, triangulation and base line measurements, establishment of vertical and horizontal controls; route surveys with application of vertical and horizontal curves to location; land surveys; construction surveys (including setting grade and slope stakes, excavation batter boards, etc.). Field problems.

4. SURVEYING. *Prerequisite: Math. 14.* I and II. (*2*).
For noncivil engineering students. Care and use of surveying instruments and equipment; differential and profile leveling; establishing grade; traverse surveys and computations. Theory, problems, and field exercises.

12. SURVEYING. *Prerequisite: Math. 13.* (*3*).
Similar to Civ. Eng. 1. Designed for forestry students. Theory, problems, and field exercises.

13. SURVEYING. *Prerequisite: Civ. Eng. 12.* (*4*).
Similar to Civ. Eng. 2. Designed for forestry students. Lectures, text, two recitations, and two four-hour field or drawing periods.

20. STRUCTURAL DRAFTING. *Prerequisite: Draw. 2.* I and II. (*2*).
Standard civil engineering drafting-room practice, including conventional signs and symbols, preparation of civil engineering computations and graphs, detailing of structural elements, and use of standard structural handbooks. Lectures, text, and drawing room practice.

21. THEORY OF STRUCTURES. *Prerequisite: Eng. Mech. 2.* I and II. (*3*).
Not open to civil engineering students. Analysis of stresses in simple structures; calculation of reactions, shear, and bending moment due to fixed and moving loads; analysis of stresses and design of simple wood, steel, and reinforced concrete structures. Lectures, text, and home problems.

22. THEORY OF STRUCTURES. *Prerequisite: Eng. Mech. 2.* I and II. (*3*).
Analysis of stresses in simple structures; calculation of reaction, shear, and bending moment in simple, restrained, and continuous beams due to fixed and moving loads; analysis of stresses in simple trusses due to fixed and moving loads. Lectures, text, and home problems.

23. ELEMENTARY DESIGN OF STRUCTURES. *Prerequisite: Civ. Eng. 20 and 22.* I and II. (*3*).
Design and details of simple beams, girders, columns, and trusses. Computations and drawing work.

30. CONCRETE MIXTURES. I and II. (*1*).
Theory and design of concrete mixtures; analysis of aggregate grading; bulking due to moisture; strength, permeability, durability, yield, and economy. Discussions, problems, laboratory.

50. FUNDAMENTALS OF SANITARY ENGINEERING. I and II. (*2*).
Environmental factors affecting public health that may be controlled through the application of engineering knowledge. Principles of public sanitation as applied to community problems of water supply, sewerage, housing, and ventilation, and to the technical problems of other sanitation activities. Open to juniors and seniors.

60. HIGHWAY ENGINEERING. *Prerequisite: Civ. Eng. 1 or 4.* I and II. (*2*).
General course covering the planning, design, construction, maintenance, economics, and financing of highways.

70. RAILROAD ENGINEERING. *Prerequisite: Civ. Eng. 1 or 4.* I and II. (*2*).
Regulation and valuation of railways; elements of the location, design, con-

struction, and maintenance of roadway and equipment; the analysis of operating problems. Open to juniors and seniors.

101. GEODESY. *Prerequisite: Civ. Eng. 3.* (*3*).

Introductory course; history; elements of modern practice and its application to several branches of surveying. Lectures, text, recitation.

102. GEODESY. *Prerequisite: Civ. Eng. 101.* (*2*).

Methods employed and field covered by the United States Coast and Geodetic Survey. Lectures, reference work.

105. LEAST SQUARES. *Prerequisite: Math. 54.* (*2*).

Theory of least squares; adjustment and comparison of data. Lectures, text, problems, and recitations.

106. ADVANCED SURVEYING. S.S. (*2–8*).

Special advanced work can be provided for those who have received credit in Civ. Eng. 3. Given only at Camp Davis.

107. MUNICIPAL SURVEYING. *Prerequisite: Civ. Eng. 3.* (*2*).

Surveys for streets, grades, paving, sewers, property lines, subdivisions. Lectures, text, drawing, field period.

109. RAILWAY SURVEYING. *Prerequisite: Civ. Eng. 3.* (*2*).

Text, field, track problems. One recitation and one four-hour field period.

111. PHOTOGRAPHY—BASIC COURSE. *Prerequisite: elementary chemistry and physics.* I and II. (*3*).

Fundamental theory and practice. Lectures, reference work, and laboratory period.

112. ADVANCED PHOTOGRAPHY. *Prerequisite: Civ. Eng. 111.* (*2*).

Continuation of Civ. Eng. 111. Lectures, reference work, laboratory period.

113. AERIAL PHOTOGRAPHY AND MAPPING. (*2*).

Map projections and map making from aerial photographs. Lectures, reference work, recitations, problems, and laboratory.

114. REGISTRATION OF LAND TITLES. *Prerequisite: Civ. Eng. 3.* (*3*).

Torrens Act of Australia and modifications as adopted to conditions of other countries. Lectures, reference work.

115. BOUNDARY SURVEYS. *Prerequisite: Civ. Eng. 3.* (*3*).

Problems relating to the establishment of boundaries. Lectures, reference work.

120. FUNDAMENTALS OF EXPERIMENTAL RESEARCH. (*2*).

Scientific method, its elements and procedures. Research project; outline, bibliography, design of experiments, selecting materials, instrumentation, analysis of data, inferences, and conclusions; preparation for publication. Seminar, problems, laboratory.

121. REINFORCED CONCRETE. *Prerequisite: preceded or accompanied by Civ. Eng. 22.* I and II. (*3*).

Properties of materials; analysis of stresses in plain and reinforced concrete structures.

122. ADVANCED THEORY OF STRUCTURES. *Prerequisite: Civ. Eng. 22. (3).*
Continuation of Civ. Eng. 22. Analysis of stresses in advanced types of trusses; statically indeterminate structures; arches. Lectures, texts, problems.

123. DESIGN OF STRUCTURES. *Prerequisite: Civ. Eng. 23, 121.* I and II. *(3).*
Design of reinforced concrete and steel structures. Computations, drawing.

124. RIGID FRAME STRUCTURES. *Prerequisite: preceded or accompanied by Civ. Eng. 121.* I and II. *(3).*
Analysis of rigid frames by methods of successive approximations and slope deflections; special problems in the design of continuous frames. Lectures, references, problems.

126. SANITARY ENGINEERING STRUCTURAL DESIGN. *Prerequisite: Civ. Eng. 23, 121, 151. (2).*
Structural design problems encountered in the field of sanitary engineering. Lectures, computations, drafting.

127. TIMBER CONSTRUCTION. *Prerequisite: Civ. Eng. 23.* II. *(1).*
Physical characteristics of structural woods; grading rules; design of timber structures.

128. DESIGN OF WELDED STEEL STRUCTURES. *Prerequisite: Civ. Eng. 123. (1).*
Elastic behavior of welded structures; designing for continuity and elastic-frame action; stress distribution in joints; expansion, contraction, distortion, and residual stresses; welding technique, methods, and equipment.

130. PHYSICAL PROPERTIES OF CONCRETE MASONRY. *(2).*
Design of concrete mixtures to obtain specified physical properties, including strength, elasticity, plasticity, impermeability, durability, and economy. Seminar, problems, laboratory.

131. COST ANALYSIS AND ESTIMATING. I. *(2).*
Open to seniors and graduates. Elements of cost in construction; determination of unit costs; analysis of cost records; estimates of cost; amortization and debt retirement; quantity surveys. Lectures, references, problems.

132. CONSTRUCTION METHODS AND EQUIPMENT. II. *(3).*
Open to seniors and graduates. Contractors' organizations; plant selection and layout; equipment studies; methods of construction. Lectures, class discussion, seminar.

135. APPLIED SOIL MECHANICS. *Prerequisite: Civ. Eng. 121, accompanied by Civ. Eng. 136.* I and II. *(3).*
Origin, evolution, and classification of soil; characteristics and properties of soil; soil moisture, ground water, capillarity, and frost action; theories of soil resistance and an introduction to practical applications including pressure distribution, bearing capacity of spread footings and pile substructures; excavations and embankment stability; problems in highway and airport construction. Lectures, references, and problems.

136. SOIL MECHANICS LABORATORY. *Prerequisite: preceded or accompanied by Civ. Eng. 135.* I and II. *(1).*

Laboratory and field practice in soil sampling and testing, analysis and interpretation of test results; mechanical analysis, Atterburg limits, shrinkage and expansion; measurement of physical properties, direct shear, unconfined and triaxial compression and internal stability; compaction characteristics; soil surveys and soil mapping. Laboratory exercises, field trips, lectures, and references.

140. HYDROLOGY. I and II. *(3)*.

The hydrograph and the various factors that affect and determine its characteristics; precipitation, evaporation, transpiration, infiltration; the unit hydrograph; the distribution graph; maximum flood flows and frequency of occurrence; normal flow and low flow; effect of forests, cultivation, and drainage; yield of wells; stream flow records. Lectures and laboratory problems.

141. HYDRAULICS. *Prerequisite: Eng. Mech. 4.* I and II. (2).

Hydrostatics; flow in pipes and pipe fittings; pipe orifices, Venturi meters; siphons; pump characteristics; flow in open channels; spillways; control meters. Lectures, demonstrations, and laboratory exercises.

142. WATER-POWER ENGINEERING. *Prerequisite: Eng. Mech. 4.* II. (2).

Hydraulics of turbines and fundamental principles of water-power development; characteristics and uses of different types of turbines; effect of load upon selection; storage and pondage; turbine testing; speed regulation. Lectures and problems.

143. ADVANCED HYDRAULICS. Prerequisite: Civ. Eng. 141 or equivalent. I and II. *(3)*.

Flow in open channels; nonuniform flow; critical depth; hydraulic jump channels of varying width; waves; flow in the laminar and transition regions in pipes and open channels; dimensional analysis; hydraulic similitude; hydraulic models.

144. HYDRAULIC STRUCTURES. *Prerequisite: Civ. Eng. 140 and 141 preceded or accompanied by Civ. Eng. 143.* II. *(3)*.

Dams, head gates, canals, flumes, pipelines, surge tanks, revetments, breakwaters, and other structures with special reference to the hydraulic problems encountered in connection with their design. Lectures and problems.

145. SEMINAR IN HYDRAULIC ENGINEERING. *Prerequisite: Civ. Eng. 140 and 141. (To be arranged).*

Lectures, assigned reading and student reports on problems dealing with theoretical hydraulics, hydrology, hydraulic models, hydraulic structures, hydroelectric power,· or multipurpose projects.

146. HYDRAULIC ENGINEERING DESIGN. *Prerequisite: Civ. Eng. 121, 140, and 141; preceded or accompanied by Civ. Eng. 143.* II. *(3)*.

Design of hydraulic structures such as diversion dams, head gates, control works, silt traps, syphon spillways, side-channel spillways, earth canals, and other structures involving accelerated flow, backwater, hydraulic jump, sedimentation, and erosion. Lectures, computations, and design.

151. WATER SUPPLY AND SEWERAGE. *Prerequisite: Eng. Mech. 4 and Civ. Eng. 50.* I and II. *(3)*.

Sources of public water supply, quality and quantity requirements; design of works for the collection, purification, and distribution of water for municipal use; requirements for municipal sewerage systems; fundamentals of design of sewage treatment plants. Lectures, problems.

152. WATER PURIFICATION AND TREATMENT. *Prerequisite: Civ. Eng. 151 and 156 or permission of instructor.* II. *(3).*

Engineering methods and devices for obtaining and improving the sanitary quality and economic value of municipal water supplies; processes of sedimentation, use of coagulants, filtration, softening, iron removal, sterilization; devices and structures for accomplishing these. Lectures, library reading, and visits to municipal water purification plants.

153. SEWERAGE AND SEWAGE DISPOSAL. *Prerequisite: Civ. Eng. 151 and 156 or permission of instructor.* I. *(3).*

Engineering, public health, legal, and economic problems involved in the design and construction of sewers and in the disposal of city sewage and industrial wastes. Lectures, library reading, and visits to nearby disposal plants.

154. SANITARY ENGINEERING DESIGN. *Prerequisite: Civ. Eng. 121 and 151.* *(3).*

Computations and drawing-board design of typical structures related to water supply, water purification, sewerage, and sewage disposal. Drawing room and visits to plants and work under construction.

155. MUNICIPAL AND INDUSTRIAL SANITATION. I *(3).*

Scientific foundations of public sanitation, in particular relation to closely built-up areas and to industrial environments. Lectures, library readings.

156. SANITARY ENGINEERING LABORATORY. *Prerequisite: Civ. Eng. 151 and Bact. 51 or other acceptable laboratory preparation.* II. (2).

Laboratory exercises to demonstrate principles of water purification and sewage treatment; development of basic design data.

157. INDUSTRIAL WASTE TREATMENT. *Prerequisite: Civ. Eng. 153 and 156, Environmental Health 225 or consent of instructor.* II. (2).

Evaluation of the industrial waste problem, the character and quantity of wastes produced, and the application of engineering principles to the satisfactory disposal of these wastes.

160. ADVANCED HIGHWAY ENGINEERING. *Prerequisite: Civ. Eng. 60.* I. (2).

Seminar course dealing with special phases of highway design and construction. Assigned reading and reports.

161. HIGHWAY MATERIALS. *Prerequisite: preceded or accompanied by Civ. Eng. 60.* I. *(3).*

Sources, production, and testing of highway materials; specifications; minor research problems. Lectures, text, laboratory.

162. BITUMINOUS MATERIALS AND PAVEMENTS. *Prerequisite: Civ. Eng. 60.* II. (2).

Selection of bituminous materials for various uses; pavement types; design of mixtures; construction and maintenance methods. Lectures, text, laboratory.

163. SOILS IN HIGHWAY ENGINEERING. *Prerequisite: Civ. Eng. 135 and 136.* I. (2).

Evaluation of soil in highway design and construction; soil surveys and mapping, identification and classification; subgrade bearing capacity, drainage, frost action, soil stabilization and design of flexible and rigid pavements; fills and embankments, swamp construction. Airphoto analysis; typical land forms, drainage patterns, field mapping, and material surveys. Lectures, references, and design problems.

164. HIGHWAY TRANSPORT. II. *(2)*.

Fundamentals of transportation of passengers and commodities over highways; regulation of motor carriers; management of transportation companies.

165. HIGHWAY TRAFFIC ENGINEERING. I. *(2)*.

Causes of and remedies for street traffic congestion and accidents.

166. HIGHWAY TRAFFIC SURVEYS. *Prerequisite: preceded or accompanied by Civ. Eng. 165.* II. *(2)*.

Traffic studies for highway planning and for the facilitation and safeguarding of traffic flow. Assigned reading and field work.

167. HIGHWAY ECONOMICS. II. *(2)*.

Open to seniors and graduates. Economics of highway location, construction, and operation; highway finance; effect on cost of grades, curves, and distance.

169. HIGHWAY DESIGN. *Prerequisite: Civ. Eng. 60.* I and II. *(3)*.

Studies of highway capacity, alignment, profiles, intersections, interchanges, and grade separations. Problems and drawing work.

170. RAILWAY LOCATION DESIGN. *Prerequisite: Civ. Eng. 70.* *(3)*.

Field and office practice of location and construction. Computation and design.

171. ADVANCED RAILROAD LOCATION. *Prerequisite: Civ. Eng. 170.* I and II. *(3)*.

Design of railroad division, including paper location, selection of rolling stock, operating schedules, and appropriate facilities.

172. RAILROAD MAINTENANCE. *Prerequisite: Civ. Eng. 70.* II. *(2)*.

Stresses in track, performance and durability of track materials, stabilization of ballast and roadway, maintenance of way-work equipment, organization and administration of maintenance operations.

173. TERMINAL DESIGN. *Prerequisite: Civ. Eng. 70.* II. *(3)*.

Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities. Text, problems, drawing work.

174. AIRPORT DESIGN AND CONSTRUCTION. *Prerequisite: Civ. Eng. 135 and Civ. Eng. 136.* I and II. *(3)*.

Airport design and construction with emphasis on soil engineering; soil investigation and use of soil surveys in site selection; runway layouts, grading plans and earthwork estimates; design of surface and subsurface drainage; airport pavement design. Airphoto analysis; typical land forms, drainage patterns, and mapping. Lectures, reference, and design problems.

175. ADVANCED TERMINAL DESIGN. *Prerequisite: Civ. Eng. 173.* *(3)*.

Technical studies of metropolitan terminals, including details of car retarder, hump-yard computations, multiple-switch installations, and provisions for movement and transfer of passengers and freight.

176. ECONOMICS OF RAILROAD CONSTRUCTION AND OPERATION. *Prerequisite: Civ. Eng. 70.* II. *(2).*

Statistical analysis of operating expenses. Curve, grade, and train resistances, ruling grades, rise and fall, and virtual profiles; line changes, grade reductions, and elimination of grade crossings. Lectures, text, problems.

177. RAILROAD ADMINISTRATION. *Prerequisite: Civ. Eng. 70. (3).*

Nature of the railroad organization; the various departmental and divisional functions; employee relationships; public relations; intercarrier traffic agreements.

178. TRANSPORTATION. I. *(2).*

Development of transportation; relation of highway, waterway, railway, pipeline, and airway transportation. Lectures, library research, seminar.

179. RAILROAD ENGINEERING SEMINAR. I and II. *(1).*

Preparation and presentation of reports covering assigned topics.

180. SPECIFICATIONS, CONTRACTS, AND PROFESSIONAL CONDUCT. I and II. *(2).*

Engineering relations; ethics; war and civil contracts, and specifications. Lectures, reading, discussion.

181. LEGAL ASPECTS OF ENGINEERING. I and II. *(3).*

Duty of care, nuisances, injunctions and damages, mines and minerals, carriers and shipping documents, N.L.R.A., F.L.S.A., social security, unemployment compensation, industrial injuries, and garnishment. Cases, lectures, discussion.

182. PATENT LAW FOR ENGINEERS. *(3).*

Monopoly as an advancement of the arts and sciences; patentability; statutory provisions; rights of inventors generally; patent royalty contracts and assignments; procedure in preparation of patents. Text, cases, discussions.

183. PUBLIC UTILITY PROBLEMS. II. *(2).*

Nature of public service corporations; organization; ownership; valuation; depreciation; accounting; regulations; taxation; rates. Lectures, library reading.

220. STRUCTURAL ENGINEERING RESEARCH. *(To be arranged).*

Assigned work in structural engineering as approved by the professor of structural engineering. A wide range of subject matter is available, including laboratory and library studies.

221. ADVANCED THEORY OF REINFORCED CONCRETE. *Prerequisite: Civ. Eng. 121.*

Design and analysis of special types of reinforced concrete structures. Lectures, text, problems.

222. STRUCTURAL MEMBERS. I *(3).*

Analysis and design of structural members under bending, torsion, and axial load. Beams on elastic foundations, box girders, and curved beams. Buckling of columns and beams. Emphasis on numerical methods. Lectures and problems.

223. ADVANCED DESIGN OF STRUCTURES. *Prerequisite: Civ. Eng. 123. (3).*

Functional design of structures, including also the selection and analysis of structural elements, usually reinforced concrete. Lectures, computations, drafting.

224. ADVANCED PROBLEMS IN STATICALLY INDETERMINATE STRUCTURES. II. *(3).*

Continuous truss bents; hinged and fixed arches; rings; frames with curved members; flexible members including suspension bridges; frames with semirigid connections. Lectures, recitations, and problems.

225. STRUCTURAL ENGINEERING SEMINAR. I and II. (*1*).

Preparation and presentation of reports covering assigned subjects.

226. METAL STRUCTURES. II. (*3*).

Critical study of specifications for metals and metal structures. Introduction to yield, fracture, and fatigue failure concepts. Design of metal structures with regard to local and general buckling. Lectures and problems.

227. BRIDGE ENGINEERING. *Prerequisite: Civ. Eng. 123.* (*2*).

Selection of the proper bridge structure for a given location; economics of bridge types; determination of waterways; erection methods.

228. BRIDGE DESIGN. *Prerequisite: Civ. Eng. 123.* (*3*).

Design of reinforced concrete and steel highway and railway bridges. Lectures, computations, drafting.

229. MECHANICAL METHODS OF STRESS ANALYSIS. *Prerequisite: preceded or accompanied by Civ. Eng. 124.* II. (*1*).

Mechanical analysis of stresses in statically indeterminate structures by means of models, use of the Begg's apparatus in analyzing complicated structures is given particular attention. Students are required to make the models and the necessary observations and calculations.

230. PRECAST AND PRESTRESSED REINFORCED CONCRETE. *Prerequisite: Civ. Eng. 30 and 123.* II. (*2*).

Shrinkage, plastic flow, bond, precast beams, cast in place floors forming T beams, and prestressed reinforced concrete, precast members.

231. ANALYSIS AND DESIGN OF SHOCK LOADED STRUCTURES. (*3*).

Response of bridges, buildings, towers, and other structures to dynamic loading by earthquake or explosive blast; vibration of structures; inelastic strength of structures exposed to atomic blast.

232. NUMERICAL AND EXPERIMENTAL STRESS ANALYSIS. (*3*).

Three-dimensional stress strain relations; strain gage techniques and strain-rosette analysis; numerical solution of stress problems; bending of flat plates; analysis by numerical procedures. Structural tests and planning of research projects.

235. FOUNDATION AND UNDERGROUND CONSTRUCTION. *Prerequisite: Civ. Eng. 135; preceded or accompanied by Civ. Eng. 136.* I and II. (*3*).

Analysis and evaluation of field borings, soil test data, and field loading tests; bearing capacity for spread footings, piles, and pile groups; earth pressure and mass stability; surface excavation and embankments; tunnel construction and design; subsidence and control of damage due to subsurface excavation; investigation of overloaded foundations. Lectures, references, and design problems.

236. SOIL MECHANICS RESEARCH. (*To be arranged*).

Advanced problems in soil mechanics, foundations or underground construction selected to provide the student with knowledge of recent application and development in engineering design and construction practice. Assigned problems must be carried to a stage of completion sufficient for a written report which will normally be required for credit.

240. HYDROLOGICAL RESEARCH. *Prerequisite: Civ. Eng. 140.* (*To be arranged*).

Assigned work on some special problem in the field of hydrology; an enormous amount of data is available for such studies.

241. HYDRAULIC ENGINEERING RESEARCH. *Prerequisite: Civ. Eng. 141.* (*To be arranged*).

Assigned work in hydraulic research; a wide range of matter and method permissible.

250. SANITARY ENGINEERING RESEARCH. (*To be arranged*).

Assigned work upon some definite problem related to public sanitation; a wide range in both subject matter and method is available, covering field investigations, experimentation in the laboratory, searches in the library and among public records, and drafting-room designing. By appointment.

251. PUBLIC WATER SUPPLY. II. (*3*).

Conservation and protection of sources of water supply; laws governing appropriation and use of water resources as affecting both quanitiy and quality; standards of water quality, purposes and results of water purification; legal rights and responsibilities of public water utilities. Text and library reading. Lectures and seminar.

252. STATE HEALTH DEPARTMENT ENGINEERING PRACTICE. II. (*2*).

Critical and analytical study of the jurisdictions, functions, standards, and activities of engineering divisions of state departments of health.

254. ADVANCED SANITARY ENGINEERING DESIGN. *Prerequisite: Civ. Eng. 152 and preceded or accompanied by Civ. Eng. 153.* II. (*3*).

Functional design of sanitary engineering structures and typical plant layouts; drafting room and field studies; preparation of design reports.

255. SANITARY ENGINEERING SEMINAR. I and II. (*1*).

Preparation and presentation of reports covering assigned topics.

260. HIGHWAY ENGINEERING AND HIGHWAY TRANSPORT RESEARCH. I and II. (*To be arranged*).

Assigned work in the fields of highway engineering, highway transport, or highway traffic control.

270. RAILROAD ENGINEERING RESEARCH. I and II. (*To be arranged*).

Assigned work in the field of railroad engineering. To obtain credit a thesis must be prepared which would be acceptable for publication.

280. CIVIL ENGINEERING RESEARCH. I and II. (*To be arranged*).

Assigned work in the fields of transportation, public utilities, or engineering relations and ethics. To obtain credit a thesis must be prepared which would be acceptable for publication.

Drawing (Engineering)

The emphasis is on the language of drawing, on exposition by orthographic projection from form concepts, and on translation of orthographic projection into form concepts or reading a drawing. It is the thorough mastery of the language of drawing which the engineering student here acquires for his courses in design, laboratory demonstrations, and later professional service.

1. Elementary Engineering Drawing. I and II. *(3)*.

Principles of orthographic projection; practice in the making of working drawings; correct drafting-room practice in conventional respresentation; the use of instruments; practice in lettering—freehand for dimensions and notes, and mechanical for titles; reading and checking of drawings; drill on geometric construction; instruction on blue and brown printing; practice in tracing; original drawing on tracing papers. Three two-hour drafting-room periods, three hours homework a week.

2. Descriptive Geometry. *Prerequisite: solid geometry and Eng. Draw. 1.* I and II. *(3)*.

The course is outlined, and problems chosen to accomplish the principal purpose of developing working facility in solving the five basic geometrical problems of engineering: determination of all problems of distances, angles, intersection of any line with any surface, intersection of surfaces, plane dimensions, areas, and patterns of developable surfaces. Three two-hour drafting-room periods, three hours homework a week.

3. Advanced Engineering Drawing. *Prerequisite: Eng. Draw. 1 and 2.* I and II. *(2)*.

Engineering sketching of models in orthographic, isometric, and oblique projection; practice in making of working drawings from sketches; sketching of engineering ideas and plans; the principles of land plats, contours, and profiles; the principles of graphical presentation of facts; structural drafting; practice in reading of drawings by analysis of structures. Two two-hour drafting periods, two hours homework a week.

11. Engineering Drawing. II. *(1)*.

Elementary drawing for forestry students. Use of instruments, geometric constructions, lettering practice, orthographic projection, dimensioning, and elementary working drawings. As far as possible drawing assignments are taken from subject material with which the forestry student will later have contact. One three-hour drawing period a week.

12. Graphical Presentation and Computation. *Prerequisite: Eng. Draw. 1, 2, and 3.* I and II. *(2)*.

Analysis of the construction and use of charts; study of the purpose, scope, and use of chart forms with reference to the presentation of specific data; construction and use of computing charts, including nomographs. Two-hour period to be arranged.

15. PRODUCTION ILLUSTRATION. *Prerequisite: Eng. Draw. 1 or its equivalent.* (2).

Various methods of making the pictorial drawings being used today by engineers and draftsmen; to more clearly show how things are to appear when manufactured; uses of production illustrations, lettering, orthographic projection, axinometric projection, oblique projection, perspective projection, sectional views, exploded views, and assembly views.

101. MECHANICAL DRAWING FOR INDUSTRIAL ARTS AND VOCATIONAL EDUCATION TEACHERS. *Prerequisite: an understanding of the basic principles of mechanical drawing.* (2).

Designed for industrial arts and vocational education teachers and includes the following aspects of mechanical drawing: freehand and mechanical sketching, orthographic drawing, dimensioning, conventions, sections, development, and auxiliary views. Drawing problems will be designed to meet the specific needs of the members of the class.

Economics*

Professor Sharfman; Professors Ackley, Boulding, Dickinson, Ford, Haber, Katona, Musgrave, Paton, Peterson, Remer, and Watkins; Associate Professors Palmer and Stolper; Assistant Professors Levinson and Suits; Mr. Anderson, Dr. Klein, and Dr. Morgan; Mr. Brouwer, Mr. Cook, Dr. Smith, and Dr. Tybout; Mr. Adams, Mr. Davies, Mr. Johnston, Mr. Jones, Mr. Mandelstamm, Mr. Reher, Mr. Schuss, Mr. Thomas, and Mr. Tiebout.

Economics 53 and 54 are introductory courses designed especially for students in the College of Engineering and are prerequisite to the election by engineering students of the more advanced courses in the Department of Economics listed below. Upperclassmen, however, may take economics 71, 73, and 175 without having had Economics 53 and 54. For further details with respect to these courses and for additional courses in the field of economics, consult the *Announcement* of the College of Literature, Science, and the Arts.

Students who elect any course without first completing the necessary prerequisites will be denied credit in that course.

53, 54. GENERAL ECONOMICS. *Econ. 53 is prerequisite to Econ. 54.* 53, I and II; 54, I and II. (*3 each*).

For students in the colleges of Engineering and of Architecture and Design and other professional schools and colleges. Not open to freshmen. General survey of economic principles and problems, with primary emphasis on the latter during the second semester. Students successfully completing these courses will be admitted to advanced study in economics.

* College of Literature, Science, and the Arts.

71, 72. ACCOUNTING. *Econ. 71 is prerequisite to Econ. 72.* 71, I and II; 72, I and II. (*4 each*).

Not open to freshmen. Concepts and procedures of accounting from the standpoint of investors and business management.

101, 102. MONEY AND CREDIT. *Prerequisite: Econ. 53 and 54. Econ. 101 is prerequisite to Econ. 102.* 101, I and II; 102, I and II. (*3 each*).

Nature and functions of money and banking and war and postwar monetary problems.

121, 122. LABOR. *Prerequisite: Econ. 53 and 54. Econ. 121 is prerequisite to Econ. 122.* 121, I and II; 122, I and II. (*3 each*).

Background and development of the American labor movement; problems of workers, including insecurity and wages; union history, organization, policies; personnel management; labor legislation.

123. SOCIAL SECURITY. *Prerequisite: Econ. 121 or permission of instructor.* I. (*3*).

Application of the principles of social insurance to the problems of economic insecurity; unemployment compensation, old age and survivors insurance, and health insurance; federal and state legislation and current proposals.

131. CORPORATIONS. *Prerequisite: Econ. 53 and 54.* I. (*3*).

Large enterprises and especially the corporate form of organization and corporation financing, with emphasis on the public interest therein and on government policies.

133. TRANSPORTATION. *Prerequisite: Econ. 53 and 54.* I. (*3*).

Nature and problems of the transportation industry from the standpoint of government regulation.

134. PUBLIC UTILITIES. *Prerequisite: Econ. 53 and 54.* II. (*3*).

Nature and problems of the public utility industries from the standpoint of government regulation.

153. MODERN ECONOMIC SOCIETY. I and II. (*3*).

For seniors and graduates who have had no course in economics and who desire one semester of work in the subject. Does not admit to advanced courses. Economic principles and their application to questions of public policy.

173. FUNDAMENTALS OF ACCOUNTING. I and II. (*3*).

Not open to students who have had Economics 71. Emphasizes cost determination and financial statements.

175. ELEMENTARY ECONOMIC STATISTICS. *Prerequisite: Econ 53 and 54. Juniors and seniors may elect this course concurrently with Econ. 53 or 54.* I and II. (*3*).

Introduction to the principal methods of statistical analysis as applied to economic problems.

181. PUBLIC FINANCE. *Prerequisite: Econ. 53 and 54.* I. (*3*).

Principles and problems of government finance—federal, state, and local.

Electrical Engineering

3. CIRCUITS I. *Prerequisite: preceded or accompanied by Phys. 46 and Math. 54 (4).*
Direct-current and alternating-current circuits, including single-phase series and parallel connections, balanced and unbalanced polyphase circuits. Two lectures, one four-hour computing period, and one four-hour laboratory period.

4. DIRECT-CURRENT MACHINERY. *Prerequisite: Elec. Eng. 3. (2).*
Operating characteristics of motors and generators. One lecture and one four-hour laboratory period.

5. DIRECT- AND ALTERNATING-CURRENT APPARATUS AND CIRCUITS. *Prerequisite: Math. 54 and Physics 46. (4).*
Not open to electrical engineering students. Characteristics of direct-and alternating-current motors and generators; problem work on these and on electric circuits. Three lectures and one three-hour laboratory period.

7. MOTOR CONTROL AND ELECTRONICS. *Prerequisite: Elec. Eng. 5. (4).*
Not open to electrical engineering students. Direct- and alternating-current motors and control equipment; electronic tubes and circuits including industrial types. Three lectures and one four-hour laboratory period.

8. CIRCUITS. *(4).*
Review of d.c. and a.c. circuits and machinery. A special course for guided-missile program. Not open to electrical engineering students.

10. PRINCIPLES OF ELECTRICITY AND MAGNETISM. *Prerequisite: Math. 54 and Physics 46. (4).*
Mathematical and physical treatment of force actions and energy relations in electrostatic and electromagnetic fields; capacitance and inductance of systems of conductors; ferromagnetism, permanent magnets; combined electric and magnetic fields; Maxwell's equations. Three lectures and one three-hour computing period.

100. CIRCUITS II. *Prerequisite: Elec. Eng. 3. (4).*
Analysis of complex alternating-current waves; average and effective values; power factor; the method of the complex variable in a.c. problems; solutions of simple transients and oscillatory circuits; use of hyperbolic functions in solving the general equation of a circuit containing distributed inductance, capacitance, resistance, and leakage. Lectures and problems.

101. NETWORKS AND LINES. *Prerequisite: Elec. Eng. 100. (3).*
General network analysis; artificial lines, attenuators, filters, equalizers; transmission electric waves on lines; reflections at terminals. Lectures and problems.

102. CIRCUIT ANALYSIS BY SYMMETRICAL COMPONENTS. *Prerequisite: Elec. Eng. 100 (3).*
Representation of unbalanced polyphase currents and voltages by component symmetrical sets; solution of unbalanced circuit problems by use of symmetrical components; faults on power systems. Lectures, recitations, and problems.

103. ELECTROACOUSTICS. *Prerequisite: Math. 57 and Elec. Eng. 100.* I. (*2*).

Derivation of the equations for propagation of sound; electromechanical and electroacoustical systems in terms of equivalent electrical networks; loudspeakers and microphones. Lectures and problems.

108. NETWORKS AND ELECTRON TUBE CIRCUITS. *Prerequisite: Elec. Eng. 5 or equivalent.* (*4*).

Not open to electrical students. Network analysis; vacuum tube circuits: amplifiers, mixers, modulators, and detectors. Lectures and laboratory.

120. RADIO COMMUNICATIONS I. *Prerequisite: Elec. Eng. 100 and 180 or Physics 165.* (*4*).

Circuit theory with special emphasis on resonant circuits; audio-frequency and radio-frequency amplification; modulation and detection; transmitting and receiving circuits. Lectures and laboratory.

121. RADIO COMMUNICATIONS II. *Prerequisite: Elec. Eng. 120.* (*4*).

Wide-band amplifiers; radio-frequency amplification; modulation and detection; transmitting and receiving circuits; radio-frequency transmission lines. Lectures and laboratory.

126. TELEPHONE COMMUNICATION. *Prerequisite: preceded or accompanied by Elec. Eng. 101.* (*4*).

Telephone circuits, networks, and apparatus. Lectures and laboratory.

130. ELECTRICAL MEASUREMENTS. *Prerequisite: Elec. Eng. 100.* (*3*).

Methods of measuring current, resistance, electromotive force, capacitance, inductance, and hysteresis of iron, and the calibration of the instruments employed. Two lectures and one four-hour laboratory period.

135. METHODS OF INSTRUMENTATION—A. *Prerequisite: Elec. Eng. 100 and 180.* (*3*).

Application of electrical methods to the measuring and recording of physical quantities, such as displacement, stress, strain, pressure, velocity, and acceleration; basic methods and their application to particular measurement problems. Lectures, demonstrations, and problems.

136. METHODS OF INSTRUMENTATION—B. *Prerequisite: Elec. Eng. 5.* (*3*).

Similar to Elec. Eng. 135 in subject matter, but the treatment is adapted to students not majoring in electrical engineering. Studies of electron tubes and circuits are introduced as required. Lectures, demonstrations, and problems.

137. INSTRUMENTATION LABORATORY. *To accompany Elec. Eng. 135 or 136.* (*1*).

Transducers of resistive, inductive, and other types; strain gages; differential transformers; frequency characteristics of transducers and recorders; amplifiers and power supplies; complete gaging systems. Laboratory experiments and special problems. One four-hour laboratory period.

140. POWER PLANTS AND TRANSMISSION SYSTEMS—ECONOMICS OF DESIGN. *Prerequisite: Elec. Eng. 3 or 5.* (*5*).

Economic features of power-plant design; economic decay, obsolescence, load division between units, plant location, conductor section, selection of circuit breakers and reactors. Lectures, recitations, and problems.

141. ECONOMIC APPLICATIONS IN ELECTRICAL ENGINEERING. *Prerequisite: Elec. Eng. 3.* (*2*).

Corporate finance, cost of exchanges, economic decay, obsolescence, plant location, and conductor section; problems with special application to the communication field. Lectures and recitations.

150. ALTERNATING-CURRENT MACHINERY. *Prerequisite: Elec. Eng. 3.* (*4*).

Theory and operating characteristics of polyphase synchronous and induction machines; various types of single-phase motors, selsyn devices. Lectures and laboratory.

151. DESIGN OF ALTERNATING-CURRENT MACHINERY. *Prerequisite: Elec. Eng. 150.* (*3*).

Design and performance of polyphase and single-phase machines, especially induction motors. Lectures and computing period.

155. INDUSTRIAL ELECTRICAL ENGINEERING. *Prerequisite: preceded by Elec. Eng. 5 or Elec. Eng. 150.* (*4*).

Motors and control equipment suited to particular applications; amplidyne and similar control; electronic motor control. Lectures and laboratory.

158. PRINCIPLES OF ELECTRIC TRACTION. *Prerequisite: Elec. Eng. 3 or 5.* (*2*).

Traffic studies, train schedules, speed-time and power curves, locomotive train haulage, signal systems, cars and locomotives, control systems, traction systems, electrification of trunk lines. Recitations and problems.

160. FUNDAMENTALS OF ELECTRICAL DESIGN. *Prerequisite: Elec. Eng. 3 and 10.* (*4*).

Design problems from various types of apparatus involving the electric and magnetic circuits; field mapping, heat-transfer and temperature-rise work. Three lectures and one four-hour computing period.

170. ILLUMINATION AND PHOTOMETRY. *Prerequisite: preceded by Physics 46, and preceded or accompanied by Math. 54.* (*2*).

Concepts, quantities, units; theory and use of typical measuring devices; calculation of illumination from point, line, and surface sources of light; laws of vision as they affect lighting; characteristics of lamps; industrial, office, school, and residence lighting. Two lectures and one two-hour laboratory period.

172. ELECTRICAL LIGHTING AND DISTRIBUTION. (*2*).

For students of architecture particularly; students of electrical engineering cannot receive credit for this course. Lectures and problems.

173. ADVANCED LIGHTING. *Prerequisite: preceded by Elec. Eng. 3 and 170.* (*3*).

Selection by the student of a topic, with instructor's approval, for continued and intensive study; short oral reports by each student to the class each week; written report and bibliography presented to instructor at end of course.

174. ELECTRICAL DISTRIBUTION, WIRING, AND CONTROL FOR LIGHTING. *Prerequisite: Elec. Eng. 3 and 170.* (*2*).

Selection and application of equipment, design of circuits, study of methods of installation for electric-power supply lamps. Lectures, problems, and surveys.

175. Lighting Equipment. *Prerequisite: Elec. Eng. 3 and 170.* (*2*).

Analysis of design and performance of lamps, reflectors, refractors, diffusers, and other light-control media, and of complete luminaires. Lectures and problems.

176. Residence Lighting. *Prerequisite: preceded by Elec. Eng. 170 or Elec. Eng. 172.* (*2*).

For students of architecture and engineering. Co-ordination of architecture with illumination as applied to residence lighting. Problems and lectures supplemented by illustrated talks.

180. Electronics and Electron Tubes I. *Prerequisite: Elec. Eng. 3 or 5; preceded or accompanied by Elec. Eng. 10.* I and II. (*4*).

Electron ballistics and space-charge flow in cathode-ray and grid-controlled vacuum tubes; thermionic emission, gaseous conduction devices; electron tube characteristics; amplifiers, rectifiers, photosensitive devices; energy-level diagrams for atoms, metals, and semiconductors. Lectures and laboratory.

181. Industrial Electronics. *Prerequisite: Elec. Eng. 100 and 180.* (*4*).

Applicational analysis of electronic circuits used in the manufacturing, power, and aeronautical industries, including: polyphase rectifiers, thyratron and ignitron controls, semiconductor and magnetic amplifiers, trigger circuits; introduction to feedback control. Lectures and laboratory.

188. Photoelectric Cells and Their Applications. *Prerequisite: permission of instructor.* (*2*).

Operating characteristics of photoelectric cells; amplifying circuits and relays; industrial applications; photoelectric photometers. Lectures and laboratory work.

189. Electron Tubes. II. *Prerequisite: Elec. Eng. 180, or permission of instructor* (*3*).

Conformal analysis of fields in space-charge control tubes; transit time loading, electron transit phase delay, and induced current effects in ultra-high frequency small-signal and large-signal triodes and tetrodes; electron optics of cathode-ray focusing; secondary emission and photoelectric phenomena in television pickup and memory storage tubes; initiation of current in thyratrons, ignitrons, glow tubes, and circuit breakers; Paschen's law; radiation counter tubes. Lectures and problems.

190. Introduction to Nuclear Engineering. *Open to seniors and graduate students.*

See description of Aero. Eng. 190.

192. Measurement in Nuclear Engineering. *Prerequisite: Elec. Eng. 190 or permission of instructor.* (*2*).

Practice in the application of radiation-matter interaction to problems in measurement and instrumentation. Study of ionization chambers, proportional and Geiger-Mueller counter systems, scintillation and crystal conduction counters and related circuitry. Instruments are used to study fundamental nuclear phenomena and the characteristic properties of alpha, beta, gamma, and neutron radiation. Lectures and laboratory.

199. DIRECTED RESEARCH PROBLEMS. *Prerequisite: Elec. Eng. 3.* (*To be arranged*).

Special problems are selected for laboratory or library investigation with the intent of developing initiative and resourcefulness. The work differs from that offered in Elec. Eng. 299 in that the instructor is in close touch with the work of the student. Elec. Eng. 199 may be elected by seniors who have suitable preparation. Elec. Eng. 299 is for graduates.

201. TRANSIENTS. *Prerequisite: Elec. Eng. 100.* (2).

Advanced theory of electrical circuits; Laplace transform method of solution for transients in circuits with lumped constants; introduction to the complex frequency domain. Lectures and discussions.

205. NETWORK SYNTHESIS I. *Prerequisite: Elec. Eng. 101.* II. (3).

Energy relations in passive networks; complex variable theory; realizability and synthesis of driving point impedance and transfer functions.

206. NETWORK SYNTHESIS II. *Prerequisite: Elec. Eng. 205.* (2).

Synthesis for prescribed transfer functions; the approximation synthesis for a prescribed time response; feed-back amplifier design.

210. ELECTROMAGNETIC FIELD THEORY. *Prerequisite: Elec. Eng. 3 and 10.* (3).

Advanced theory and problems in electric and magnetic fields, using elementary vector methods which are introduced as required. Maxwell's equations, waves, and propagation of energy.

211. ENGINEERING APPLICATION OF ELECTROMAGNETIC FIELD THEORY. *Prerequisite: Elec. Eng. 210.* (3).

Maxwell's equations; plane waves through semiconductors; dispersion, polarization; reflection and refraction; retarded potentials; Hertz vector radiation; fields and forces on moving charges; dielectric and induction heating.

212. ELECTRICAL AND MAGNETIC PROPERTIES OF MATERIALS. *Prerequisite: Elec. Eng. 180, 210, and 211.* (3).

Electric and magnetic properties of gaseous, liquid, and solid materials used in electrical engineering. Lectures and recitations.

220. MICROWAVE ENGINEERING. *Prerequisite: preceded or accompanied by Elec. Eng. 121.* (4).

Theory and practice of microwave techniques; microwave generation, detection, and measurement; electromagnetic waves; wave guides and cavity resonance phenomena; special circuits. Lectures and laboratory.

221. RADIATION AND PROPAGATION. *Prerequisite: Elec. Eng. 120.* (3).

Fundamental theory; simple antennas, arrays and reflecting systems; ionosphere; reflection, refraction, and diffraction; tropospheric propagation. Lectures.

225. TELEVISION. *Prerequisite: preceded or accompanied by Elec. Eng. 121.* (2).

Basic principles, cathode-ray scanning devices, and television receivers and transmitters. Lectures.

228. MICROWAVES, RADIATION, AND PROPAGATION. *Prerequisite: Elec. Eng. 120. (4).*
Transmission lines, standing waves, impedance transformation; Maxwell's equations, waves, waveguides, cavity resonators; antennas, arrays, radiation patterns; tropospheric and ionospheric propagation, radar equation, ducts. A special course for guided-missile program. Not open to electrical engineering students.

240. STUDY OF DESIGN—POWER PLANTS. *Prerequisite: Elec. Eng. 100 and 140. (2).*
Modern power station design and performance; detailed study of electrical equipment; special problems of interconnection, frequency control, stability, single-phase short-circuit study through use of symmetrical components.

241. STUDY OF DESIGN—ELECTRIC TRANSMISSION AND DISTRIBUTION SYSTEMS. *Prerequisite: Elec. Eng. 100 and 140. (3).*
Mechanical features of conductors and supports; electrical studies of lines; inductance by g.m.d. method, capacitance, equivalent circuits, and circle diagrams; distribution systems; surges. Lectures and recitations.

242. ELECTRIC RATES AND COST ANALYSIS. *Prerequisite: Elec. Eng. 140.* II. *(1).*
Capitalization; fair return on investments; analysis of costs and value of electrical energy; customer charge, demand charges, energy charges; investigations of practical systems used in charging for electrical energy. Lectures.

245. POWER SYSTEM STABILITY. *Prerequisite: Elec. Eng. 100 and 140.* II. *(2).*
Steady-state and transient; development of swing equation for a rotating machine and methods of calculating swing curve; equal area criterion for two-machine system; studies of actual power systems.

255. SERVOMECHANISMS I. *Prerequisite: preceded or accompanied by Elec. Eng. 201 or Math. 147. Elec. Eng. 155 recommended. (3).*
Automatic controller design and application, including mathematical theory. Two lectures and one four-hour laboratory period.

256. SERVOMECHANISMS II. *Prerequisite: Elec. Eng. 255.* I. *(2).*
Analysis and synthesis of several control systems using log-modulus control and phase-plane methods; use of analog computer; design of servocomponents. Lectures, laboratory, and computing period.

258. ANALOG AND DIGITAL COMPUTER TECHNOLOGY. *Prerequisite: Math. 57 or 103; Elec. Eng. 100 and 180, or permission of instructor.* II. *(3).*
Logical structure of computers; methods of problem preparation and scope of problems; study of computer components such as integrating amplifiers, magnetic and electrostatic storage elements, input and output devices. Lectures, laboratory work on department computers, and demonstrations of University computing facilities.

260. HEAT PROBLEMS IN ELECTRICAL DESIGN. *Prerequisite: permission of instructor. (2).*
Advanced work in the fundamentals of heat transfer by radiation, conduction, and natural and forced convection; application to specific situations.

261. DESIGN OF D.C. AND SYNCHRONOUS A.C. MOTORS AND GENERATORS. *Prerequisite: Elec. Eng. 150 and 160. (3).*

Calculation for machines of given ratings, use of design sheets, practical limits for many items of design, calculation of performance, and use of ventilation. Computing period.

271. INTERIOR ILLUMINATION, STUDY OF DESIGN. *Prerequisite: Elec. Eng. 170 or equivalent. (2).*

Unusual as well as typical designs of lighting, particularly those which have been actually built and are available for testing as a check upon the calculations, are analyzed quantitatively and qualitatively.

283. PHYSICAL ELECTRONICS. *Prerequisite: Elec. Eng. 189 or permission of instructor. (3 or 2).*

Theory of thermionic, photoelectric, and field emission; initial electron velocity effects; space-charge suppression of shot noise; high-density beam formation, focusing, hysteresis, and instability. Probe measurements, ambipolar diffusion, balance relationships, electron and ion characteristic frequencies in plasmas; electron and ion mobilities and ionization rates; initiation of microwave gas discharges. Lectures and optional laboratory.

284. INTRODUCTION TO ELECTRICAL FLUCTUATION PHENOMENA. *Prerequisite: Elec. Eng. 100, Math. 57, and preceded or accompanied by Math. 152, or permission of instructor. (2).*

Generation of random fluctuations, shot noise in vacuum tubes, thermal noise in conductors, random errors in servo systems, e.g. radar tracking; fundamentals of probability and random processes; fluctuation phenomena as superposition of many transients with random distribution in time; correlation, power spectrum; response of linear and nonlinear circuits to noise excitation; statistical properties of currents produced by noise and of currents produced by communication signals; outline of information theory. Lectures.

286. MICROWAVE ELECTRON TUBES. *Prerequisite: Elec. Eng. 189 or permission of instructor. (3).*

Energy conversion in electron devices, klystrons and velocity modulation principles, waves on electron streams, traveling wave tubes, double stream amplifiers, backward wave oscillators, magnetron traveling wave amplifiers, magnetron oscillators, particle accelerators. Lectures and laboratory.

288. SEMICONDUCTOR ELECTRONICS. *Prerequisite: Elec. Eng. 180.* I. *(2).*

Outline of the band theory of solids; distribution of electron energies in conductors, insulators, and semiconductors; Fermi level; intrinsic and impurity semiconductors; barrier layers at boundary surfaces; rectifiers, thermistors, transistors and photocells.

291. INTERACTION OF RADIATION AND MATTER. *Prerequisite: Elec. Eng. 190 or permission of instructor. (3).*

Review of nuclear structure and the nature of radioactivity. Analysis of the major processes by which radiation interacts with matter; photoelectric process. Thompson scatter, Compton scatter, pair production, bremmstrahlung, Cerenkov radiation, Wigner effect, and others. Both mechanism and cross section are studied. The application of these processes to produce radiation effects, to actuate instruments, and also in the design of shielding are considered.

294. WAVE MECHANICS IN NUCLEAR ENGINEERING. *Prerequisite: Elec. Eng. 291.* (*3*).

Formulation of wave description of matter through the Schroedinger wave equation. Application to box problem and hydogen-like atom. Energy level transition probabilities. Finite thickness potential barriers and transmission problems — alpha decay model. Particle and particle wave interaction.

298 (AERO. ENG. 298). PRACTICE OF NUCLEAR ENGINEERING. *Prerequisite: Elec. Eng. 190 and 291 and permission of Nuclear Engineering Committee.* (*6*).

Admission is restricted to United States citizens who are given security clearance by the United States Atomic Energy Commission.

A five-month full-time program of original investigations of a development and plant test nature at atomic energy installations at Oak Ridge National Laboratory, Argonne National Laboratory, or other co-operating laboratories. The program provides education in atomic energy and its related fields with emphasis on the engineering aspects of atomic energy production.

299. RESEARCH WORK IN ELECTRICAL ENGINEERING. *Prerequisite: permission of program adviser.* (*To be arranged*).

Students electing the course, while working under the general supervision of a member of the staff, are expected to plan and carry out the work themselves, and to make a report in the form of a thesis.

Engineering Mechanics

1. STATICS. *Prerequisite: must be preceded or accompanied by Math. 53 and Phys. 45.* I and II. (*3*).

Fundamental principles of mechanics and their application to the simpler problems of engineering: forces, components, vectors, moments, couples, friction, and centroids. Recitations, lectures, problems.

2. STRENGTH AND ELASTICITY OF MATERIALS. *Prerequisite: preceded by Eng. Mech. 1 and preceded or accompanied by Math. 54.* I and II. (*4*).

Application of principles of mechanics to solution of problems in stress and strain on engineering materials, including resistance to direct force, bending, torque, shear, eccentric load, deflection of beams, buckling of columns, and compounding of simple stresses. Recitations, lectures, and problems.

2*a*. LABORATORY IN STRENGTH OF MATERIALS. *Prerequisite: preceded or accompanied by Eng. Mech. 2.* I and II. (*1*).

Behavior of engineering materials under load in both the elastic and the plastic ranges; use and calibrating of testing machines and their accessories; strain measuring equipment ranges through the mechanical, optical, and electrical. Approximately twenty experiments are performed in which all the testing machines and strain gages are employed. In addition to the usual tests, such as tension, compression, torsion, bending, impact, hardness, and columns, a photoelastic experiment is performed.

3. Dynamics. *Prerequisite: Eng. Mech. 1 and Math. 54.* I and II. (*3*).

Motion of a particle, dynamics of moving bodies. Newton's laws, simple harmonic motion, elementary vibration problems, balancing, pendulums, impulse and momentum, work and energy. Recitations, lectures, problems.

3*a*. Experimental Dynamics. *Prerequisite: preceded or accompanied by Eng. Mech. 3.* (*1*).

Experiments with acceleration, vibration, balancing, critical speeds, and gyroscopics. One-hour laboratory period, with report, each week.

4. Fluid Mechanics. *Prerequisite: Eng. Mech. 2 and Math. 54.* I and II. (*3*).

Principles of conservation of energy and momentum and of dynamic similitude; special assumptions and properties which differentiate classes of fluids; hydrostatics, flotation, Bernoulli's theorem, cavitation, flow of viscous fluids, resistance to flow and resistance to motion of bodies through fluids, flow in conduits, hydraulics of piping systems; boundary layer, turbulence, stability of flows, free surface flows, critical depth, Pi theorem, and dimensionless ratios. Recitation, lectures, and demonstrations.

4*a*. Fluid Mechanics Laboratory. *Prerequisite: preceded or accompanied by Eng. Mech. 4.* (*1*).

Visualizing flow of liquids; Reynolds' experiment; viscometry; hydrostatics; stability of floating bodies; photographing flow patterns; measuring flow and calibrating of orifices; flow nozzles, Venturi meters, weirs; hydraulic jump and critical depth; resistance to flow, boundary layer, transition. Experiments, demonstrations, reports.

5. Static and Stresses. *Prerequisite: Phys. 45 and Math. 54. For chemical engineering students only.* (*4*).

Fundamental principles of statics and their application to engineering problems: forces, moments, couples, friction, and centroids; moment of inertia followed by application of statics to the solution of problems in stress and strain on engineering materials, including resistance to direct loads, bending, torque, shear, eccentric loads. Recitations, lectures, and problems.

100. Seminar in Engineering Mechanics. (*To be arranged*).

103. Experimental Mechanics. *Prerequisite: Eng. Mech. 2, 3, and 4 and Elec. Eng. 5.* (*3*).

Theoretical and laboratory analysis of the basic fundamentals and designs of research instruments for measuring and recording displacement, velocity, acceleration, and static; dynamic stress, strain, pressure, temperature, viscosity, etc.; graphical and numerical methods of reducing experimental data, and methods of obtaining the over-all accuracy of an experimental program; summarized with several example research problems. Lectures, laboratory, and problems.

120. Research in Theory of Elasticity, Structures and Materials. (*To be arranged*).

Special problems involving application of theory and experimental investigation. Research in theory of elasticity, structures and materials.

123. ADVANCED THEORY OF STRENGTH. *Prerequisite: Eng. Mech. 2.* (*4*).

Analysis of redundant structures by the theory of elastic energy and by the theory of limit design, with special emphasis on the determination of strength based on limiting strain rather than on limiting stress; the analysis of columns.

124. THEORY OF ELASTICITY I. *Prerequisite: Eng. Mech. 2 and 3, and Math. 103 and 150.* (*3*).

Fundamentals of the theory of elasticity; three-dimensional analysis of stress, strain, and displacements; generalized Hooke's law and its connection with the strain-energy function; thermoelastic equations. Applications to flexure and torsion of prismatical bars, membrane analogy, and problems involving plane strain and plane stress in both rectangular and polar co-ordinates, including the thermal stress and determination of the stress concentration factor.

125. THEORY OF THIN ELASTIC PLATES. *Prerequisite: Eng. Mech. 2 and 3, and Math. 103, 150, and 152.* (*3*).

Bending of thin plates with small deflections; the exact theory of plates. Application to rectangular, circular, and other shapes with various edge and loading conditions; plates of variable thickness; plates on elastic foundations; and anisotropic plates. Bending of plates with large deflections and applications to rectangular and circular plates.

126. ADVANCED STRESS ANALYSIS. *Prerequisite: Eng. Mech. 2 and 3, and Math. 103.* (*2*).

Notion of stress and strain, theories of failure, concept of plastic flow and yield criteria; problems of tension, bending, and torsion beyond elastic limit; stresses in thick-walled cylinders and rotating disks; elementary analysis of plates and thin-walled pressure vessels, including the thermal effect; design of members subjected to static, impact, vibrational, and fatigue stresses.

127. THEORY OF STRUCTURES IN SHIP DESIGN. *Prerequisite: Eng. Mech. 2 and Math. 103 or equivalent.* (*3*).

Statically indeterminate structures in general; reciprocal theorem; internal deformation and strain energy; deflection of beams and trusses; Castigliano's theorems; continuous beams and frames; moment distribution method; elementary theory of thin plates on continuous and elastic supports.

128. STABILITY OF ELASTIC STRUCTURES. *Prerequisite: Eng. Mech. 2 and 3, and Math. 103, 147, and 150.* (*3*).

Buckling of slender bars with large deflections; buckling of bars under the action of lateral and direct load, with variable cross sections, with elastic supports, on elastic foundations, etc.; effect of eccentricity, initial curvature, and shear deformation; energy and other methods of determination of critical loads; buckling of frames, rings, and curved bars; lateral buckling of beams; buckling of thin plates of various shapes with small and large deflections.

129. THEORY OF PLASTICITY I. *Prerequisite: Eng. Mech. 124.* (*2*).

Fundamentals of plasticity; stress-strain relations, yield criteria, and the general behavior of metals and nonmetals beyond proportional limit in the light of experimental evidence. Various approximate theories with emphasis on the theory of plastic flow. Application to problems of bending, torsion, plane strain, and plane stress; technological problems.

130. Research in Dynamical Problems. (*To be arranged*).

Original investigations in the field of body motions. Problems may deal with the vibrations of mechanical systems; oscillations in fluid systems; control problems which tie together fluid motion and the motion of physical bodies. May also deal with the fundamentals of mechanics, such as the study of friction and internal hysteresis of materials.

131. Fundamental Vibration Analysis. *Prerequisite: Eng. Mech. 3, Math. 103.* (*3*).

Theory of vibration of single and multiple mass systems with or without damping in translation and rotation; the impedance of mobility methods in analysis of complex vibratory systems; vibration of distributed mass systems (strings, beams, and shafts; self-induced vibration, stability).

132. Advanced Dynamics. *Prerequisite: Eng. Mech. 131, Math. 103, 147, 150.* (*3*).

Advanced dynamics of rigid bodies in systems of engineering interest. Lagrange's equations.

133. History of Dynamics. *Prerequisite: Eng. Mech. 3 and Math. 103.* (*2*).

Review of the important publications in which the fundamental principles of dynamics were developed. *Mechanical Questions,* Aristotle. The influence of astronomical theories on the development of dynamics. *Almagest,* Ptolemy, *Revolution of the Heavenly Bodies,* Copernicus; the work of Tycho Brahe and Kepler, Leonardo da Vinci; *Two New Sciences,* Galileo; *Pendulum Clock, Centrifugal Forces, Theory of Light,* Huygens; *Principia,* Newton. The transition from the geometrical treatment to the analytical treatment of dynamical problems; Bernoulli, Euler, d'Alembert, and Lagrange.

134. Vibration Analysis of Rotors and Reciprocating Engines. *Prerequisite: Eng. Mech. 131.* (*3*).

Dynamic balancing of rotors and crankshafts; torsion and vibration analysis of equivalent masses and shaft systems in engines; geared systems; Holzer methods of analysis; harmonic analysis of indicated gas torque; vibration absorbers; vibration stress analysis.

135. Vibrations of Continuous Elastic Systems. *Prerequisite: Eng. Mech. 131 and Math. 147 and 152.* (*3*).

Fundamental equations of motion of strings, bars, shafts, and beams. Problems in free and forced vibrations with various end conditions and types of loading; effect of damping on the motion; application of the methods of Rayleigh, Ritz, Holzer, Trefftz, and Stodola to the approximate calculation frequencies and normal modes of nonuniform systems.

140. Research in Flow of Fluids. (*To be arranged*).

Special problems in the laboratory or research in literature, such as hydraulic roughness, flow of solid suspensions, boundary layer studies, turbulence, photoviscosity, secondary flow in conduits and channels, stability of modes of fluid flow.

141. ADVANCED FLUID MECHANICS I. *Prerequisite: Eng. Mech. 4 and Math. 150. (3).*

Equations of motion of nonviscous fluids, continuity, potential flow relations, conformal transformations, vortex motion; equations of motion of viscous fluids, dimensional analysis; velocity distribution, boundary layer, lubrication, turbulence.

142. THERMODYNAMICS. *Prerequisite: Math. 103 or 150. (2).*

Fundamental concepts; first and second laws of thermodynamics; equilibrium of homogeneous systems; applications to elastic deformations and fluid dynamics.

200. THEORY OF A CONTINUOUS MEDIUM. *Prerequisite: Eng. Mech. 124, 141, 142. (3).*

General theory of a continuous medium and its specialization to the theories of elasticity, fluid mechanics, and plasticity; basic kinematics; stress and strain tensors and their invariants; conservation of momentum, conservation of energy; the restrictions placed upon the equation of state and the dissipation equations by the second law of thermodynamics.

224. THEORY OF ELASTICITY II. *Prerequisite: Eng. Mech. 124 and Math. 155 and 157. (3).*

Variational methods and their application to problems of flexure and torsion; three-dimensional stress and displacement functions; nuclei of strain; application to three-dimensional problems including elastic bodies in contact and the three-dimensional solution of stress concentration. Problems of multiply connected regions; finite deformation and nonlinear elasticity.

225. THEORY OF SHELLS. *Prerequisite: Eng. Mech. 125. (3).*

The general theory for deformation of thin shells with small deflections; various approximate theories, including the membrane theory. Application to various configurations with special reference to shells of revolution; stability of shells. Shells of revolution with large deflections.

226. PHOTOELASTICITY. *Prerequisite: Eng. Mech. 124. (2).*

Lectures and laboratory experiments involving the fundamental principles of the photoelastic method of stress determination. Covers the basic properties of light with particular reference to the use of double refraction and interference as applied to a loaded specimen; determinations of the maximum shear in various tension and bending models; methods of separating the principle stresses.

229. THEORY OF PLASTICITY II. *Prerequisite: Eng. Mech. 200. (3).*

Rheological properties of single crystals; polycrystalline materials, amorphous substances, and liquids; theories of plastic flow and creep; the statistical approach to irreversible rate processes; equations of state and dissipation relations.

231. TRANSIENT MOTION AND VIBRATION OF NONLINEAR SYSTEMS. *Prerequisite: Eng. Mech. 131, Math. 147, 150. (2).*

Transient motion in linear systems caused by forces which are functions of time; methods of operational calculus used for the solution of free and forced vibrations of linear mechanical systems; methods for treating the motions of nonlinear mechanical systems.

241. Advanced Fluid Mechanics II. *Prerequisite: Eng. Mech. 141 and 142; others by special permission.* (2).

Equations of motion and energy for viscous liquids and viscous gases; some simple flows of each; energy dissipation, vorticity, and circulation in liquids and gases; boundary layers; shock waves in gases; turbulent flow of liquids and gases; practical applications of potential theory to the flow of liquids and gases at low speeds; approximate methods for high-speed flow of inviscid gases; calculating transsonic flows.

English

The work offered in English aims to prepare the student to write and speak effectively and to broaden and deepen his interest in literature. To these ends the department offers a variety of courses in written composition, speech, and literature.

It is presupposed that the student is adequately prepared in the fundamentals of English usage and that he has some knowledge of literature. Normally, a student will take ten hours of English: six hours in Group I, two hours in Group II, and two hours in Group III. The actual number of hours required, however, will depend in part upon the student's preparation and ability. The student of marked superiority may graduate with fewer hours in English; and, conversely, the student who needs additional training may be required to take additional hours of work in English. The student who enters with advanced credit will be required to show a proficiency equal to that of the student with the same number of hours of English credit earned in this College.

In his work for other courses in the engineering curriculum the student is also expected to maintain a satisfactory standard of English. If he fails to do so, he may be reported to the Assistant Dean, who, with the student's program adviser and the chairman of the Department of English, may prescribe additional study.

GROUP I

Normally, English 11, 21, and 12 are required of all engineering students. English 11 and 21 should be taken in the student's first semester; English 12 in his second semester. The student, who, in the opinion of the department, needs further preparatory work before taking English 11 may be required to elect English 10; the student with demonstrated superior ability may be excused from one or more courses in Group I.

10. Preparatory Composition. (*3*).

A practice course in composition and reading, designed for those in need of further preparatory training. Study and drill in diction, spelling, grammar, punctuation; the structure of the sentence, paragraph, and short essay; and in the techniques of reading.

11. THEME WRITING. I and II. *(3)*.
An introductory course in composition and the study of literature. Practice in writing of prepared and impromptu themes and in the reading and analysis of essays, prose fiction, drama, and poetry.

12. EXPOSITORY WRITING. *Prerequisite: English 11; to be preceded by or accompanied by English 21.* I and II. *(2)*.
A continuation of English 11 with special emphasis on the longer composition.

21. ORAL EXPOSITION. I and II. *(1)*.
A practice course in extemporaneous and impromptu speaking, normally taken with English 11. Two hours of classwork.

GROUP II

To satisfy the Group II requirement the student must either elect one of these courses or present a satisfactory equivalent. The courses in this group may also be taken for credit as nontechnical electives. Three to five papers, besides impromptus, are required. *Prerequisite: English 11 and 21; to be preceded or accompanied by English 12.*

31. ADVANCED COMPOSITION. *(2)*.
For students who desire special practice in the various forms of composition.

41. PUBLIC SPEAKING FOR ENGINEERS. *(2)*.
Preparation and delivery of persuasive speeches. Frequent opportunity for practice and class criticism.

46. SCIENTIFIC AND TECHNICAL LECTURE. *(2)*.
Preparation and delivery of lectures on scientific subjects intended for scientific societies or for popular assemblies. Emphasis on demonstration methods.

51. CONTEMPORARY LITERATURE. *(2)*.
Reading and analysis of contemporary fiction, drama, and poetry.

55. MODERN BIOGRAPHY. *(2)*.
Reading and analysis of twentieth-century biographies and autobiographies.

56. SHORT STORY. *(2)*.
Reading and analysis of contemporary short stories.

63. CONTEMPORARY DRAMA. *(2)*.
Study of representative dramas from Ibsen to the present day.

65. CONTEMPORARY NOVEL. *(2)*.
Reading and discussion of outstanding European and American novels from about 1890 to the present.

75. CONTEMPORARY POETRY. *(2)*.
Study of the principal British and American poetry of the twentieth century.

GROUP III

To satisfy the Group III requirement the student must either elect one of these courses, which are open only to juniors, seniors, and graduate students, or present a satisfactory equivalent. The courses in this group may also be taken for credit as nontechnical electives. With the exception of English 141, all courses in the group may be taken for graduate credit, provided that the student has the approval of his program adviser and that he completes additional work. A considerable amount of written work is required in all these courses. *Prerequisite: English 11, 12, 21, and one course in Group II.*

136. TECHNICAL REPORT. *Open to seniors and graduate students only.* (*2*).

Written and oral exercises, the major assignments to be correlated as closely as possible with the technical work of the student.

141. ARGUMENTATION AND DEBATE. (*2*).

Training in the organization and the delivery of the principal types of persuasive speeches, with emphasis on conference speaking and debating.

156. PROFESSIONAL STUDENT AND HIS READING. (*2*).

Studies in literature in relation to philosophy and the social sciences.

158. LITERATURE OF SCIENCE. (*2*).

Review of the writings of eminent scientists—ancient, modern, and contemporary.

161. SHAKESPEARE. (*2*).

A study of twelve or more of the principal plays with a view to acquainting the student with something of Shakespeare's breadth and variety and illustrating the growth of his mind and art.

162. DRAMA. (*2*).

Study of significant dramas in classical, Elizabethan, neoclassic, and modern western civilizations.

167. NOVEL. (*2*).

Reading and discussion of major works in the prose fiction of the eighteenth and nineteenth centuries.

175. AMERICAN LITERATURE. (*2*).

Readings in the works of representative leaders in American thought.

185. LITERARY MASTERPIECES. (*2*).

Works of exceptional merit in the various literary forms.

Geology*

Professor Goddard; Professors Arnold, Ehlers, Hussey, Kellum, Landes, and Turneaure; Associate Professors Belknap, Hibbard, Senstius, and Wilson; Assistant Professors Kesling, Sinclair, Stumm, and Zumberge; Dr. Briggs.

* College of Literature, Science, and the Arts.

11. INTRODUCTORY GEOLOGY. I and II. (*4*).

Principles of physical and structural geology. Either Geology 11 or Geology 99 is required of students of civil engineering and is open to others as an elective. Lectures, recitations, laboratory, and excursions.

99. GEOLOGY AND MAN. I. (*4*).

Geological processes and their effect on civilization.

For other courses in geology to which students of engineering are eligible, see the *Announcement* of the College of Literature, Science, and the Arts. It is suggested that Geology 12 (Historical Geology), 131 (Soil Geology), and 90 (Minerals and World Affairs) are especially useful for engineering students.

Mathematics*

Professor Hildebrandt; Professors Carver, Churchill, Copeland, Craig, Dieudonné, Dwyer, Fischer, Myers, Nesbitt, Rainich, and Wilder; Associate Professors Bartels, Coburn, Dushnik, Hay, Kaplan, Nyswander, Rainville, Reade, Rothe, Samelson, Thrall, and Young; Assistant Professors Anning, Bott, Coe, Darling, Dolph, Jones, Leisenring, LeVeque, Lohwater, Moise, Piranian, Rouse, and Tornheim; Dr. Büchi, Mr. Butcher, Dr. Clarke, Dr. Davis, Dr. Griffin, Dr. Harary, Mr. Kazarinoff, Dr. Lee, Dr. Livesay, Dr. Marx, Dr. McLaughlin, Dr. Raiford, Mr. Ritt, Dr. Titus, Dr. Ullman, and Miss VanEenam; Lecturers Dr. Carr and Dr. Tepping.

6. SOLID EUCLIDEAN GEOMETRY. *Prerequisite: one year of plane geometry.* I and II. (*No credit*).

Postulates; basic constructions and propositions; original exercises; mensuration.

7. ALGEBRA AND TRIGONOMETRY. I and II. (*2*).

Review of elementary operations; linear equations; exponents; radicals; quadratic equations; simultaneous quadratics, progressions; binomial theorem. Trigonometry—the same as in Math. 8.

8. TRIGONOMETRY. I and II. (*2*).

Trigonometric ratios; trigonometric identities and equations; inverse functions; reduction and addition formulas; laws of sines, cosines, and tangents; theory and use of logarithms; solution of triangles.

13. ALGEBRA AND ANALYTIC GEOMETRY. I and II. (*4*).

Review of exponents, radicals, quadratic equations; theory of equations; determinants; complex numbers; curve tracing and locus problems in Cartesian and polar co-ordinates; straight line; circle; conic sections.

* College of Literature, Science, and the Arts.

14. Plane and Solid Analytic Geometry. I and II. (*4*).

Properties of conics involving tangents and asymptotes; parametric equations; surface tracing and locus problems in space; plane; straight line; quadric surfaces; space curves; introduction to calculus; differentiation of algebraic functions.

15. Solid Analytic Geometry. I and II. (*2*).

Surface tracing and locus problems in space; planes; straight lines; quadric surfaces; space curves.

17, 18. Plane and Solid Analytic Geometry and Calculus. *Prerequisite: permission of chairman of department and student's classifier.* 17, I; 18, II. (*4 each*).

For students outstanding in mathematics. Material covered will be that included in Math. 13, 14, and 53, so that students who have completed these two courses are prepared for Math. 54.

20. Introduction to Air Navigation. I. (*3*).

Graphical and numerical methods of solving geometrical problems arising in air navigation; solution of wind diagrams, and drift on two headings; plane, Mercator, and great circle flyings; radius of action and intercept problems; bearings and fixes.

52. Calculus I. I and II. (*5*).

For students who have not had an introduction to calculus in their freshman course. The beginning of calculus, with differentiation of algebraic functions and then the material of Math. 53. Followed by Math. 54.

53. Calculus I. I and II. (*4*).

Functions; limits; continuity; derivative; differentiation of trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; integration.

54. Calculus II. *Prerequisite: Math. 53 or equivalent.* I and II. (*4*).

Definite integral; definite integral as the limit of a sum; centroids; moments of inertia; infinite series; Maclaurin's series; Taylor's series; partial differentiation; multiple integrals; introduction to differential equations.

57. Differential Equations. *Prerequisite: Math. 54.* I and II. (*2*).

Simple types of ordinary equations of the first and second order; linear equations with constant coefficients; applications to geometry, mechanics, and electrical circuits.

[60. Introduction to Advanced Calculus. Omitted in 1953–54.]

103. Differential Equations. *Prerequisite: one year of calculus.* I and II. (*3*).

Elementary course in ordinary differential equations, with more detailed treatment of topics listed in Math. 57, together with the study of more general linear and nonlinear equations.

104. Differential Equations for Systems Analysis. *Prerequisite: one year of calculus.* (*3*).

Elementary methods for solution of ordinary differential equations; graphical, numerical, and differential analyzer methods. Linear equations and systems of linear equations. Nonlinear equations. Physical applications; notions of input and output and their applications to control of physical systems.

[109. DIFFERENTIAL EQUATIONS WITH APPLICATIONS TO CHEMICAL ENGINEERING. Omitted in 1953–54.]

113. INTRODUCTION TO MATRICES. *Prerequisite: Math. 62 or permission of instructor.* I and II. *(3).*

Vector spaces; linear transformations and matrices; equivalence of matrices and forms; canonical forms; application to linear differential equations.

141. THEORETICAL MECHANICS I. *Prerequisite: Math. 53 and 54.* I. *(3).*

Introduction to vectors; fundamental concepts of mechanics, plane statics, work, energy, thin beams, cables, frames; plane kinematics and dynamics.

142. THEORETICAL MECHANICS II. *Prerequisite: Math. 141 and 103.* II. *(3).*

Kinematics and dynamics of a particle and of a rigid body in space, including a study of the spherical pendulum, the gyroscope, and impulsive motion.

145. CELESTIAL MECHANICS. *Prerequisite: Math. 103 and 141 or equivalent.* II. *(3).*

Mathematical theory of the motion of astronomical bodies. Problems of two, three, and *n* bodies.

147. MODERN OPERATIONAL MATHEMATICS. *Prerequisite: elementary differential equations or advanced calculus (or Math. 150).* I and II. *(2).*

Laplace transformation, with emphasis on its application to problems in ordinary and partial differential equations of engineering and physics; vibrations of simple mechanical systems, of bars and shafts; simple electric circuits, transient temperatures, and other problems.

148. OPERATIONAL METHODS FOR SYSTEMS ANALYSIS. *Prerequisite: preferably 104, or 103, and 150, or equivalent.* II. *(4).*

Introduction to complex variables, Fourier series and integrals, Laplace transforms; application to systems of linear differential equations; theory of weighting function, frequency response function, transfer function; stability criteria, including those of Hurwitz-Routh and Nyquist.

150. ADVANCED MATHEMATICS FOR ENGINEERS. *Prerequisite: Math. 54 and preferably Math. 57 or 103.* I and II. *(4).*

Topics in advanced calculus including infinite series, Fourier series, improper integrals, partial derivatives, directional derivatives, line integrals, Green's theorem, vector analysis. Students cannot receive credit for both Math. 150 and 151.

151. ADVANCED CALCULUS. *Prerequisite: Math. 54 and preferably Math. 103.* I and II. *(4).*

Continuity and differentiation properties of functions of one and several variables; the definite integral and improper definite integrals; surface integrals and line integrals, Stokes and Green's theorem, infinite series.

152. FOURIER SERIES AND APPLICATIONS. *Prerequisite: Math. 150 or 151.* I and II. *(3).*

Orthogonal functions, Fourier series, Bessel functions, Legendre polynomials and their applications to boundary value problems in mathematical physics.

154. Advanced Calculus II. *Prerequisite: Math. 151.* II. *(3).*

Selected topics from elliptic integrals, calculus of variations, Fourier series, and complex valued functions.

155. Introduction to Functions of a Complex Variable with Applications. *Prerequisite: Math. 151 or 150.* I and II. *(3).*

Complex numbers; limit, continuity; derivative; conformal representation; integration; Cauchy theorems; power series; singularities; applications to engineering and mathematical physics.

157. Intermediate Course in Differential Equations. *Prerequisite: Math. 103 and 150 or 151 or their equivalents.* I and II. *(3).*

Linear equations of the second order; solution by power series; Riccati equations; extensive treatment of the hypergeometric equation; solutions of the equations of Bessel, Hermite, Legendre, and Laguerre.

161. Statistical Methods for Engineers I. *Prerequisite: one year of calculus.* I. *(3).*

Statistical methods of quality control; normal, binomial, and Poisson distributions; Shewhart control chart; sampling methods for scientific acceptance inspection. Mathematics 161 and 162 together form an introductory course especially designed for the needs of engineers in both experimental work and the flow of production.

162. Statistical Methods for Engineers II. *Prerequisite: Math. 161 or 163.* II. *(3).*

Significance tests; tests valid for small samples; introduction to linear correlation; elementary design of experiments.

163. Theory of Statistics I. *Prerequisite: one year of calculus.* I and II. *(3).*

An introduction to the mathematical theory of statistics; general theory of averages and dispersion; standard variates and moments; frequency distributions and frequency functions; introduction to the theory of sampling. This course should be followed by Math. 164. Students cannot receive credit for both Math. 161 and 163.

164. Theory of Statistics II. *Prerequisite: Math. 163.* I and II. *(3).*

Simple and multiple correlation, bivariate frequency function, nonlinear regression; sampling theory and probable error. General principles of statistical inference; estimation. Students cannot receive credit for both Math. 162 and 164.

165. Significance Tests. *Prerequisite: Math. 163 and 164 or equivalent.* I. *(2).*

Theory of significance tests suitable for small samples, including the Student-Fisher and the variance ratio and χ^2 and varied applications, including standardization and quality control in industry.

166. Analysis of Variance and Fiducial Inference. *Prerequisite: Math. 165.* II. *(2).*

Theory and application of the analysis of variance and covariance; design of experiment; confidence intervals and coefficients with applications.

172. GRAPHICAL METHODS AND EMPIRICAL FORMULAS. *Prerequisite: Math. 53 and 54.* II. *(3).*

Graphical representation of functions, construction of graphical charts, graphical differentiation and integration, curve fitting, determination of constants in empirical formulas, application of the method of least squares, interpolation, graphical solution of differential equations.

174. METHODS IN HIGH-SPEED COMPUTATION. *Prerequisite: Math. 103 and 113.* II. *(2).*

Organization of, problem preparation for, and the mathematics used with high-speed electronic computing machines. Coding and solution of experimental problems on the Michigan Digital Automatic Computer (MIDAC).

175. THEORY OF THE POTENTIAL FUNCTION. *Prerequisite: Math. 150 or 151.* I. *(3).*

Newtonian attraction, Newtonian and logarithmic potentials, the equations of Laplace and Poisson, harmonic functions, principle of Dirichlet, the problems of Dirichlet and Neumann, the Green's function.

176. VECTOR ANALYSIS. I and II. *(2).*

Study of the formal processes of vector analysis, followed by applications to problems in mechanics and geometry.

178. INTRODUCTION TO THE MATHEMATICAL THEORY OF OPTICS. *Prerequisite: Math. 103, 150 (or 151), 155.* II. *(3).*

Propagation of light through transparent, isotropic media including: *(a)* geometrical optics; Fermat's and Huyghens' principles, Hamilton's characteristic functions, optical instruments of revolution, spherical aberration and coma; *(b)* introduction to wave optics: Maxwell's equations, propagation of discontinuities and wave fronts, Snell's law, formulation of the problem of diffraction.

[242. PROBLEMS IN HEAT CONDUCTION AND DIFFUSION. Omitted in 1953–54.]

243. MATHEMATICAL THEORY OF TURBULENCE. *Prerequisite: advanced calculus.* I. *(3).*

The kinematics and dynamics of the von Karman-Howarth theory for general isotropic turbulence and Kolmogsroff's similarity hypothesis for local isotropic turbulence. Applications to the decay of turbulence. The theory of self-preserving correlation functions, Robertson's invariant theory of isotropic turbulence, and other recent developments of the theory.

[244. COMPRESSIBLE FLUID FLOWS. Omitted in 1953–54.]

245. ADVANCED MECHANICS. I. *(3).*

The equations of motion in terms of generalized co-ordinates; some solutions of these equations; vibrations; Hamilton's principle; principle of least action; Hamiltonian systems.

[246. HYDRODYNAMICS. Omitted in 1953-54.]

247. MATHEMATICAL ELASTICITY. II. *(3).*

Analysis of stress; equations of equilibrium; analysis of strain; equations of compatibility; stress-strain relations; elastic energy; extension, torsion, and flexure of homogeneous beams. Plane stress, plane strain; Airy's stress functions and the biharmonic equation; thin plates and shells.

249. METHODS IN PARTIAL DIFFERENTIAL EQUATIONS. I. (*3*).

Theory and application of the solution of boundary value problems in the partial differential equations of engineering and physics by various methods: orthogonal functions, Laplace transformation, other transformation methods, Green's functions.

250. TOPICS IN MATHEMATICAL PHYSICS. I. (*3*).

Boundary value problems and initial value problems; elliptic, hyperbolic, and parabolic equations; method of integral equations, expansion in characteristic functions. Green's function; variational methods.

[251. MODERN TOPICS IN MATHEMATICAL PHYSICS. Omitted in 1953–54.]

[255. DIRECT METHODS IN CALCULUS OF VARIATIONS. Omitted in 1953–54.]

257. SPECIAL FUNCTIONS IN CLASSICAL ANALYSIS. *Prerequisite: permission of instructor.*

Gamma, Bessel, Legendre, hypergeometric, and elliptic functions as treated in Whittaker and Watson's *Modern Analysis*. Generalized hypergeometric functions, Hermite and Laguerre polynomials.

[277. TENSOR ANALYSIS. Omitted in 1953-54.]

Mechanical and Industrial Engineering

1. INTRODUCTORY COURSE IN MECHANICAL ENGINEERING. *Prerequisite: completion of freshman year in engineering.* I and II. (*1*).

The field of mechanical engineering. Lectures, bluebooks, and written assignments. Two one-hour periods a week.

13. HEAT ENGINES. *Prerequisite: Phys. 45 and Math. 53.* I and II. (*4*).

Elementary thermodynamics, fuels and combustion, and principles involved in the application of heat to the various forms of heat engines, including steam boiler, steam engine, steam turbine, internal-combustion engine, and plant auxiliaries. Lectures, recitations, problems. For nonmechanical students.

14. MECHANICAL ENGINEERING LABORATORY. *Prerequisite: Mech. and Ind. Eng. 13.* I and II. (*1*).

Elective for students who are not required to take Mech. and Ind. Eng. 17. Methods of testing and some of the principles of power engineering.

17. MECHANICAL ENGINEERING LABORATORY. *Prerequisite: Eng. Mech. 1, Mech. and Ind. Eng. 105, and accompanied by Ch. and Met. Eng. 10.* I and II. (*2*).

First course. Elementary testing of a steam turbine, diesel-electric plant, centrifugal pump, power pump, and steam boiler; use and calibration of instruments, and calculation and interpretation of results. Laboratory, computation, and reports. Two periods of four and one-half hours a week.

80. MECHANISM. *Prerequisite: Phys. 45 and Drawing 2.* I and II. (*2*).

Elementary course covering linkages, cams and followers, gear trains, wrapping connectors, and other mechanism. Two two-hour periods a week.

82. ELEMENTS OF MACHINE DESIGN. *Prerequisite: Drawing 3, Eng. Mech. 2 (and Mech. and Ind. Eng. 80 for students in mechanical engineering and naval architecture).* I and II. *(3).*

Application of the theory of strength and rigidity to machine elements, and a study of the transmission of power by them. Three one-hour recitations a week.

86. ADVANCED MACHINE DESIGN. *Prerequisite: Mech. and Ind. Eng. 82.* I and II. *(3).*

Analysis, layout, and design of machines and machine parts. Two four-hour periods a week.

104. HYDRAULIC MACHINERY. *Prerequisite: Mech. and Ind. Eng. 105.* I and II. *(3).*

Theory, construction, and operation of the principal types of hydraulic machinery. Lectures, problems, and written recitations.

105. THERMODYNAMICS I. *Prerequisite: Phys. 45 and Math. 53.* I and II. *(3).*

Basic course in engineering thermodynamics, embracing: First Law, ideal gases, specific heats, properties of vapors, steady flow and nonflow processes, reversibility, Carnot cycle and the Second Law, available and unavailable energy and entropy, mixtures of ideal gases and vapors, combustion.

106. THERMODYNAMICS II. *Prerequisite: Mech. and Ind. Eng. 105 and Math. 54.* I and II. *(3).*

Primarily for mechanical engineers. Equations of state for real gases, flow of gases and vapors through nozzles and orifices, air compressors and air engines, gas turbines and jet propulsion, vapor cycles for power plants, mechanical refrigeration, introduction to heat transfer.

107. APPLIED ENERGY CONVERSION. *Prerequisite: Mech. and Ind. Eng. 106 or equivalent.* I and II. *(3).*

Economic conversion of natural energy in stationary power plants. Major topics treated: combustion practice, steam generation, steam turbines, diesel engine power plants, hydraulic power plants, gas turbines, atomic energy, power plant economics, load curves, energy rates. Selected power plant problems are assigned.

108. MECHANICAL ENGINEERING LABORATORY. *Prerequisite: Mech. and Ind. Eng. 17 and 106.* I and II. *(3).*

Experimental study of a steam turbo-electric plant, C.F.R. engine, fan, steam injector, air compressor, air conditioning and refrigerating plant, Unaflow steam engine, centrifugal pump, and impulse water turbine. Laboratory, computations, and reports; two periods of four and one-half hours each a week.

109. HEAT POWER ENGINEERING. *Prerequisite: Ch. and Met. Eng. 111.* I and II. *(3).*

Cycles, apparatus, and operation of vapor power plant and of internal combustion engine power plant; gas turbine power plant; refrigerating plant.

110. DESIGN OF POWER PLANTS. *Prerequisite: Mech. and Ind. Eng. 107 and Eng. Mech. 4.* II. *(3).*

Type, capacity, and arrangement of equipment to meet the requirements of a modern steam-power plant. Drafting-room work consists of a layout of a plant showing arrangement of principal equipment. Computations and drawing; two four-hour periods a week.

[111. STEAM-GENERATING EQUIPMENT. *Prerequisite: Mech. and Ind. Eng. 106.* I. (*3*). Omitted in 1953-54.]

[112. DESIGN OF STEAM-GENERATING EQUIPMENT. *Prerequisite: Mech. and Ind. Eng. 82 and 111.* II. (*3*). Omitted in 1953–54.]

113. STEAM TURBINES. *Prerequisite: Mech. and Ind. Eng. 106.* I. (*3*).
Application of the laws of thermodynamics, fluid flow and kinetic effects to the steam turbine; various types and forms of turbines; applications, including electric generation and marine populsion; general principles of governing. Lectures, recitations, problems.

114. INTERNAL-COMBUSTION ENGINES. *Prerequisite: Mech. and Ind. Eng. 106.* I and II. (*3*).
Thermodynamic analysis of various internal-combustion engine cycles as used by both piston and turbine type engines; fuels, combustion, detonation; fuel systems, superchargers, and other auxiliaries as they apply to these engines.

*116. DESIGN OF INTERNAL-COMBUSTION ENGINES. *Prerequisite: Mech. and Ind. Eng. 82, and preceded or accompanied by Mech. and Ind. Eng. 114.* I and II. (*3*).
Calculations, design of important details, and layout drawings of a standard diesel or Otto type internal-combustion engine. Drawing, problems. Two four-hour periods a week.

120. REFRIGERATION AND AIR CONDITIONING. *Prerequisite: Mech. and Ind. Eng. 106.* II. (*3*).
Theory, design, and construction of refrigerating and air-conditioning equipment; characteristics of various refrigerants; the application of refrigeration to cold storage, ice making, and air conditioning. Lectures, recitations, problems.

123. INDUSTRIAL AIR CONDITIONING. *Prerequisite: Mech. and Ind. Eng. 105.* (*2*).
Fans and fan laws, air flow, dust collection, spray booth exhaust systems, pneumatic conveying, vapor exhaust, air conditioning for health and safety, and related topics. Lectures, recitations, problems.

124. INDUSTRIAL EXHAUST AND VENTILATION LABORATORY. *Prerequisite: preceded or accompanied by Mech. and Ind. Eng. 123.* II. (*2*).
Measurement of low velocity air flow; determination of air-flow pattern around exhaust slots and hoods over cold and heated tables; determination of efficiency of dust collecting equipment. Laboratory, computations, and reports. Two three-hour periods a week.

125. HEATING AND AIR CONDITIONING. *Prerequisite: Mech. and Ind. Eng. 105.* (*3*).
Theory, design, and installation of hot-air, direct- and indirect-steam, hot-

* Only one of the following courses may be taken for credit toward a degree: Mech. and Ind. Eng. 116, 151, 152, 162.

water, and fan-heating systems; central heating; air conditioning; temperature control. Lectures, recitations.

126. DESIGN OF HEATING AND AIR-CONDITIONING SYSTEMS. *Prerequisite: Mech. and Ind. Eng. 125.* II. *(3).*

The student is given the usual data furnished the heating and ventilating engineer. He then makes a layout of piping, ducts, and auxiliary apparatus, with computation for the size of principal equipment. Two four-hour periods a week.

127. AIR-CONDITIONING LABORATORY. *Prerequisite: Mech. and Ind. Eng. 108 and 125.* II. *(2–3).*

Advanced experimental study in the field of air conditioning.

128. HEATING AND VENTILATION. *(3).*

Theory, design, and construction of hot-air, direct- and indirect-steam, hot-water, and fan-heating systems, air conditioning and temperature control. Lectures, recitations. For architects only.

130. PLANT LAYOUT AND MATERIALS HANDLING. *Prerequisite: Mech. and Ind. Eng. 82.* I and II. *(3).*

Layout of industrial plants and study of materials handling equipment as influenced by processes, materials, productive equipment, buildings, and related factors.

131. DESIGN OF HOISTING AND CONVEYING MACHINERY. *Prerequisite: Mech. and Ind. Eng. 82.* *(3).*

Calculations and layout work on hoists, cranes, and conveyors. Two four-hour periods a week.

135. FACTORY MANAGEMENT. I and II. *(3).*

Management problems and methods involved in the operation of manufacturing institutions, including location, layout, equipment investment, motion study, time study, methods of wage payment, inspection, organization procedures, production control, material control, and budgets. Lectures, recitations, and problems. Not open to students below junior year.

136. MOTION AND TIME STUDY. *Prerequisite: Mech. and Ind. Eng. 135.* I and II. *(3).*

Operating methods, work-center layout according to the laws of motion economy, and time-study technique. Recitations, problems, and laboratory exercises constitute the work of this course.

137. WAGE INCENTIVES AND JOB EVALUATION. *Prerequisite: Mech. and Ind. Eng. 136.* I and II. (2).

Principles of major types of wage incentive systems and their evaluation. Appraisal of various job evaluating systems and use of job evaluation in developing equitable wage structures.

138. PRODUCTION CONTROL. *Prerequisite: Mech. and Ind. Eng. 137.* I and II. (2).

Principles of planning and control in mass production and job lot industries; includes analysis of operating times and plant capacity, routing, scheduling and dispatching, inventory control, and techniques of evaluating operating results.

139. ENGINEERING ECONOMY. *Prerequisite: Econ. 153.* I and II. (*2*).

Economic selection of equipment, consideration of cost, methods of financing, depreciation methods, and the planning for future production.

142. DESIGN THEORY OF PUMPING MACHINERY. *Prerequisite: Mech. and Ind. Eng. 104.* (*3*).

Advanced development of the laws of thermodynamics, laws of motion, and flow of fluids as applied to the design theory of axial and radial flow turbomachinery. Lectures, recitations, and problems.

143. DESIGN OF PUMPING MACHINERY. *Prerequisite: Mech. and Ind. Eng. 82 and 104 or equivalent and Mech. and Ind. Eng. 142.* (*3*).

Calculations and drawings for a centrifugal or reciprocating pump. Special attention is given to the design of runners, casings, and valves. Two four-hour periods a week.

150. AUTOMOBILES AND MOTOR TRUCKS. *Not open to students below senior level except by permission of instructor.* (*3*).

Fundamental principles of construction, operation; application in current practice; engine cycle, details of construction, cooling, lubrication, carburetion, electrical systems, clutch, transmission, axle, differential, steering, springs, brakes; engine and car testing, performance curves, operations and control. Lectures, recitations, laboratory demonstrations.

*151. AUTOMOBILE AND TRUCK ENGINES. *Prerequisite: Mech. and Ind. Eng. 82 and 150.* I. (*3*).

Student selects the type of car or truck, makes expectancy curves for engine performance, and computes the dimensions and sketches principal parts. Lectures, problems, drawing. Two four-hour periods a week.

*152. DESIGN OF AUTOMOBILE AND MOTOR-TRUCK ENGINES. *Prerequisite: Mech. and Ind. Eng. 151.* II. (*3*).

Continuation of Mech. and Ind. Eng. 151. Lectures, assembly drawing, and details. Two four-hour periods a week.

153. DESIGN OF AUTOMOBILE AND MOTOR-TRUCK CHASSIS. *Prerequisite: Mech. and Ind. Eng. 82 and 150.* I. (*3*).

Student selects the type of engine for assumed conditions, then computes the dimensions and sketches the principal parts of the chassis. Lectures, problems, drawing.

154. DESIGN OF AUTOMOBILE AND MOTOR-TRUCK CHASSIS. *Prerequisite: Mech. and Ind. Eng. 153.* II. (*3*).

Continuation of Mech. and Ind. Eng. 153. Lectures, assembly drawings, and details.

155. AUTOMOTIVE LABORATORY. *Prerequisite: Mech. and Ind. Eng. 17 and 114 or 150.* I, may be elected for II. (*3*).

Experimental study of automobile and aircraft engines, including horsepower, fuel economy, thermal efficiency, mechanical efficiency, heat balance, indicator

* See footnote in connection with Mech. and Ind. Eng. 116, page 132.

cards, carburetion, compression ratio, electrical systems, and road tests for car performance. Laboratory and reports. Four or five hours each week.

160. Aircraft Power Plants. *Prerequisite: Mech. and Ind. Eng. 105. (3).*

Construction and operation of aircraft engines and their auxiliaries. Critical discussion of the reasons for the various types of construction used in reciprocating and turbine engines now in service.

161. Aircraft Power Plants—Experimental Tests. *Prerequisite: Mech. and Ind. Eng. 17 and 114 or 160. (3).*

Experimental study of aircraft engines, test apparatus, and methods, and the determination of their characteristic performance, including speed, timing, mixture ratios, compression ratio, and fuels.

*162. Design of Aircraft Engines. *Prerequisite: Mech. and Ind. Eng. 82 and 114.* I. *(2).*

Current practice; preliminary calculations for principal dimensions of an aircraft engine, determination of gas pressure and inertia forces and resultant bearing loads; sketches of principal parts. Lectures, drawing. Two three-hour periods a week.

164. Gas Turbines and Jet Propulsion. *Prerequisite: Mech. and Ind. Eng. 106.* I. *(3).*

Thermodynamics, theoretical cycles of combustion, fuels, gas turbine cycle, regenerators, compressors, turbines, and blading; fundamentals of the jet engine. Lectures, recitations, and problems.

165. Rocket Motors. *Prerequisite: Mech. and Ind. Eng. 106.* II. *(3).*

Rocket power plant, including thermodynamics, flow of fluids and combustion; theory and application of propellants; liquid propellant feed systems; heat transfer; performance and testing.

170. Diesel Power Plants. *Prerequisite: Mech. and Ind. Eng. 106.* II. *(2).*

Construction and operation of Diesel engines for marine, stationary, and automotive purposes, together with their auxiliaries.

181. Design of Machine Tools. *Prerequisite: Mech. and Ind. Eng. 82 and Prod. Eng. 131.* I. *(3).*

Specification, design, construction, and operation of a variety of tool-room and production machine tools; bearings, lubrication, materials, motors, and controls. Hydraulic units and circuits are studied and units of machine tools are designed, bill of materials prepared, and vibrations studied. Power requirements based on specified cutting practice are determined and used as a basis of design.

[182. Process Equipment Selection and Design. *Prerequisite: Eng. Mech. 2 and Mech. and Ind. Eng. 82 or Ch. and Met. Eng. 113. (3).* Open to seniors and graduate students only. Not offered in 1953–54.]

203. Advanced Instrumentation and Control. *Prerequisite: a degree in engineering or permission of instructor.* I and II. *(3).*

Measuring devices and their characteristics; system characteristics; errors;

* See footnote in connection with Mech. and Ind. Eng. 116, page 132.

automatic control, single and proportional speed, proportional position with reset and rate response.

204. RESEARCH IN HYDROMECHANICAL ENGINEERING. *Prerequisite: Mech. and Ind. Eng. 104 and 108.* I, may be elected for II. *(2–3).*

Advanced study in the hydromechanical field. Theory, design, equipment performance, or laboratory research.

205. ADVANCED THERMODYNAMICS. *Prerequisite: Mech. and Ind. Eng. 106 and 108.* I. *(3).*

Definitions and scope of thermodynamics, First and Second Laws, Maxwell's relations, Clapeyron relation, equation of state, thermodynamics of chemical reactions, availability.

206. ADVANCED APPLIED THERMODYNAMICS. *Prerequisite: Mech. and Ind. Eng. 205 or permission of instructor.* II. *(3).*

Thermodynamic behavior of solids, liquids, and gases at high and low pressures; power from solar energy, nuclear energy and other nonfuel energy sources; thermodynamics of kinetic pumps; high-speed turbines and turbo-compressors; steam power plant cycles at high temperatures and pressures; other subjects selected in allied fields of application.

207. ADVANCED MECHANICAL ENGINEERING PROBLEMS. *Prerequisite: preceded by Math. 57 or Math. 103.* I and II. *(3).*

Analysis of problems in mechanical vibrations, resonance and critical speeds, fluid flow, thermodynamics, heat flow, weight distribution, and strength of materials.

208. RESEARCH IN HEAT POWER ENGINEERING. *Prerequisite: Mech. and Ind. Eng. 106 and 108.* I, may be elected for II. *(2–3).*

Advanced study in special lines of work in which the student may be interested. Theory, design, equipment performance, or laboratory research.

211. HEAT TRANSMISSION. *Prerequisite: Mech. and Ind. Eng. 106 and Eng. Mech. 4.* II. *(3).*

Theory of heat transmission to vapors, liquids, and solids; steady and transient flow of heat; insulating materials; industrial application in the field of mechanical engineering. Lectures, recitations, and problems.

214. ADVANCED THEORY OF INTERNAL COMBUSTION ENGINES. *Prerequisite: Mech. and Ind. Eng. 114.* II. *(3).*

Advanced thermodynamics of the reciprocating and flow engines; chemical equilibrium and kinetics of combustion; theory and control of detonation; combustion chamber analysis; superchargers and supercharging.

215. RESEARCH IN INTERNAL-COMBUSTION ENGINEERING. *Prerequisite: permission of instructor. (To be arranged).*

Investigation of the theory, design, and construction of internal-combustion engines, and laboratory research.

228. STUDIES IN NATURAL VENTILATION. *Prerequisite: Mech. and Ind. Eng. 108.* *(2).*

Theory of air movement through buildings by wind and temperature difference; deductions from test data at hand; some experimental work of an illustrative nature, and possibly something of a research nature.

237. Industrial Management—Field Work. *Prerequisite: Mech. and Ind. Eng. 136.* I and II. (*3*).

Principles of production developed in Mechanical and Industrial Engineering 135 and 136 are applied to specific problems in factory management. Inspection trips to manufacturing plants, with problems and discussions based on these trips. A laboratory fee is required.

238. Industrial Procurement. *Prerequisite: Mech. and Ind. Eng. 135.* I. (*3*).

Inventory management, selection of sources, price analysis, standards and specifications, organization of a purchasing department, government regulations, buying policies. Lectures, recitations, and semester report.

240. Seminar in Industrial Engineering. *Prerequisite: Mech. and Ind. Eng. 237 or permission of instructor.* II. (*2*).

Current topics in industrial engineering. Reading, research, and preparation of papers.

251. Automobile Engineering Seminar. (*1*).

Preparation of one paper on current topics of the automobile industry and one covering an investigation on some special subject. Reading, preparation of papers, and class discussions.

253. Advanced Automobile Design and Research. *Prerequisite: Mech. and Ind. Eng. 151 and 153.* (*To be arranged*).

Special problems in the design of some automobile or truck unit. Drawing.

255. Advanced Automobile Testing and Research. *Prerequisite: Mech. and Ind. Eng. 155 or 161, and permission of instructor.* I, may be elected for II. (*3*).

Advanced experimental and research work. Laboratory, reports.

[280. Balancing, Critical Speeds, and Gyroscopic Action. *Prerequisite: Eng. Mech. 3.* (*2*). Omitted in 1953–54.]

[282. Superpressure Process Equipment and Technique. *Prerequisite: Mech. and Ind. Eng. 82 and 106 or Ch. and Met. Eng. 111.* (*3*). Omitted in 1953–54.]

Naval Architecture and Marine Engineering

11. Introduction to Practice. *Prerequisite: sophomore standing and Draw. 1 and 2.* I and II. (*2*).

Types of ships, nomenclature, methods and materials of construction, shipyard and drawing room practices; details of shell expansion and other mold loft work. The lines of a small vessel are faired, and drawings prepared for simple ship structures. Lectures, recitations, and drawing room.

12. FORM CALCULATIONS I. *Prerequisite: Nav. Arch. 11, Math. 53, and Eng. Mech. 1.* I and II. *(3).*

Methods of determining areas, volumes, centers of buoyancy, displacement and wetted surface; the use of hydrostatic curves; trim; initial stability; stability in damaged condition; and watertight subdivision. Lectures and recitations.

13. FORM CALCULATIONS II. *Prerequisite: preceded or accompanied by Nav. Arch. 12.* I and II. *(3).*

Preparation of a body plan from given offsets; the necessary calculations for the preparation of hydrostatic and launching curves, curves of floodable and permissible lengths, and locations of bulkheads. Drawing room.

21. STRUCTURAL DESIGN I. *Prerequisite: Eng. Mech. 2 and Nav. Arch. 12.* I and II. *(3).*

Design of the ship's principal structure and fastenings to meet the general and local strength requirements. Application of the Classification Society's rules to framing, shell, decks, bulkheads, welding, riveting, and testing. Lectures, recitations.

22. STRUCTURAL DESIGN II. *Prerequisite: preceded by Nav. Arch. 21.* I and II. *(2).*

Student develops the "Midship Section" and "Structural Profile and Decks" for an assigned vessel according to the Rules of the Classification Society.

123. ADVANCED STRUCTURAL DESIGN. *(To be arranged).*

131. SHIP DESIGN I. *Prerequisite: Nav. Arch 13 and preceded or accompanied by Nav. Arch. 21.* I. *(3).*

Review of statical stability and the dynamical stability of ships. Rolling, pitching, and seagoing qualities of ships; rudders, turning, and maneuvering; freeboard; tonnage; grounding and dry docking; estimates and calculations involved in the preliminary design of ships. Lectures and recitations.

132. SHIP DESIGN II. *Prerequisite: Nav. Arch. 22 and 137 and preceded or accompanied by Nav. Arch. 131.* I and II. *(4).*

Given the owner's general requirements the student prepares a complete design of a suitable ship, including form, power, and strength calculations; midship section, lines, inboard and profiles, and arrangement plans. Drawing room.

135. ADVANCED SHIP DRAWING AND DESIGN. I and II. *(To be arranged).*

136. SMALL BOAT DESIGN. *Prerequisite: Nav. Arch. 12 and 21.* I. *(2).*

Designs of motor and sailing yachts and small fishing and work boats. Recitations and problems.

137. SPECIFICATIONS, CONTRACTS, AND THE GENERAL ARRANGEMENT OF VESSELS. *Prerequisite: senior standing and permission of instructor.* I. *(3).*

Principal features of ship specification and contracts, methods and practices of planning and estimating for new construction and repair work; design and function of the various items of outfit, such as bilge and ballast systems, cargo gear, etc., and practices in the general arrangements of vessels. Lectures and recitations.

141. MARINE MACHINERY. *Prerequisite: Mech. and Ind. Eng. 105 and Eng. Mech. 1.* II. (*4*).

Different types of machinery used for propelling vessels; principles of heat transfer in boilers, heaters, and condensers; calculations to determine the steam consumption of reciprocating engines and turbines, and capacity of different types of boilers to supply steam for their needs; use of coal and fuel oil in connection with boilers and internal-combustion engines; various other auxiliaries. Lectures, recitations.

142. MARINE STEAM GENERATORS. *Prerequisite: Nav. Arch. 141.* I and II. (*3*).

Heat transfer calculations, design, and layout drawings are prepared for a modern type of marine steam generator. Drawing room.

143. MARINE PROPULSION MACHINERY. *Prerequisite: Nav. Arch. 141 and Mech. and Ind. Eng. 113.* I and II. (*3*).

Design calculations and principal drawings are prepared for either a triple expansion steam engine or a main propulsion turbine. Drawing room.

144. HEAT BALANCE. *Prerequisite: Nav. Arch. 141.* I and II. (*3*).

Detailed design calculations and engine and fireroom layouts are prepared for a large steam- or motorship. Drawing room.

145. ADVANCED READING AND SEMINAR IN MARINE ENGINEERING. I and II. (*To be arranged*).

151. RESISTANCE, POWER, PROPELLERS. *Prerequisite: Nav. Arch. 12.* II. (*3*).

All items affecting the resistance and propulsion of various ships' forms, investigation of the theory and practice involved in the design of propellers, and methods of conducting trial trips, etc. Lectures and recitations.

152. NAVAL TANK. *Prerequisite: Eng. Mech. 4.* I and II. (*2*).

Theory of model testing, with particular attention to surface vessels; methods of estimating speed, power, and revolutions. A model is towed in the tank, and resistance, trim, wake, and other data are worked up. Lectures, drawing room, and laboratory.

153. RESEARCH IN NAVAL TANK. *Prerequisite: Nav. Arch. 152.* I and II. (*To be arranged*).

154. ADVANCED READING AND SEMINAR IN NAVAL ARCHITECTURE. I and II. (*To be arranged*).

155. PILOTING AND CELONAVIGATION. (*3*).

Compass error, piloting, various sailings, latitude, longitude, and lines of position from celestial observations; use of radar and direction finders.

156. THESIS RESEARCH. *Prerequisite: Nav. Arch. 132 or design course in Option B and Nav. Arch. 151.* I and II. (*3*).

Research and experimental work necessary in connection with thesis required for the degree of Master of Science in Engineering.

Physics*

Professor Barker; Professors Cork, Crane, Dennison, Laporte, Sutherland, Uhlenbeck, and Wolfe; Associate Professors Case, Hazen, Katz, McCormick, Sleator, and Wiedenbeck; Assistant Professors Hough, Lennox, Levinthal, Parkinson, Peters, Pidd, Simpson, and Wood; Instructors Mr. Edwards, Dr. Glaser, Dr. Jones, Dr. Krimm, Dr. Sherman, and Dr. Terwilliger.

37. PHYSICS PROBLEMS: MECHANICS, SOUND, AND HEAT. *Must be preceded or accompanied by Phys. 25.* I and II. *(1)*.

38. PHYSICS PROBLEMS: ELECTRICITY AND LIGHT. *Must be preceded or accompanied by Phys. 26.* I and II. *(1)*.

45. MECHANICS, SOUND, AND HEAT. I and II. *(5)*.
Calculus should be elected concurrently. Two lectures, three recitations, and one two-hour laboratory period a week.

46. ELECTRICITY AND LIGHT. *Prerequisite: Phys. 45.* I and II. *(5)*.
Two lectures, three recitations, and one two-hour laboratory period a week.

103. INTRODUCTION TO THE USE OF RADIOACTIVE ISOTOPES. *Prerequisite: Phys. 26 or 46.* II. *(2)*.
Sources, properties, and methods of measuring radiations; determination of safe dosage; tracer techniques and their applications.

105. MODERN PHYSICS. *Prerequisite: Phys. 46.* I. *(2)*.
Fundamental experiments on the nature of light, electricity, and matter.

147. ELECTRICAL MEASUREMENTS. *Prerequisite: Phys. 46 and Math. 54.* I. *(4)*.
Direct, alternating, and transient currents; measurements of inductance, capacitance, and losses due to hysteresis. Two lectures and one four-hour laboratory period a week.

165. ELECTRON TUBES. *Prerequisite: Phys. 147.* II. *(3)*.
Characteristics of electron tubes and their functions as detectors, amplifiers, and generators.

166. ELECTRON CIRCUITS. *Prerequisite: Phys. 165.* I. *(3)*.
Characteristics of high-frequency circuits and their radiations. Two lectures, one laboratory period a week.

171. INTERMEDIATE MECHANICS. *Prerequisite: Phys. 46, Math. 103.* I. *(3)*.
Statics and dynamics; the equations of d'Alembert, Poisson, Laplace, and Lagrange.

172. MECHANICS OF FLUIDS. *Prerequisite: Phys. 171.* II. *(2)*.
Statics and elementary dynamics of fluids.

173. INTRODUCTION TO PHYSICS OF THE SOLID STATE. *Prerequisite: Phys. 196 or permission of instructor.* II. *(3)*.
Structure and properties of crystalline solids.

* College of Literature, Science, and the Arts.

175. VIBRATION AND SOUND. *Prerequisite: Phys. 171 and Math. 57.* I. (*2*).
Mathematical study of waves and of vibrating mechanical systems.

176. LABORATORY IN SOUND. *Prerequisite: Phys. 165 and 175.* II. (*2*).
Methods and instruments used in the detection and recording of sound and noise.

177. APPLICATIONS OF PHYSICAL MEASUREMENTS TO BIOLOGY. *Prerequisite: Phys. 46 and eight hours of biological science.* I. (*3*).

178. SELECTED PROBLEMS IN BIOPHYSICS. *Prerequisite: Phys. 105 and Math. 53.* II. (*2*).
Structures of proteins, steroids, and other molecules of biological interest, and methods for their determination.

179. BIOPHYSICS: LARGE MOLECULES. *Prerequisite: Phys. 186 and Math. 54.* II. (*2*).
Thermodynamics and optical properties of assemblies of large molecules.

180. INTERMEDIATE ELECTRICITY AND MAGNETISM. *Prerequisite: Phys. 147 and Math. 151.* II. (*3*).
Principles of electrostatics and of electromagnetism.

181. HEAT. *Prerequisite: Phys. 46 and Math. 54.* I. (*2*).
Thermal expansion, specific heats, change of state, and van der Waals' equation; elementary kinetic theory and the absolute scale of temperature.

183. LABORATORY IN HEAT. I. (*2*).
To follow or accompany Physics 181. Use of modern methods and instruments for the measurement of thermal quantities.

185. INTRODUCTION TO INFRARED SPECTRA. *Prerequisite: Phys. 26 or 46 and Math. 54.* II. (*2*).
Elements of infrared spectroscopy and the basic principles involved in the interpretation of Raman and infrared data in terms of molecular structure.

186. LIGHT. *Prerequisite: Phys. 46 and Math. 54.* II. (*3*).
Theory of interference, diffraction, polarization.

188. LABORATORY IN LIGHT. II. (*2*).
To accompany or follow Physics 186. Experiments on interference, diffraction, polarization, double refraction, and the fundamental properties in light.

191, 192. INTRODUCTION TO THEORETICAL PHYSICS. *Prerequisite: Phys. 171 and Math. 150 or 154.* 191, I; 192, II. (*3 each*).
Procedures employed in the mathematical formulation and solution of problems in theoretical physics. Recommended as a preparation for the courses numbered 205 and above.

193, 194. APPLIED SPECTROSCOPY. *Prerequisite: Phys. 196.* 193, I; 194, II. (*4 each*).
Equipment and methods for spectrochemical analysis, with laboratory practice.

196. ATOMIC AND MOLECULAR STRUCTURE. *Prerequisite: Math. 57 and five hours of intermediate physics or physical chemistry.* II. (*3*).
Recent developments, based on fundamental experiments; determination and description of characteristic energy levels, and the classification of electrons.

197. NUCLEAR PHYSICS. *Prerequisite: Phys. 105 or 196.* II. (*2*).

Natural radioactivity; nuclear physics; apparatus and methods of nuclear physics; artificial transmutations and cosmic rays.

198. INTRODUCTION TO QUANTUM THEORY. *Prerequisite: Phys. 171 and 196, Math. 103.* I. (*3*).

Suitable for advanced undergraduates and beginning graduate students.

199. LABORATORY IN NUCLEAR PHYSICS. II. (*2*).

To accompany or follow Phys. 197. Measurements on the characteristics of various nuclear transformations.

205, 206. ELECTRICITY AND MAGNETISM. *Prerequisite: Phys. 147 and Math. 151 or 154.* 205, I; 206, II. (*3 each*).

Electromagnetic theory; Maxwell's equations and the radiation from a Hertzian oscillator; connections with the special relativity theory.

207, 208. THEORETICAL MECHANICS. *Prerequisite: an adequate knowledge of differential equations; Phys. 207 is a prerequisite for Phys. 208; an introductory course in mechanics is desirable.* 207, I; 208, II. (*3 each*).

Lagrange equations of motion, the principle of least action, Hamilton's principle, the Hamilton-Jacobi equation; Poisson brackets.

209. THERMODYNAMICS. *Prerequisite: Phys. 181.* II. (*3*).

The two laws and their foundation; gas equilibria and dilute solutions; phase rule of Gibbs; theory of binary mixtures.

210. KINETIC THEORY OF MATTER. *Prerequisite: Phys. 209.* I. (*3*).

Kinetic and statistical methods of Boltzmann, and explanation of the second law; extension to the quantum theory; nonideal gases and the theory of the solid body; theory of radiation; fluctuation phenomena.

211, 212. QUANTUM THEORY AND ATOMIC STRUCTURE. *Prerequisite: Phys. 196. Phys. 211 is a prerequisite for Phys. 212.* 211, I; 212, II. (*3 each*).

Wave mechanics, matrix mechanics, and methods of quantizations, with applications.

215. SPECIAL PROBLEMS. I and II. (*To be arranged*).

Qualified graduate students who desire to obtain research experience in work supervised by members of the staff may, upon consultation, elect these courses.

218. PHYSICS OF CONTINUOUS MEDIA. II. (*3*).

219. PHYSICS OF THE SOLID STATE. I. (*3*).

224. COSMIC RADIATION. II. (*3*).

256. MOLECULAR SPECTRA AND MOLECULAR STRUCTURE. (*3*).

Production Engineering

1 (CH. AND MET. ENG. 1). ENGINEERING MATERIALS AND PROCESSES. ***Prerequisite:*** *an acceptable high-school course in chemistry or Chem. 3.* (*5*).

Metals, alloys, cement, clay products, protective coatings, plastics, fuels, and water; processes of forming: pressing, forging, rolling, welding, casting; testing of materials: hardness, tensile, compressive, bending, impact. Required of all engineering students. An introductory course.

11. CASTING. *Prerequisite: Ch. and Met. Eng. 1 (Prod. Eng. 1). (2).*

For mechanical engineers. Predominant features of casting design and foundry operations are surveyed. One lecture and one three-hour laboratory period a week.

12. PROCESSING OF CAST METALS. *Prerequisite: Chem. and Met. Eng. 1 (Prod. Eng. 1). (3).*

For industrial engineers — Production Option. Quantitative study of the operation of melting, molding, cleaning as well as exercises in quality control. Melting experiments include investigations of gases in metals and refining slags; also operation of the cupola, induction, and arc furnaces. Molding instruction covers sand ceramics, gating and risering, in addition to the use of a variety of standard molding machines. Precision casting methods, radiographic and magnaflux inspection of castings, and rapid chemical control procedures are also reviewed. Two lectures and one three-hour laboratory period a week.

13. PROCESSING OF CAST METALS. *Prerequisite: Ch. and Met. Eng. 118 and Chem. 83E. (2).*

Quantitative study of the operations of melting, molding, pouring, cleaning, and inspection as well as exercises in quality control. Melting experiments emphasize the application of physical chemistry to liquid metals. Operation and critical evaluation of cupola, induction, and arc furnaces are included. Molding experiments correlate the principles of gating and risering with heat transfer from liquid metal. Radiographic, magnaflux, metallographic, and rapid chemical control procedures are surveyed. One lecture and one three-hour laboratory period a week. For metallurgical engineers.

31. MACHINING—IA. *Prerequisite: Ch. and Met. Eng. 1 (Prod. Eng. 1) and Mech. and Ind. Eng. 80 or Phy. 46. (2).*

Use of metal cutting tools, machine tools, and accessories; composition, preparation, and application of cutting tools, cutting fluids, and properties of the materials worked correlated with cutting speeds and feeds for efficient production; observance of use and design of basic machine tools and application of the above principles to their operation. One recitation and one three-hour laboratory period a week. For mechanical and aeronautical engineers.

32. MACHINING I. *Prerequisite: Ch. and Met. Eng. 1 (Prod. Eng. 1) and Mech. and Ind. Eng. 80 or Phys. 46. (3).*

Fundamental relations between product requirements, properties of materials, metal cutting behavior, machine tools and cutting tools; nature of machine tools and their use in machining parts; influence of original design on this use; case studies of parts to be machined, selected to emphasize the unique characteristics of each basic type of machine tool. In the laboratory the student operates the machines. Two one-hour recitations and one three-hour laboratory period a week.

107a. METALS AND ALLOYS LABORATORY. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 107. (1).*

Laboratory evaluation of structures and properties as affected by composition and mechanical and thermal treatment, with special emphasis on the utilization of common metals and alloys and their behavior in service.

113. RESEARCH IN CAST METALS AND FOUNDRY PROCESSES. *Prerequisite: Prod. Eng. 11, 12, or 13. (3).*

Affords an opportunity for the student to participate in research in problems of importance to the cast metals industry. Both short individual investigations as well as parts of long-range projects are available. These problems include experimental determination of equilibrium constants for slag-metal couples, machinability of cast metals, experimental cupola design and operation, new precision casting processes. Progress is reported at a weekly seminar for the benefit and criticism of the group.

114. PLASTICS FABRICATION. *Prerequisite: Prod. Eng. 31 or 32 and Eng. Mech. 4. (2).*

Principles underlying the design of products manufactured from plastic materials; correlation of properties of materials and process limitations with the functional requirements of the product followed by problems and cost studies. Two lectures and one two-hour design period each week.

115. DIE CASTING AND POWDER METALLURGY. *Prerequisite: Ch. and Met. Eng. 1 (Prod. Eng. 1) or Prod. Eng. 13 and Ch. and Met. Eng. 125 or Ch. and Met. Eng. 107 and Prod. Eng. 11 or 12. (2).*

Development of die-casting alloys and practice; modern alloys, machines, alloying, casting, machining, and finishing practice; elements of the die and product design for the economical utilization of die castings; costs of die castings; underlying theoretical principles of powder metallurgy; characteristics, preparation, and treatment of metal powders, compacting and sintering, and equipment. One lecture, one recitation, one two-hour design period each week.

123. STAMPING. *Prerequisite: Prod. Eng. 102 and 131. (2).*

Physical and metallurgical properties of materials for stamped metal parts are studied as to their influence on product design and production practice. Particular emphasis is placed on the unique design features of a product which permit its manufacture by the metal stamping process. The operating characteristics of presses, dies, and auxiliaries are also studied.

131. MACHINING II—MANUFACTURING EQUIPMENT AND PROCESSES. *Prerequisite: Prod. Eng. 31 or 32. (3).*

Design, operation, and use of machine tools, jigs and fixtures, dies, cutting tools, and other accessories as applied to job shop, semiproduction and mass production processes; relation between design of product, metal, and fabricating process. Fits, surface quality, and production costs; routings, cutting tools, machinability, and speeds and feeds. Two recitations and two three-hour laboratory periods a week.

132. ADVANCED STUDIES IN PRODUCTION. *Prerequisite: Prod. Eng. 131.* (3).

The student may specialize in one or more machine shop processes such as automatic screw machines, production lathes, gear-processing machines, various types of bore-finishing machines, and production milling machines; or machines of a tool-room type, involving complex cycles and controls such as in thread grinders, jig mills, and die-sinkers.

141. DESIGN FOR PRODUCTION. *Prerequisite: Prod. Eng. 11 or 12, and 131.* (2).

Correlations between functional specifications of a product and process characteristics; tolerances, properties of materials, surface finish, and other process characteristics which tend to limit the quality of a product. Two one-hour periods a week.

142. TOOL DESIGN. *Prerequisite: Prod. Eng. 131.* (2).

Machine tools and their uses, the application of theories of machinability to cutting practice, design of jigs, fixtures, and small tools, and cost estimates. Two lectures and one two-hour design period a week.

151. PROCESS INSTRUMENTATION. *Prerequisite: Math. 54 and Physics 46.* (2).

Principles involved in the measurement of temperature, pressure, flow, liquid level, and speed; the fundamentals of automatic control systems and the use of components in the design of production control equipment. Two lectures and one recitation a week.

161. WELDING. *Prerequisite: Ch. and Met. Eng. 107 or 117 or 127 or permission instructor.* (2).

Engineering approach to welding, including consideration of welding metallurgy, stresses, distortion, shrinkage, costs, and the capabilities and limitations of welding equipment as they relate to the design and application of weldments. Laboratory assignments include evaluation and use of all of the common welding processes, inspection and testing procedures.

162. GAS WELDING. *Prerequisite: Prod. Eng. 161 or permission of instructor.* (2).

Theory and equipment of gas welding, its applications to industry, and its cost. Practice in the welding and brazing of steels, cast iron, and nonferrous metals; testing of standard test specimens of joints welded by gas; training in manual and machine cutting and practice in pipe and airplane tube welding. One hour class and one three-hour laboratory period each week.

163. ELECTRIC WELDING. *Prerequisite: same as for Prod. Eng. 162.* (2).

Theoretical and practical knowledge of the principles of direct and alternating current arc welding, and practice in atomic hydrogen and inert arc welding as applied to industry. Training in welding in the four positions; welding costs and the standard welding tests to evaluate the different types of welds. One hour class and one three-hour laboratory period each week.

171. DIMENSIONAL QUALITY CONTROL. *Prerequisite: Math. 161 and Prod. Eng. 131* (3).

Standards, specifications, the nature of quality, inspection principles, measuring and gaging equipment, and the nature of variables of machining processes requiring control; the limitations of personnel as they affect inspection procedures. Class periods are devoted to discussions of pertinent topics while the laboratory periods are used to observe inspection practices and to evaluate the different types of equipment available for this purpose. Two one-hour recitations and two three-hour laboratory periods a week.

181 (MECH. AND IND. ENG. 181). DESIGN OF MACHINE TOOLS. *Prerequisite: Prod. Eng. 131. (3).*

Specification, design, construction, and operation of a variety of tool-room and production machine tools; bearings, lubrication, materials, motors, and controls; hydraulic units and circuits are studied and units of machine tools are designed, bill of materials prepared, and vibrations studied. Power requirements based on specified cutting practice are determined and used as a basis of design.

182. PARTS PROCESSING. *Prerequisite: Prod. Eng. 131 and permission of instructor. (3).*

Complete routings are made for each of several selected parts which are to be manufactured in accordance with a given schedule. Each routing covers the list of operations; the machine tools for each operation together with their accessories, such as cutting tools, jigs, fixtures, dies, inspection instruments, and cutting fluids; the time of each operation, based on speeds, feeds, handling time, etc., and the number of machines for each operation.

244 (CH. AND MET. ENG. 244). CAST METALS IN ENGINEERING DESIGN. *Prerequisite: Prod. Eng. 11, 12, or 13 and Ch. and Met. Eng. 107, 117, or 127.* (2).

An understanding of the properties of the important cast metals is obtained by melting, casting, and testing. In addition to measurement of mechanical properties, resistance to heat, wear, and corrosion is discussed. The application of these properties in the design of critical parts in the aircraft, automotive, chemical, mining, and railroad industries is presented by case histories and examination of castings. One lecture and one three-hour laboratory period a week.

264. ADVANCED WORKING, TREATING, AND WELDING OF METAL. *Prerequisite: Ch. and Met. Eng. 1 (Prod. Eng. 1), Ch. and Met. Eng. 107, or their equivalent.* (2).

Special problems on these subjects may be elected by students interested in steel treatment and processing. Two recitations a week.

273. MACHINABILITY. *Prerequisite: Prod. Eng. 131. (3).*

Metal cutting theory and its application to practical problems. Basic theory of tool wear, cutting forces, surface finish, and chip formation is studied in class and correlated with work in the laboratory. Special research problems are investigated. Field trips to local manufacturing plants are included.

COMMITTEES AND FACULTY*

EXECUTIVE COMMITTEE

Dean BROWN, *Chairman* ex officio

Professor NELSON, term, 1949–53
Professor VINCENT, term, 1950–54
Professor ORMONDROYD, term, 1951–55
Professor DOW, term, 1952–56

STANDING COMMITTEE

Dean BROWN, Assistant Dean EMMONS, Professors BAIER, BOSTON, BOYCE, BRANDT, CONLON, DOW, ERIKSEN, KATZ, LOVELL, MILLER, NELSON, ORMONDROYD, and VINCENT.

COMMITTEE ON CLASSIFICATION

Associate Professor LEGATSKI, Professors STOUT and PALMER, and Associate Professors MCCREADY and ALT.

COMMITTEE ON SCHOLASTIC STANDING

Professors GORDY, BAIER, CALHOON, HAGERTY, MAUGH, SCHNEIDEWIND, and WALTON, and Assistant Professor CLARK.

COMMITTEE ON DISCIPLINE

Professor MARIN, Assistant Dean EMMONS, and Professor BRATER.

COMMITTEE ON SCHOLARSHIPS

Professors MILLER, MENEFEE, CHURCHILL, ATTWOOD, and BRIER.

COMMITTEE ON SUBSTITUTIONS AND EXTENSION OF TIME

Professors DODGE, NICKELSEN, and HOBART.

* Listed for the academic year, 1952–53.

COMMITTEE ON COMBINED COURSES WITH COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS

Professors SHERLOCK and SCHNEIDEWIND and Assistant Dean EMMONS.

Aeronautical Engineering

EMERSON WARD CONLON, B.S. (A.E.), *Professor of Aeronautical Engineering and Chairman of the Department of Aeronautical Engineering*

ARNOLD MARTIN KUETHE, Ph.D., *Professor of Aerodynamics*

WILBUR CLIFTON NELSON, M.S.E., *Professor of Aeronautical Engineering*

MYRON HIRAM NICHOLS, Ph.D., *Professor of Aeronautical Engineering*

EDGAR JAMES LESHER, M.S.E., *Associate Professor of Aeronautical Engineering*

JULIUS DAVID SCHETZER, M.S., *Associate Professor of Aeronautical Engineering*

LAWRENCE LEE RAUCH, Ph.D., *Associate Professor of Aeronautical Engineering*

JOHN WILLIAM LUECHT, B.S.E. (Ae.E.), *Assistant Professor of Aeronautical Engineering*

ROBERT MILTON HOWE, Ph.D., *Assistant Professor of Aeronautical Engineering*

MAURICE ANDRE BRULL, M.S., *Assistant Professor of Aeronautical Engineering*

JAMES EUGENE BROADWELL, M.S., *Assistant Professor of Aeronautical Engineering*

JOHN RANDOLPH SELLARS, M.S., *Assistant Professor of Aeronautical Engineering*

Chemical and Metallurgical Engineering

DONALD LAVERNE KATZ, Ph.D., *Professor of Chemical Engineering and Chairman of the Department of Chemical and Metallurgical Engineering*

GEO. GRANGER BROWN, Ph.D., Ch.E., *Edward DeMille Campbell University Professor of Chemical Engineering and Dean of the College of Engineering*

ALBERT EASTON WHITE, Sc.D., *Professor of Metallurgical Engineering and Director of the Engineering Research Institute*

JOHN CROWE BRIER, M.S., *Professor of Chemical Engineering*

CLAIR UPTHEGROVE, B.Ch.E., *Professor of Metallurgical Engineering*

WILLIAM PLATT WOOD, M.S.E., *Professor of Metallurgical Engineering*

RICHARD SCHNEIDEWIND, Ph.D., *Professor of Metallurgical Engineering*

LEO LEHR CARRICK, Ph.D., *Professor of Chemical Engineering*

LARS THOMASSEN, Ph.D., *Professor of Chemical and Metallurgical Engineering*

CLARENCE ARNOLD SIEBERT, Ph.D., *Professor of Chemical and Metallurgical Engineering*

ROBERT ROY WHITE, Ph.D., *Professor of Chemical and Metallurgical Engineering*

JAMES WRIGHT FREEMAN, M.S.E., Ph.D., *Associate Professor of Chemical and Metallurgical Engineering and Project Engineer in the Engineering Research Institute*

DONALD WILLIAM MCCREADY, Ph.D., *Associate Professor of Chemical Engineering*

RICHARD EMORY TOWNSEND, M.S.E., Ch.E., *Associate Professor of Chemical and Metallurgical Engineering*

JOSEPH J. MARTIN, D.Sc., *Associate Professor of Chemical and Metallurgical Engineering*

GEORGE BRYMER WILLIAMS, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

LLOYD EARL BROWNELL, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

LINDSEY M. HOBBS, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

MAURICE JOSEPH SINNOTT, Sc.D., *Associate Professor of Chemical and Metallurgical Engineering*

CEDOMIR M. SLIEPCEVICH, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

JESSE LOUIS YORK, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

RICHARD A. FLINN, Sc.D., *Associate Professor of Chemical and Metallurgical Engineering and of Production Engineering*

JULIUS THOMAS BANCHERO, Ch.E., Ph.D., *Assistant Professor of Chemical and Metallurgical Engineering*

STUART WINSTON CHURCHILL, Ph.D., *Assistant Professor of Chemical Engineering*

ROBERT LAWRENCE HESS, Ph.D., *Assistant Professor of Chemical and Metallurgical Engineering*

JAMES GEORGE KNUDSEN, Ph.D., *Assistant Professor of Chemical and Metallurgical Engineering*

EDWIN HAROLD YOUNG, M.S.E., *Assistant Professor of Chemical and Metallurgical Engineering*

HOWARD ROBERT VOORHEES, S.M., *Instructor in Chemical and Metallurgical Engineering*

CHARLES MANSON THATCHER, M.S.E., *Instructor in Chemical and Metallurgical Engineering*

CHARLES WILLIAMS PHILLIPS, M.S., *Instructor in Chemical and Metallurgical Engineering*

Civil Engineering

EARNEST BOYCE, M.S., C.E., *Professor of Municipal and Sanitary Engineering in the College of Engineering, Chairman of the Department of Civil Engineering, and Professor of Public Health Engineering in the School of Public Health*

ROBERT HENRY SHERLOCK, B.S. (C.E.), *Professor of Civil Engineering.*

HARRY BOUCHARD, B.C.E., *Professor of Geodesy and Surveying and Director of Camp Davis*

WALTER CLIFFORD SADLER, M.S., C.E., LL.B., *Professor of Civil Engineering*

LAWRENCE CARNAHAN MAUGH, Ph.D., *Professor of Civil Engineering*

WILLIAM STUART HOUSEL, M.S.E., *Professor of Civil Engineering*

BRUCE GILBERT JOHNSTON, Ph.D., *Professor of Structural Engineering*

ERNEST FREDERICK BRATER, Ph.D., *Professor of Hydraulic Engineering*

WALTER JOHNSON EMMONS, A.M., *Professor of Highway Engineering and Assistant Dean and Secretary of the College of Engineering*

GLENN LESLIE ALT, C.E., *Associate Professor of Civil Engineering*

EDWARD YOUNG, B.S.E. (C.E.), *Associate Professor of Geodesy and Surveying*

JOHN CLAYTON KOHL, B.S.E. (C.E.), *Associate Professor of Civil Engineering and Director of the Transportation Institute*

LEO MAX LEGATSKI, Sc.D., *Associate Professor of Civil Engineering*

HAROLD JAMES MCFARLAN, B.S.E. (C.E.), *Assistant Professor of Geodesy and Surveying*

GEORGE MOYER BLEEKMAN, M.S.E., *Assistant Professor of Geodesy and Surveying*

JACK ADOLPH BORCHARDT, Ph.D., *Assistant Professor of Civil Engineering*

ROBERT BLYNN HARRIS, M.S.C.E., *Assistant Professor of Civil Engineering*

FRANK EVARISTE LEGG, JR., M.S., *Assistant Professor of Engineering Materials*

DONALD NATHAN CORTRIGHT, M.S.E., *Assistant Professor of Civil Engineering*

ROBERT O. GOETZ, M.S.E., *Instructor in Civil Engineering*

EUGENE ANDRUS GLYSSON, M.S.E., *Instructor in Civil Engineering*

VLADAS DOMINIC MERKYS, Dr. Eng., *Resident Lecturer in Civil Engineering*

WADI SALIBA RUMMAN, B.S.E. (C.E.), *Instructor in Civil Engineering*

Drawing (Engineering)

HENRY WILLARD MILLER, B.S., M.E., *Professor of Engineering Drawing and Chairman of the Department of Engineering Drawing*

JULIUS CLARK PALMER, B.S., *Professor of Engineering Drawing*

DEAN ESTES HOBART, B.S. *Professor of Engineering Drawing*

ROBERT CARL COLE, A.M., *Professor of Engineering Drawing*

MARTIN J. ORBECK, C.E., M.S.E., *Professor of Engineering Drawing*

PHILIP ORLAND POTTS, B.M.E., *Associate Professor of Engineering Drawing*

ALBERT LORING CLARK, JR., B.S.E. (M.E.), *Assistant Professor of Engineering Drawing*

MAURICE BARKLEY EICHELBERGER, B.S., *Assistant Professor of Engineering Drawing*

FRANK HAROLD SMITH, M.S.E., *Assistant Professor of Engineering Drawing*

FRANCIS X. LAKE, Ph.D., *Assistant Professor of Engineering Drawing*

ROBERT SEATON HEPPINSTALL, M.S., *Assistant Professor of Engineering Drawing*

DONALD CRAIG DOUGLAS, B.S.M.E., *Assistant Professor of Engineering Drawing*

ALFRED WILLIAM LIPPHART, B.S.E. (Ae.E.) LL.B., *Assistant Professor of Engineering Drawing*

ROBERT HORACE HOISINGTON, M.S., *Assistant Professor of Engineering Drawing*

RAYMOND CLARE SCOTT, M.Ed., *Assistant Professor of Engineering Drawing*

Electrical Engineering

ALFRED HENRY LOVELL, M.S.E., *Professor of Electrical Engineering and Chairman of the Department of Electrical Engineering*

JOSEPH HENDERSON CANNON, B.S. (E.E.), *Professor of Electrical Engineering*

ARTHUR DEARTH MOORE, M.S., *Professor of Electrical Engineering and Research Associate in the Institute of Human Biology*

STEPHEN STANLEY ATTWOOD, M.S., *Professor of Electrical Engineering*

JOSEPH GALLUCHAT TARBOUX, Ph.D., *Professor of Electrical Engineering*

MELVILLE BIGHAM STOUT, M.S., *Professor of Electrical Engineering*

WILLIAM GOULD DOW, M.S.E., *Professor of Electrical Engineering*

LEWIS NELSON HOLLAND, M.S., *Professor of Electrical Engineering*

EDWIN RICHARD MARTIN, E.E., *Professor of Electrical Engineering*

HEMPSTEAD STRATTON BULL, M.S., *Associate Professor of Electrical Engineering*

JOHN JOSEPH CAREY, B.S.E.E., *Associate Professor of Electrical Engineering*

ALAN BRECK MACNEE, Sc.D., *Associate Professor of Electrical Engineering*

WALTER ALFRED HEDRICH, M.S., *Assistant Professor of Electrical Engineering*

JACK FRIBLEY CLINE, Ph.D., *Assistant Professor of Electrical Engineering*

HENRY JACOB GOMBERG, Ph.D., *Assistant Professor of Electrical Engineering, Assistant Director, Michigan Memorial-Phoenix Project, and Research Associate, AEC: Biological Effects of Irradiation*

GUNNAR HOK, E.E., *Lecturer in Electrical Engineering and Research Engineer in the Engineering Research Institute*

NORMAN ROSS SCOTT, Ph.D., *Assistant Professor of Electrical Engineering*

JULES SID NEEDLE, Ph.D., *Assistant Professor of Electrical Engineering*

LOUIS FRANK KAZDA, M.S.E., *Assistant Professor of Electrical Engineering*

THOMAS EDWIN TALPEY, M.S.E. (E.E.), *Instructor in Electrical Engineering*

RICHARD KEMP BROWN, Ph.D., *Instructor in Electrical Engineering*

MELVIN BURTUS FOLKERT, M.S.E., *Instructor in Electrical Engineering*

PHIL H. ROGERS, M.S., *Instructor in Electrical Engineering*

WILLIAM KERR, M.S. (E.E.), *Instructor in Electrical Engineering*

KENNETH A. STONE, B.S.E. (E.E.), *Instructor in Electrical Engineering.*

EARL M. BROHL, B.S. (E.E.), *Lecturer in Electrical Engineering*

JOSEPH A. BOYD, M.S.E.E., *Instructor in Electrical Engineering*

Engineering Mechanics

EDWARD LEERDRUP ERIKSEN, B.C.E., *Professor of Engineering Mechanics and Chairman of the Department of Engineering Mechanics*

FERDINAND NORTHRUP MENEFEE, C.E., D.Eng., *Professor of Engineering Mechanics*

JAN ABRAM VAN DEN BROEK, Ph.D., *Professor of Engineering Mechanics*

JESSE ORMONDROYD, A.B., *Professor of Engineering Mechanics*

RUSSELL ALGER DODGE, M.S.E., *Professor of Engineering Mechanics*

HOLGER MADS HANSEN, B.C.E., *Professor of Engineering Mechanics*

WILLIAM WALSH HAGERTY, Ph.D., *Professor of Engineering Mechanics*

ROY STANLEY SWINTON, M.S.E., *Professor of Engineering Mechanics*

CHARLES THOMAS OLMSTED, B.S. (C.E.), *Professor of Engineering Mechanics*

RICHARD THOMAS LIDDICOAT, Ph.D., *Associate Professor of Engineering Mechanics*

FRANKLIN L. EVERETT, Ph.D., *Associate Professor of Engineering Mechanics*

EDWARD AXEL YATES, M.S.E., *Assistant Professor of Engineering Mechanics*

PAUL MANSOUR NAGHDI, M.S.E., Ph.D., *Assistant Professor of Engineering Mechanics*

THOMAS ALEXANDER HUNTER, Ph.D., *Assistant Professor of Engineering Mechanics*

ROBERT LAURENCE HESS, Ph.D., *Assistant Professor of Engineering Mechanics and of Chemical and Metallurgical Engineering*

LYLE GERALD CLARK, M.S. (E.M.), *Instructor in Engineering Mechanics*

LLOYD GUNNERD DANIELSON, M.S.E., *Instructor in Engineering Mechanics*

JAMES GILBERT BERRY, M.S.E., *Instructor in Engineering Mechanics*

ALFRED RANDOLPH BOBROWSKY, M.S.E., *Instructor in Engineering Mechanics*

PATARASP RUSTOMJI SETHNA, M.S.E., *Instructor in Engineering Mechanics*

English

CARL GUNARD BRANDT, LL.M., *Professor of English and Chairman of the Department of English in the College of Engineering and Lecturer in Speech in the College of Literature, Science, and the Arts*

JESSE EARL THORNTON, A.M., *Professor of English, College of Engineering*

CARL EDWIN BURKLUND, Ph.D., *Professor of English, College of Engineering*

IVAN HENRY WALTON, A.M., *Professor of English, College of Engineering*

ROBERT D. BRACKETT, A.M., *Associate Professor of English, College of Engineering*

WILLIAM HENRY EGLY, A.M., *Associate Professor of English, College of Engineering*

WEBSTER EARL BRITTON, Ph.D., *Associate Professor of English, College of Engineering*

GEORGE MIDDLETON McEWEN, Ph.D., *Associate Professor of English, College of Engineering, and Assistant Director of the Summer Session*

JOSHUA McCLENNEN, Ph.D., *Associate Professor of English, College of Engineering*

WILLIAM HARRISON MACK, A.M., *Assistant Professor of English, College of Engineering*

WILFRED MINNICH SENSEMAN, Ph.D., *Assistant Professor of English, College of Engineering*

THOMAS MITCHELL SAWYER, JR., A.M., *Instructor in English, College of Engineering*

ROBERT PERCY WEEKS, Ph.D., *Instructor in English, College of Engineering*

EDMUND PENDLETON DANDRIDGE, JR., A.M., *Instructor in English, College of Engineering*

THOMAS C. EDWARDS, A.M., *Instructor in English, College of Engineering*

WARNE CONWELL HOLCOMBE, A.M., *Instructor in English, College of Engineering*

ARTHUR WILLARD FORBES, A.M., *Instructor in English, College of Engineering*

RICHARD JOHN ROSS, A.M., *Instructor in English, College of Engineering*

Mechanical and Industrial Engineering

EDWARD THOMAS VINCENT, B.Sc., *Professor of Mechanical Engineering and Chairman of the Department of Mechanical and Industrial Engineering*

WALTER EDWIN LAY, B.M.E., *Professor of Mechanical Engineering*

HUGH EDWARD KEELER, M.S.E., M.E., *Professor of Mechanical Engineering*

CHARLES BURTON GORDY, Ph.D., *Professor of Industrial Engineering*

JOHN MINERT NICKELSEN, B.S. (M.E.), *Professor of Mechanical Engineering*

CHARLES WINFRED GOOD, B.S.E. (M.E.), *Professor of Mechanical Engineering*

AXEL MARIN, B.S.E. (M.E.), *Professor of Mechanical Engineering*

RICHMOND CLAY PORTER, M.E., M.S., *Professor of Mechanical Engineering*

FRANK LEROY SCHWARTZ, Ph.D., *Professor of Mechanical Engineering*

FLOYD NEWTON CALHOON, M.S., *Professor of Mechanical Engineering*

JAY ARTHUR BOLT, M.S., M.E., *Associate Professor of Mechanical Engineering*

GLENN VERNON EDMONSON, M.E., *Associate Professor of Mechanical Engineering*

QUENTIN C. VINES, B.S.E. (E.E.), M.E., *Associate Professor of Industrial Engineering*

ARNET BERTHOLD EPPLE, M.S., *Associate Professor of Mechanical Engineering*

KEITH WILLIS HALL, B.S.M.E., *Associate Professor of Mechanical Engineering*

HARRY JAMES WATSON, B.M.E., *Assistant Professor of Mechanical Engineering*

HOWARD REX COLBY, M.S.E., *Assistant Professor of Mechanical Engineering*

WILBERT STEFFY, B.S.E. (Ind.-Mech.), *Assistant Professor of Industrial Engineering*

GORDON JOHN VAN WYLEN, Sc.D., *Assistant Professor of Mechanical Engineering*

HERBERT HERLE ALVORD, M.S.E., *Assistant Professor of Mechanical Engineering*

THOMAS ALLAN BOYLE, JR., M.S., *Assistant Professor of Mechanical Engineering*

FREDERICK JOHN VESPER, M.S.E., *Assistant Professor of Mechanical Engineering*

WILLIAM JOSEPH FLAHERTY, M.S., *Assistant Professor of Mechanical and Industrial Engineering*

EDWARD LUPTON PAGE, B.S.E. (M.E.), *Instructor in Industrial Engineering*

FREDERICK KENT BOUTWELL, M.S.E., *Instructor in Mechanical Engineering*

DONALD RAYMOND LONG, B.S.E. (M.E.), *Instructor in Mechanical Engineering*

PAUL FREDERICK YOUNGDAHL, M.S.E., *Instructor in Mechanical Engineering*

Naval Architecture and Marine Engineering

LOUIS ARTHUR BAIER, B.Mar.E.,Nav.Arch., *Professor of Naval Architecture and Marine Engineering and Chairman of the Department of Naval Architecture and Marine Engineering*

HENRY CARTER ADAMS 2d, M.S., *Associate Professor of Naval Architecture and Marine Engineering*

CHARLES WILLETT SPOONER, JR., M.E., M.S., *Associate Professor of Mechanical and Marine Engineering*

HARRY BELL BENFORD, B.S.E. (Nav. Arch. and Mar. E.), *Assistant Professor of Naval Architecture and Marine Engineering*

Production Engineering

ORLAN WILLIAM BOSTON, M.S.E., M.E., *Professor of Mechanical Engineering, Professor of Production Engineering, Chairman of the Department of Production Engineering, Director of the University Instrument Shop, and Supervisor of War Department Gaging and Measuring Laboratory*

WILLIAM WAYNE GILBERT, Sc.D., *Professor of Production Engineering*

LESTER VERN COLWELL, M.S., *Professor of Production Engineering*

WILLIAM CALVIN TRUCKENMILLER, M.S.E., *Associate Professor of Production Engineering*

ROBERT EDWIN MCKEE, A.M., *Associate Professor of Production Engineering*

RICHARD A. FLINN, Sc.D., *Associate Professor of Chemical and Metallurgical Engineering and of Production Engineering*

WILLIAM ALLEN SPINDLER, M.S., *Assistant Professor of Production Engineering*

FRANK WALTER SOWA, M.S.E., LL.B., *Assistant Professor of Production Engineering*

LESLIE E. WAGNER, M.A., *Assistant Professor of Production Engineering*

WALTER BERTRAM PIERCE, *Assistant Professor of Production Engineering*

ROBERT MACORMAC CADDELL, M.S.E., *Instructor in Production Engineering*

HOMER WILLIAM SMITH, B.S.E. (M.E.), *Instructor in Production Engineering*

KENNETH FREDERICK PACKER, M.S.E., *Instructor in Production Engineering*

KARL ERNST HANS MOLTRECHT, M.S., *Instructor in Production Engineering*

PHILIP REINDERT VISSER, B.S.E. (M.E.), *Instructor in Production Engineering*

RULES AND PROCEDURES

Counseling

Counseling services of many types are available. A freshman desiring advice should call on his mentor who will refer him, if necessary, to other persons or agencies.

Program advisers, whose names are at the heads of the several degree programs, are happy to discuss fields of engineering, selection of electives, and similar matters.

The Assistant Dean is available for consultation at his office at any time. Students who have special problems or who are uncertain concerning procedures may go to him for advice.

Health Service Approval

The following classes of students require Health Service approval before payment of fees:

a) Students who wish to enroll for the first time, to re-enroll after an absence of a full semester, or who are specifically listed for approval, must obtain Health Service approval as a part of registration. Such approval is to be based upon assurance of health safety to the entrant and associates as determined by a suitable examination and evidence of vaccination (immunity to smallpox). Vaccination may be waived by the Director of the Health Service for applicants who file statements of objection on religious grounds, properly signed, in case of minors, by parents or guardians. Such waiver shall release the University from the responsibility of financial assistance to the applicant who contracts smallpox.

b) Treatment by the Health Service of those students entitled to that service is optional on their part, except when in the opinion of the Director they may be a source of danger to student health. The type and amount of service rendered is in conformity with the rules and regulations of the Health Service.

Physical Education and Health Lectures

Each student upon entering the University as a freshman or with advanced standing is given a complete health examination on the basis of which he or she is placed in a health group. Students are limited to suitable types of activity according to their health groupings.

All students entering the University from the secondary schools shall be required to complete satisfactorily a one-year course in physical education.*

Each entering freshman is required to take a series of lectures in community and personal health and to pass an examination on the content of these lectures. Transfer students with freshman standing are also required to take the course unless they have had this course elsewhere. The requirements for passing the course are based on (1) attendance, (2) efficiency in activities, (3) sports knowledge, and (4) motor fitness scores.

All students are required to take a *swimming* test. Those students who are unable to meet the swimming standards are required to elect beginning swimming.

All *unexcused absences* must be made up. Health Service statements will be accepted only for illness of more than twenty-four hours. All excuses for absences must be presented to the Waterman Gymnasium office for approval.

Mentor System and Assembly

Upon admission to the University each freshman student is assigned to a mentor group under the supervision of a member of the faculty. Following a carefully arranged schedule, each group as a unit progresses through the social activities, tests, and examinations of the Orientation period which finally terminates with assignment to classes.

Students who are admitted from other colleges with academic standing above the freshman level also are assigned to groups in order to facilitate the various steps leading to classification and election of courses.

* By Regents' action of December 29, 1944, all veterans of World War II who have had basic training or its equivalent are excused from the regular requirements of physical education.

The freshman student continues to be a member of his mentor group throughout his first two semesters of attendance and the faculty adviser continues as mentor for the group. Both socially and in an advisory capacity he is the personal representative of the Dean, so that each student may call upon him at any time to discuss any subject relating to his college life.

Freshman students receive reports on each of their studies through their mentors or faculty advisers. These reports reach the mentor about six weeks after the beginning of the semester. He is, therefore, able to give the students in his group definite information regarding their progress.

Attendance at a weekly assembly is required of all freshmen. Unexcused absences subject the absentee to discipline. In the assemblies matters are discussed pertaining to the students' orientation to college life and the improvement of study habits, or faculty members and visiting engineers may be invited to discuss subjects of interest.

Unexcused absences from assembly are considered by the Discipline Committee as acts of insubordination. After two absences unexcused by the head freshman mentor, the student may be placed on probation by the Discipline Committee. For more than two unexcused absences, the Discipline Committee may dismiss the student from the University.

Election of Studies

1. Each classifier has the responsibility for the proper election of courses by the student. The classifier should carefully consider the student's preparation, his demonstrated ability, his other activities and desires, and particularly any special recommendations of the Committee on Scholastic Standing. In general, no student is permitted to elect fewer than twelve hours, and may not elect more than eighteen hours unless his grade average for the preceding semester is at least 3.0. No credit will be allowed to a student for work in any course unless the election of that course is formally entered on his office classification card.

2. All requests for changes in classification must be made on a printed form furnished by the Secretary of the College. A course may be dropped with the permission of the classifier after conference with the instructor in the course, and, except under extraordinary circumstances, any course dropped after the first eight weeks of the semester will carry a grade of "E."

3. A student who has been absent from studies any time in the semester for more than a week, because of illness or other emergency, should consult his classifier or the Assistant Dean concerning a revision of his elections.

4. A student may be required to drop part of his course work at any time he appears to be undertaking too much, or to take additional work if he is not sufficiently employed. A student who supports himself wholly or in part should so inform his classifier and should elect a limited number of courses. It is very difficult for a student supporting himself to carry a full schedule and retain his health. It is even more difficult under such conditions to carry a full schedule and to earn grades sufficiently high to qualify for graduation.

5. The classifier shall see that a student entering this College with a deficiency remove this deficiency, so far as possible, during the first semester of residence and, in all cases, before the beginning of the second year of residence.

6. All regular students are required to complete a group of nontechnical electives in order that they may explore areas other than engineering. The choice of subjects is defined as follows:

a) English beyond the required courses is acceptable as a nontechnical elective as, also, are courses in the College of Architecture and Design whose major emphasis is on the fine arts.

b). Nontechnical electives may also be selected from the offerings of any instructional department or unit of this University except the following:

1. A department already represented by a required course in the student's degree program
2. The departments of Air, Military, or Naval Science
3. The College of Engineering (See *a*, above)
4. The School of Business Administration
5. The College of Architecture (See *a*, above)

7. Substitution of a course for one which is a requirement for graduation is possible only by permission of the Committee on Substitutions and Extension of Time.

8. After admission, a student will not be allowed, without special permission of the faculty, to take quizzes, tests, or examinations in any of the courses given unless he is regularly enrolled in such courses.

9. The faculty reserves the right to withdraw the offering of any elective course not chosen by at least six persons.

Examinations

The regular examination at the end of the semester is an essential part of the work of the course. Classes may be examined at any time, with or without notice, on any part of the work.

Grades and Scholarship

1. The average semester grade and the general average grade are computed for each student at the end of each semester and become part of his permanent record.

2. The average grade is determined on the basis of A (excellent) equals 4 points, B (good) equals 3 points, C (satisfactory) equals 2 points, D (passed) equals 1 point, and E (not passed) equals 0.

3. The average grade is computed by multiplying the number corresponding to the grade in each course by the hours of credit for the course and dividing the sum of these products by the total number of hours represented by all the courses elected. A supplementary grade removing an incomplete shall be used in computing averages when that grade is different from the original semester grade qualifying the report of incomplete.

4. No student who has earned a general average grade below 2.0 in the courses elected in this College may be graduated. A student whose general average or semester average falls below 2.0 should consult with his adviser immediately.

5. A student whose average grade for a semester or summer session is from 1.7 to less than 2.0 shall be automatically placed on the warned list.

6. A student on the warned list whose average for the following semester or summer session is 2.0 or better shall be restored to good standing, provided his general average grade is 2.0 or better; if not, he shall be continued on the warned list.

7. A student on the warned list whose average for the following semester or summer session is from 1.7 to less than 2.0 shall be automatically placed on probation.

8. When the average semester or summer session grade of a student falls below 1.7 he is automatically placed on probation.

9. A student on probation who fulfils the requirements of paragraph 10 and obtains an average semester or summer session grade of 2.0 or more is automatically removed from probation, provided his general average is 2.0 or better; if not, he shall be placed on the warned list.

10. A student on probation or under warning shall not be removed from the probation or warned list unless he elects and carries at least twelve hours of work in a semester or six hours in a summer session.

11. For any one of the following reasons a student will be placed on the home list and will not be permitted to register or classify in the College of Engineering unless authorized by the Committee on Scholastic Standing after a thorough review of his case:

a) If his average semester or summer session grade falls below 1.1.

b) If he is on probation and fails to obtain an average grade of 2.0, or C, during a semester or summer session.

c) If he is on the warned list and obtains a semester or summer session average below 1.7.

d) If he has been on probation during any two semesters and subsequently fails to obtain an average semester or summer session grade of 1.7.

12. In cases of extenuating circumstances, at the discretion of the Committee on Scholastic Standing, students on the warned list or probation may be removed from these lists, and students who have been required to withdraw may be reinstated on probation.

13. A student reinstated on probation to elect a program in another school or college of this University must obtain permission to classify from the Committee on Scholastic Standing each semester as long as he is registered in the College of Engineering. This provision, in the case of such a student, supersedes paragraphs 5, 6, 7, 8, 9, 10, and 11.

14. A student who is placed on probation or under warning at the end of a semester must repeat as soon as possible all courses in which he received a grade of D in that semester. In exceptional cases this requirement may be waived by the student's program adviser (for freshmen, the Assistant Dean).

15. Any student may at his own option repeat a course in which he has a D grade provided he does so during the next two semesters and summer session he is in residence.

16. Except as provided above, a student may not repeat a course which he has already passed. In exceptional cases this rule may be abrogated by the student's program adviser (for freshmen, the Assistant Dean) upon recommendation of the department of instruction concerned.

17. All grades received in legally repeated courses shall be included in computing the student's average grade.

Incompletes

When a student is prevented by illness or by any other cause beyond his control from taking an examination or from completing any other part of a course, or if credit in a course is temporarily withheld for any reason, the mark I with a qualifying grade may be given to indicate that the course has not been completed. An incomplete course is thus reported IA, IB, IC, ID, or IE. The grade indicates the quality of work done in the part of the course which has been completed.

The qualifying grade is used to compute a temporary grade average. Should an I be incorrectly reported without a qualifying quality grade, it is used as a D grade in the temporary average. A permanent average is recorded when a final grade is filed by the instructor.

Any student absent from an examination is required to report to his instructor as soon thereafter as possible. If a student presents a valid excuse for his absence, he may take the examination at such time as may be arranged by the instructor. In order that credit for a course may be given, it must be completed before the end of the eighth week of the semester of residence next succeeding that in which it was elected unless an extension is granted by the Committee on Substitution and Extension of Time.

The final grade in a course which has been completed during the semester of residence following that in which it was elected will be based upon all of the work done in the course and may not be the grade reported for the partly completed course. At the time of completing such a course students must obtain from the Secretary a blank form for presentation to the instructor. The blank when filled out is to be sent at once by campus mail, or delivered by the instructor, directly to the Secretary's office.

Class Standing

The following classification of a student in terms of credit hours applicable to his program has been approved by the faculty: *sophomores* should have from thirty to thirty-three hours, *juniors* sixty-seven to seventy hours, and *seniors* 100 to 104 hours, or a reasonable chance to graduate within a year. The Assistant Dean will make decisions in unusual cases. The faculty recognizes as *upperclassmen:* (*a*) those students in good standing, i.e., not under scholastic discipline, who have obtained at least sixty-seven hours of credit, with an average grade of at least C for all work taken at the University of Michigan; (*b*) all new students who have completed a four-year program at approved colleges and other like institutions; and (*c*) other new students with good previous records who in the opinion of the program adviser may qualify for graduation within one year.

Excuses for Absences

Underclassmen in the College of Engineering must take the initiative in securing from the Assistant Dean excuses for absences from classes, which excuses must be applied for within five days after the return to class.

Upperclassmen are not required to obtain excuses for irregularities of attendance from the Assistant Dean, but should explain them to their instructors.

Withdrawal from the College

A student should not withdraw from class even temporarily without obtaining permission from the Assistant Dean.

Leave of absence will be granted to those who expect to return before the end of the year.

Honorable dismissal will be granted to those who wish to transfer to another college of the University and to those going elsewhere, provided in either case they are in good standing. (The written approval of parent or guardian is generally required.) This permission must be obtained from the Assistant Dean.

Requirements for Graduation

In order to secure a degree in the College of Engineering, a student must meet the following requirements:

1. (*a*) He must demonstrate a basic level of attainment in English, Drawing, Mathematics, Chemistry, Physics, and Engineering Materials which are common to all degree programs; (*b*) he must complete the remaining specified professional subjects and electives in the program of his choice.

2. His grade average for all courses taken at the University must be 2.0 or more.

3. He must spend at least one year in residence and complete at the University of Michigan a minimum of thirty credit hours. Attendance at four summer sessions will be accepted as the equivalent of one year in satisfying the present residence requirements.

4. He must be in residence during the term in which he completes the requirements for the degree.

5. To obtain a second bachelor's degree the student must complete such subject requirements as are acceptable to the program advisers in both departments and have completed not less than eight credit hours more than would be required for one degree.

The credit hours of work required at the University to earn the degree depend upon the quality and extent of the student's preparation. Those who possess average ability and present the admission units as stated on page 17 should complete the requirements of any one of the degree programs with 140 hours of credit. Significant acceleration is possible in the cases of those students who are able to achieve earlier the basic level of attainment through the medium of a planned program of preparation in high school or at another college.

A credit hour represents as a rule one hour of recitation or lecture a week for one semester, preparation for which should require two hours of study; or in the case of laboratory work, the credit hours are one-half to one-third of the actual hours spent in session, the time required depending on the necessary outside preparation.

All students who complete the requirements for graduation and who are entitled to receive degrees in June are expected to be present at the Commencement exercises.

Foreign Students

All students whose native language is other than English shall, before matriculation and registration in the College of Engineering, be required to report at once to the Counselor to Foreign Students, Dr. Esson M. Gale. Before they may be classified, such students shall satisfy him that they possess a sufficient knowledge of English to carry on work in the College of Engineering.

On recommendation of the counselor they may be referred to the proper classifier, who will give them a program of work such as he deems best. For his first semester, however, every foreign student is considered to be on trial. If at the end of the semester he passes his work, credit will be given; if, however, in spite of conscientious effort he fails, and his difficulties are, in the judgment of his instructors and of the counselor, due primarily to his lack of facility in the use of the English language, his record will be disregarded but he will then be referred to the Department of English for such work in English as he needs, to the limit of eight hours.

If a student is judged by the counselor to be unfitted even for such a trial program as that outlined above, he will be required to take for one semester such work in English as the counselor thinks necessary and may be allowed to visit such classes as may in the judgment of the counselor be profitable to him.

SUMMARY OF STUDENTS

1951–52

Both Semesters and 1951 Summer Session

	1st Year	2d Year	3d Year	4th Year	Special	Total
Civil	...	48	70	116	4	238
Mechanical	...	87	60	160	2	309
Electrical	...	60	65	139	7	271
Chemical	...	51	45	92	2	190
Naval Architecture and Marine.	...	22	19	35	8	84
Aeronautical	...	24	23	41	2	90
Mathematics	...	3	8	35	...	46
Physics	...	6	16	25	1	48
Engineering Mechanics	...	2	2	6	...	10
Mechanical and Industrial	...	10	25	63	...	98
Metallurgical	...	6	12	36	1	55
Industrial	...	31	17	11	2	61
Unclassified, first year	356	...	...	...	8	364
Grand Total	356	350	362	759	37	1,864
Counted Twice	...	5	4	43	...	52
Net Total in Engineering	356	345	358	716	37	1,812

Undergraduates, College of Engineering	1,812
Students in engineering enrolled in Summer Session only	187
Students in engineering enrolled in Graduate School	572
Students enrolled in engineering extension courses*	136

* Extension students have been grouped according to schools and colleges from which instructors offering courses have been drawn. This does not indicate enrollment of the Extension Service students in the schools and colleges.

REGISTRATION SCHEDULES, 1953-1954

FIRST SEMESTER

Each of the following groups is allotted a definite period for admission to the gymnasiums for registration. Deviation from this alphabetical schedule is not permitted.

WEDNESDAY, SEPTEMBER 16, 1953

8:00– 8:40	Roa to Roz
8:40– 9:00	Ru to Sca
9:00– 9:20	Sch to Se
9:20– 9:40	Sh to Sl
9:40–10:00	Sm to Sp
10:00–10:20	St to Sv
10:20–10:40	Sw to To
10:40–11:00	Tr to Vi
11:00–11:20	Vl to Weh
1:00–1:25	Wei to Wik
1:25–1:50	Wil to Woo
1:50–2:15	Wop to Z
2:15–2:40	A to Ao
2:40–3:05	Ap to Ban
3:05–3:30	Bao to Bel

THURSDAY, SEPTEMBER 17, 1953

8:00– 8:20	Bem to Boe
8:20– 8:40	Bof to Bre
8:40– 9:00	Bri to Bz
9:00– 9:20	C to Cha
9:20– 9:40	Che to Col
9:40–10:00	Com to Cr
10:00–10:20	Cu to Dem
10:20–10:40	Den to Dr
10:40–11:00	Du to Er
11:00–11:20	Es to Fis
1:00–1:25	Fit to Fr
1:25–1:50	Fu to Gim
1:50–2:15	Gin to Gra
2:15–2:40	Gre to Hal
2:40–3:05	Ham to Haz
3:05–3:30	He to Hof

FRIDAY, SEPTEMBER 18, 1953

8:00– 8:20	Hog to Hz
8:20– 8:40	I to Jok
8:40– 9:00	Jol to Ken
9:00– 9:20	Keo to Kol
9:20– 9:40	Kom to Laq
9:40–10:00	Lar to Le
10:00–10:20	Li to Lz
10:20–10:40	Mc to Mac
10:40–11:00	M to Mav
11:00–11:20	Maw to Mil
1:00–1:25	Mim to Muo
1:25–1:50	Mup to Nz
1:50–2:15	O to Paq
2:15–2:40	Par to Pl
2:40–3:05	Po to Ran
3:05–3:30	Rao to Ri

SATURDAY, SEPTEMBER 19, 1953

Any student may register from 8:00 to 10:30 A.M. Saturday registration is inadvisable as many sections will be closed making classification impossible.

SECOND SEMESTER

Each of the following groups is allotted a definite period for admission to the gymnasiums for registration. Deviation from this alphabetical schedule is not permitted.

WEDNESDAY, FEBRUARY 3, 1954

8:00– 8:40	Sw to To	1:00–1:25	Bem to Boe
8:40– 9:00	Tr to Vi	1:25–1:50	Bof to Bre
9:00– 9:20	Vl to Weh	1:50–2:15	Bri to Bz
9:20– 9:40	Wei to Wik	2:15–2:40	C to Cha
9:40–10:00	Wil to Woo	2:40–3:05	Che to Col
10:00–10:20	Wop to Z	3:05–3:30	Com to Cr
10:20–10:40	A to Ao		
10:40–11:00	Ap to Ban		
11:00–11:20	Bao to Bel		

THURSDAY, FEBRUARY 4, 1954

8:00– 8:20	Cu to Dem	1:00–1:25	Hog to Hz
8:20– 8:40	Den to Dr	1:25–1:50	I to Jok
8:40– 9:00	Du to Er	1:50–2:15	Jol to Ken
9:00– 9:20	Es to Fis	2:15–2:40	Keo to Kol
9:20– 9:40	Fit to Fr	2:40–3:05	Kom to Laq
9:40–10:00	Fu to Gim	3:05–3:30	Lar to Le
10:00–10:20	Gin to Gra		
10:20–10:40	Gre to Hal		
10:40–11:00	Ham to Haz		
11:00–11:20	He to Hof		

FRIDAY, FEBRUARY 5, 1954

8:00– 8:20	Li to Lz	1:00–1:25	Roa to Roz
8:20– 8:40	Mc to Mac	1:25–1:50	Ru to Sce
8:40– 9:00	M to Mav	1:50–2:15	Sch to Se
9:00– 9:20	Maw to Mil	2:15–2:40	Sh to Sl
9:20– 9:40	Mim to Muo	2:40–3:05	Sm to Sp
9:40–10:00	Mup to Nz	3:05–3:30	St to Sv
10:00–10:30	O to Paq		
10:20–10:40	Par to Pl		
10:40–11:00	Po to Ran		
11:00–11:20	Rao to Ri		

SATURDAY, FEBRUARY 6, 1954

Any student may register from 8:00 to 10:30 A.M. Saturday registration is inadvisable as many sections will be closed making classification impossible.

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UNIVERSITY OF MICHIGAN OFFICIAL PUBLICATION

The University of Michigan Official Publication is the title given to the series of administrative bulletins published by the University. This series includes the following:

BULLETINS FOR PROSPECTIVE STUDENTS

The prospective student should have, in addition to a copy of the bulletin of General Information, a copy of one or more of the announcements or bulletins listed under this head. These will be sent, without charge, on request to the University of Michigan.

General Information

Announcements:

Architecture and Design, College of
Business Administration, School of
Dentistry, School of
Education, School of
Engineering, College of
Graduate Dentistry, W. K. Kellogg Foundation Institute
Graduate Studies, Horace H. Rackham School of
Law School
Literature, Science, and the Arts, College of
Medical School
Music, School of
Natural Resources, School of
Nursing, School of
Pharmacy, College of
Postgraduate Dentistry, W. K. Kellogg Institute
Public Administration, Institute of
Public Health, School of
Social Work, School of
Summer Session

Bulletins describing the work of various departments and curriculums.

OTHER BULLETINS

The President's Report
Reports and communications of University officers

For general information concerning the University, address University of Michigan, Ann Arbor, Michigan.