Announcement

College of Engineering

1958/1959

University of Michigan

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Published by the University Ann Arbor

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Summer session ends..............................August 16, Saturday

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Orientation period.................September 15–20, Monday–Saturday
*Registration ....September 17–20, Wednesday–Saturday
First semester classes begin.....................September 22, Monday
Thanksgiving recess begins..........November 26, Wednesday (evening)
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Classes resume ....January 5, Monday (morning)
Classes end ....January 17, Saturday (evening)
Study period......................................January 18, Sunday
Examination period ....January 19–29, Monday–Thursday
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Orientation period ....February 2–7, Monday–Saturday
*Registration ....February 4–7, Wednesday–Saturday
Second semester classes begin.....................February 9, Monday
Spring recess begins.........................March 28, Saturday (noon)
Classes resume ....April 6, Monday (morning)
Classes end ....May 27, Wednesday
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Commencement ....June 13, Saturday

SUMMER SESSION, 1959

Registration ....June 18–20, Thursday–Saturday
Summer session classes begin..........................June 22, Monday
Independence Day, a holiday..........................July 4, Saturday
Summer session ends...........................August 15, Saturday

This calendar is subject to revision.

*For registration schedules, see pages 162 to 163.

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*
STEPHEN STANLEY ATTWOOD, M.S., *Acting Dean of the College of Engineering*
WALTER JOHNSON EMMONS, B.S., A.M., *Associate Dean and Secretary of the College of 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 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.

The programs offered by the College of Engineering cover a wide spectrum, from "science engineering" for those interested in the scientific side of engineering as evident in research and development to "industrial engineering" for those planning careers in manufacturing. The final decision as to the particular program desired need not be made until the end of the second year.

* 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.

FACILITIES

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

The **West Engineering Building** (1904) contains the offices of the College; 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 with 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; process operations laboratory; catalytic pilot plants; the petroleum, gas, electrochemical, high pressure, paper, paint and varnish, plastics, and measurements laboratories of chemical engineering; and the highway and soil mechanics laboratory. The **East Engineering Addition** (1947) contains two subsonic wind tunnels, supersonic jet, structures, propulsion, and instrumentation laboratories of aeronautical engineering; the electrical machinery, communications, photometry electronics, servomechanisms, and other laboratories of electrical engineering; and the meteorological laboratory.

The **Automotive Laboratory** (1956) on the North Campus, generously equipped by the industry of the state, provides modern test cells for instruction and research on automotive and aircraft engines and gas turbines; a vehicle laboratory for work on chassis, body, and suspension, as well as the complete vehicle; also shops and the various special instruments and laboratories associated with the important work in the automotive field.

The **North Campus** includes also the Mortimer E. Cooley Building, which now serves the Engineering Research Institute and the Industrial Program of the Engineering College as well as providing conference rooms for other activities; the Fluids Engineering Laboratory, which serves all departments concerned with fluid flow; the Phoenix Memorial Laboratory and accompanying Ford Nuclear Reactor, which provide facilities for research in the field of atomic energy and support the program in nuclear engineering; and special supersonic and low turbulence wind tunnels.

Buildings at the **Willow Run Airport** contain the Lake Hydraulic 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, and a propulsion laboratory equipped with stands for testing various types of jet and rocket motors and with auxiliary equipment.

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 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 for the location of the present camp. 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.

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 the 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."

COMBINED PROGRAMS WITH OTHER INSTITUTIONS

The College of Engineering has agreements with Albion College, Alma College, Calvin College, Central Michigan College, Emmanuel Missionary College, Kalamazoo College, Eastern Michigan College, and Western Michigan College 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, with the exception of Calvin College, 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 the end of this fourth year. Calvin College grants its degree upon completion of the requirements for the degree in engineering at the University.

Similar programs sometimes can be arranged with the College of Literature, Science, and the Arts of the University and such combined programs are regularly scheduled in the fields of chemical engineering and civil engineering. Each of the 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 stated on pages 27 and 31.

Students may be admitted with advanced standing from junior colleges or other institutions (see pages 14–17).

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.

Most of the leading companies which employ engineers visit the College at least annually for the purpose of recruiting students for their training programs and operations. 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.

Students make all appointments for placement interviews at the Engineering Placement Office, 347 West Engineering Building. Likewise, any resident student who desires employment, either permanent, temporary, or part time may register at this same office.

In order to assist students with placement and with the transition to professional and industrial work, the Engineering Placement Office conducts meetings on such subjects as techniques for obtaining employment, opportunities for engineering graduates, and professional problems during the first semester of the academic year. See page 156.

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 communicate with the Engineering Placement Office or with members of the faculty whenever they feel that the College can be of assistance in helping them to find more suitable positions.

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.

Alpha Pi Mu, national industrial engineering honor society
American institute of chemical engineers, student chapter
American institute of electrical engineers, student chapter
American institute of metallurgical engineers, student chapter
American military engineers (University of Michigan Post)
American nuclear society, student branch
American society of civil engineers, student branch
American society of mechanical engineers, student branch
Chi epsilon, national civil engineering honor fraternity
Engineering student council
Eta kappa nu, national electrical engineering honor society
Institute of radio engineers, student branch
Institute of the aeronautical sciences, student branch
Mechanical engineering society
Michigan Technic, a monthly magazine containing articles on technical subjects and other matters of interest to the College, staffed by engineering students
Phi eta sigma, national honor society for freshman men
Phi kappa phi, national honor society for seniors of all schools and colleges
Pi tau sigma, national mechanical engineering honor fraternity

QUARTERDECK SOCIETY, student branch of Society of Naval Architects and Marine Engineers.
SAILING CLUB, an organization for dinghy sailing, iceboating, intercollegiate competition
SCABBARD AND BLADE, national ROTC honor fraternity
SIGMA XI, a national society devoted to the encouragement of research
SOCIETY FOR THE ADVANCEMENT OF MANAGEMENT, student branch
SOCIETY OF AUTOMOTIVE ENGINEERS, student branch
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 GRANTS AND LOANS

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 bulletin, *University Scholarships, Fellowships, and Prizes,* which is available upon request. For information regarding student loans, write to the Office of Student Affairs, 2011 Student Activities Building.

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

Student loans are under the jurisdiction of the Office of Student Affairs, to whom application for them should be made.

Qualified 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 $125
Non-Michigan students $300

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 bank drafts 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 bank drafts. 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 *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 Associate 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.

Indebtedness to the University. Students shall pay all accounts due the University not later than the last day of classes of each semester or summer session. Student loans which fall due during any semester or summer session and which are not paid or renewed are subject to this regulation; however, student loans not yet due are exempt. Any unpaid accounts at the close of business on the last day of classes will be reported to the Cashier of the University and until such accounts are paid:

a) All academic credit will be withheld, the grades for the semester or summer session just completed will not be released, and no transcripts of credit will be issued.

b) No student owing such accounts will be allowed to register in any subsequent semester or summer session until payment has been made.

Admission

Applicants for admission should be at least sixteen years of age. They must present satisfactory evidence of good moral character. Freshmen must present an application for admission directly to the Director of Admissions. 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 Associate Dean, College of Engineering. University Health Service approval is required in all cases. See page 154.

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. These 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. 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, four units of mathematics, including one-half unit of trigonometry, and one unit of chemistry should be presented whenever feasible since, with excellent preparation, some acceleration is possible at the University, 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. When conditions warrant such action, provisional admission may be granted if not more than two units are lacking.

ADMISSION BY CERTIFICATE

Only those applicants are admitted by certificate who are officially recommended graduates of accredited high schools and who have completed in an accredited 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 beginning of the senior year, upon the blank furnished by the University, the application of each prospective graduate intending to enter the freshman class at the beginning of the ensuing year. If the applicant's credentials are satisfactory, he will receive admission to the University without examination, contingent only upon his satisfactory completion of the secondary school program.

ADMISSION BY CERTIFICATE AND EXAMINATION

Michigan applicants whose high school backgrounds are somewhat below the usual standards may be asked to take examinations, if the Committee on Admissions feels they can be given further consideration for admission. Such applicants may be invited to the campus for tests and an interview after the initial review of their applications for admission. Freshmen are not admitted to the University on the basis of test results in lieu of satisfactory high school records. All out-of-state students are required to submit scores on the College Board Scholastic Aptitude Test.

ADVANCED STANDING

A student in another college or university who intends to transfer to the College of Engineering should examine carefully the program which he plans to elect and arrange his work accordingly. The applicant must present to the Associate Dean evidence of honorable dismissal from an approved college, together with an official transcript of his college work and preparatory studies. The transcript must list the subjects studied, the grade earned in each subject, and the basis upon which grades are assigned. A scholastic average corresponding to at least a C grade in this College is required, and, for admission without deficiencies, he must satisfy the requirements for admission from high school as stated on page 13.

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

FOREIGN STUDENTS

The University does not admit foreign students whose native language is other than English directly from their secondary schools into the first year or freshman class. It is recommended that they remain at a home university, preferably for two years, to obtain their basic subjects before applying to the University as transfer students. In some cases, foreign students enter smaller liberal arts colleges in the United States as freshmen before transferring to the University. This enables them to earn credit in such subjects as mathematics, chemistry, physics, drawing, etc., to become accustomed to the educational system of this country and, also, to improve their proficiency in English.

Those foreign students who feel that they meet the admission requirements as stated under "Advanced Standing" are welcome to file applications. They are advised to submit them, together with complete detailed scholastic transcripts, as early as possible. Considerable time is required for a review of each case. If the candidate is found to be eligible, the English test abroad, as outlined below, remains to be arranged and the results reported to the Admissions Officer before the formal certificate of admission is issued.

All students, of whatever nationality, attend the same classes and must maintain the same scholastic standards. Thus, foreign students must possess or acquire a degree of proficiency in English sufficient to enable them to carry on their studies without serious handicap.

They should know in advance of their arrival whether or not their control of English is adequate. Therefore, in order that students and the University may plan intelligently, the University requires all foreign students whose native language is not Englisn to take an English proficiency examination during the process of admission. These tests are prepared and regularly administered abroad by the English Language Institute. Information concerning the place and time for the test will be sent to the candidate by the English Language Institute upon request. The charge for the examination is $5.00.

A second English proficiency examination, parallel to the first, will be required of all foreign students whose native language is not English, after their arrival in Ann Arbor. The English Language Institute administers this examination also. There is no charge for this second examination.

Students who arrive and whose English is not considered adequate may be required to take an intensive course in English at the English Language Institute before beginning credit studies, thus delaying attainment of the desired objective.

In his first semester every foreign student is considered to be on trial. It is generally desirable that he elect a rather light schedule of studies in the first semester, since he is living in an unfamiliar environment and is studying under an educational system which is new to him. At the end of the semester, credit will be given if he passes his work. If, in spite of conscientious effort, he fails in his studies and his failure is due primarily, in the judgment of his instructors and adviser, to his lack of proficiency in the English language, his record will be disregarded and he will be required to elect additional remedial study of English as may be deemed necessary.

ADJUSTMENT OF ADVANCED CREDIT

During the period of registration preceding each session, records of studies taken elsewhere are reviewed by representatives of the several teaching departments of the College, or by the Associate Dean in the case 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.

Students desiring excuse from courses in drawing may be required to submit for examination all drawings completed previous to entrance.

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 not granted. When experience in industry closely parallels the content of a required course, however, the student may be excused from taking such course.

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 appropriate program adviser, 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 page 13.

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 Associate Dean for advice.

Studies of the First Year

Students entering without deficiencies have the choice of two schedules of studies for the first year as stated below. Schedule S is required for those who plan to continue with science engineering and may also be elected, up to the capacity of the classes, by those who plan to enter any one of the other degree programs. Schedule T is the traditional pattern which has been followed for many years and may be selected by all students except those in science engineering. In Schedule S, calculus, physics, and mechanics are introduced in the first year. These subjects are deferred to the sophomore year for those who begin with Schedule T. Whichever schedule is selected by the student, it is expected that he will follow that schedule in mathematics and science for four semesters.

After one year a student is expected to choose the degree program in which he plans to graduate. 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. Programs leading to the several degrees and typical semester schedules will be found in the following section. The normal schedules for the first year are as follows:

FIRST SEMESTER	HOURS		SECOND SEMESTER	HOURS	
Schedule	*T*	*S*	*Schedule*	*T*	*S*
Math. 13 (or 17)	4	–	Math. 14 (or 18)	4	–
Math. 33	–	4	Math. 34	–	4
English 11	3	3	English 12	2	2
English 21	1	1	English, Group II	2	–
Drawing 1 or 11	3	–	Drawing 2 or 12	3	–
Drawing 21	–	3	Drawing 22	–	3
Chem. 5E (or 1 or 3), or Chem.-Met. Eng. 1 and Mech. Eng. 2	5 or 4	–	Chem.-Met. Eng. 1 and Mech. Eng. 2, or Chem. 5E (or 4 or 6)	5 or 4	–
Physics 53	–	4	Chemistry 14	–	4
Assembly	0	0	Eng. Mech. 11	–	3
Phys. Ed.*	0	0	Phys. Ed.*	0	0
	16 or 15	15		16 or 15	16
Air Sci.*	2		Air Sci.*	2	
Mil. Sci.*	2		Mil. Sci.*	2	
Nav. Sci.*	3		Nav. Sci.*	3	

Modifications in the first-year schedules are necessary for those who enter with deficiencies in preparation. Changes are also made as seem desirable in accordance with the ability of the individual student. These schedules assume that at least 1½ units of algebra, solid geometry, and trigonometry have been taken in the high school.

The scholastic requirements for graduation are expressed in terms of the quality and level of attainment reached by the student and not in terms

* Those who choose to enroll in one of the three ROTC programs are excused from taking physical education.

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 12 and 21, Drawing 2 or 22, Mathematics 54 or 56, Chemistry 5E or 15, Physics 46 or 54, Chemical and Metallurgical Engineering 1, and Mechanical Engineering 2. 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 tabulation on page 20 indicates the required courses at the University for those entering with various degrees of preparation and ability in mathematics and chemistry. Proficiency tests are given during the orientation period which precedes registration.

As indicated, it is clearly to the advantage of the high school student to elect 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 or materials engineering may facilitate their progress by electing Chemistry 5E, five hours, in the first semester and Chemistry 20, three 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 3 and 8 during the first year for a total of nine 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 enrolled in air, military, or naval science.

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.

* See statement concerning Reserve Officers' Training Corps, pages 54–55.

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				Mathematics Courses to Be Elected (See course descriptions pages 119–21)	
Group	Alg.	Geom.	Trig.	Courses	Hours
1	1	1	0	Math. 6, 7, — 13, 14, 53, 54	22
2	1	1½	0	Math. — 7, — 13, 14, 53, 54	20
3	2	1	0	Math. 6, — 8, 13, 14, 53, 54	20
4	1½	1½	0	Math. — — 8, 13, 14, 53, 54, or — — 8, 33, 34, 55, 56	18
5	2	1½	0	Math. — — 8, 13, 14, 53, 54, or — — 8, 33, 34, 55, 56	18
6	2	1	½	Math. 6, — — 13, 14, 53, 54, or 6, — — 33, 34, 55, 56	18
7	1½	1½	½	Math. — — — 13, 14, 53, 54, or — — — 33, 34, 55, 56	16
8	2	1½	½	Math. — — — 13, 14, 53, 54, or — — — 33, 34, 55, 56	16

Students who do not present credits listed in Group 7 of the above tabulation are advised to take, if possible, the lacking school algebra, solid geometry, or trigonometry during the summer preceding the first semester of the freshman year.

Students of superior ability, prepared as indicated above, may make more rapid progress by electing courses as follows:

Groups 4 and 5: Math. 8 and 13 or 33 in the first semester.

Group 8: Math. 17, 18, 54 in place of Math. 13, 14, 53, 54, a saving of four credit hours in Schedule T.

Chemistry 5E, in place of two four-hour courses, a saving of three credit hours in Schedule T.

Undergraduate Degree Programs

All degree programs of the College of Engineering which are normally examined by the Engineers' Council for Professional Development are accredited by that body.

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.

Each degree program is composed of two groups of subjects. Group A includes subjects in certain basic areas common to all programs. These must be elected and passed or equivalent proficiencies must be demonstrated. Group B is composed chiefly of professional subjects and varies in the several degree programs. The Group A subjects with the credit normally assigned to them are as follows:

	HOURS	
Schedule	*T*	*S*
English 11, 12, 21	6	6
Math. 8, 13, 14, 53, 54	12–18	–
Math. 8, 33, 34, 55, 56	–	16–18
Chem. 5E, or two 4-hour courses	5 or 8	–
Chem. 14, 15	–	8
Draw. 1, 2, or 11, 12	6	–
Draw. 21, 22	–	6
Chem.-Met. Eng. 1 and Mech. Eng. 2	5	–
Eng. Mech. 11	–	3
Physics 45, 46	10	–
Physics 53, 54	–	8
	44–53	47–49

The degree of attainment in the several subjects of Group A will be determined from a consideration of a student's scholastic records supplemented, generally, by examinations given during the orientation period which precedes the opening of each semester.

Students admitted without deficiency, with normal high school preparation, may expect to graduate with 140 credit hours. Those of high ability and with preparation beyond that required for admission may materially expedite their progress toward the degree.

Courses taken at other recognized colleges or universities, if passed with at least a C grade, will be accepted for appropriate credit.

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.

Co-operative Programs with Industry. In certain fields a desirable combination of theory and practice is available through the medium of co-operative courses with industry. To be eligible for acceptance in a co-operative program a student must have completed a substantial part of his program, at least one year in residence, with good grades. He must be acceptable to the company with which he plans to work. He will devote alternate semesters to study at the University and in the employ of the company. He will receive regular compensation for his work and will be subject to the regulations of the company by which he is employed. When accepted in a co-operative program, he is expected to continue in it until he graduates or leaves the University.

Co-operative programs, arranged by several companies and public organizations, have been approved. Also, the College is willing to consider the proposals of students who find it possible to arrange for alternate semesters of study and work with any organization offering opportunities for experience which will contribute to their educational progress.

Credit is not granted for work experience, but obviously such experience is desirable in many ways and, when approved and adopted by the College, constitutes a part of a student's degree program and is entered upon his records.

AERONAUTICAL ENGINEERING

Program Adviser: Professor Schetzer, 1511 East Engineering

The design of modern aircraft involves problems in many branches of engineering and the sciences. The program in aeronautical engineering, therefore, has been arranged to provide the student with a broad and fundamental background. It includes a study of subsonic and supersonic aerodynamics with applications to the design of wings and bodies. A sequence of courses in propulsion treats the theory and design of power plants, with special emphasis on the turboprop, turbojet, ramjet, and rocket motors. The stress analysis and design of elastic bodies is offered in a series of aircraft structures courses. Studies in the field of instrumentation include principles of measurement, data transmission, automatic control, and systems of analysis.

In the senior year, the engineering sciences described above are brought together in a sequence of courses that present the mechanics of flight. The performance and design of all types of aircraft are treated from the dynamics point of view.

All theoretical work is co-ordinated with laboratory periods in which the student acquires a working familiarity with modern experimental equipment.

Electives are provided with which the student may emphasize aerodynamics, propulsion, structures and design, aeroelasticity, or instrumentation.

Students are encouraged to take employment in the aeronautical or allied industries during the summer periods.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Econ. 53, 54*	6
Math. 103 or Math. 104, Differential Equations	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials I	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 123, Strength and Elasticity of Materials II	3
Mech. Eng. 105, Thermodynamics I	3
Elec. Eng. 5, Direct and Alternating Current Apparatus and Circuits	4
Aero. Eng. 1, General Aeronautics	1
Aero. Eng. 101, Airplane Design	3
Aero. Eng. 110, Aerodynamics I	4
Aero. Eng. 114, Aerodynamics II	4
Aero. Eng. 130, Aircraft Structures I	4
Aero. Eng. 131, Aircraft Structures II	3
Aero. Eng. 141, Mechanics of Flight I	3
Aero. Eng. 142, Mechanics of Flight II	3
Aero. Eng. 143, Aircraft Control Systems	3
Aero. Eng. 163, Aircraft Propulsion I	3
Aero. Eng. 164, Aircraft Propulsion II	3
Nontechnical electives	9
Group options and electives†	10
Total, professional subjects and electives	87

* Econ. 153 and 173, or Econ. 153 and three hours additional of nontechnical electives also will satisfy this requirement.

† A maximum of 4 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

SUGGESTED SCHEDULE

For common first-year schedule see page 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Physics 46	5
Aero. Eng. 1	1	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Elective	3	Elective	3
	16		17

SUMMER SESSION	
Elective	3
Elec. Eng. 5	4
	7

FIFTH SEMESTER		SIXTH SEMESTER	
Math. 103 or 104	3	Aero. Eng. 130	3
Aero. Eng. 110	4	Aero. Eng. 114	4
Eng. Mech. 3	3	Econ. 54	3
Mech. Eng. 105	3	Aero. Eng. 163	3
Econ. 53	3	Eng. Mech. 123	3
	16		16

SEVENTH SEMESTER		EIGHTH SEMESTER	
Aero. Eng. 131	4	Aero. Eng. 143	3
Aero. Eng. 164	3	Aero. Eng. 101	3
Aero. Eng. 141	3	Electives	7
Aero. Eng. 142	3	Engl., Group III	2
Elective	3		15
	16		

CHEMICAL ENGINEERING

Program Adviser: Professor Williams, 3213 East Engineering

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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Economics 153, 173	6
Eng. Mech. 5, Statics and Stresses	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Chemistry 20, 41, Introductory Analytical	7
Chemistry 61, 161R, Organic	8
Chemistry 182, 183, Physical	6
Chem.-Met. Eng. 2, Engineering Calculations	3
Chem.-Met. Eng. 16, Measurements Laboratory	3
Chem.-Met. Eng. 111, Thermodynamics	3
Chem.-Met. Eng. 113, Unit Operations	4
Chem.-Met. Eng. 115, Unit Operations Design	3
Chem.-Met. Eng. 117, Metals and Alloys	3
Chem.-Met. Eng. 118, Structure of Solids	3
Chem.-Met. Eng. 121, Design of Process Equipment	3
Chem.-Met. Eng. 129, Engineering Operations Laboratory	3
Chem.-Met. Eng. 130, Chemical Process Design, or equivalent	3
Nontechnical electives	6
Group options and electives*	8
Total, professional subjects and electives	87

After graduation, it is most likely that a practicing engineer will identify himself with a particular chemical industry. If this interest develops during a student's college career, he may profitably utilize some of his elective courses to prepare for such specialization. A total of 14 elective credit hours are available, at least 6 of which must be of the nontechnical variety. The program adviser will be pleased to direct students interested in a particular area of study to a member of the staff for further details. Some typical electives are:

* A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

Bio-engineering: *Bact. 109, 160; Chem.-Met. Eng. †238, †239
Combustion: Chem.-Met. Eng. 105, Aero-Eng. 260, Mech. Eng. 164, 165 or Aero.-Eng. 165
Electrochemistry: Chem.-Met. Eng. 268, Chem. 277
Electronic materials: Elec. Eng. 108, 112; Math. 57 or 103; Phys. 196, 173
Graduate preparation: Math. 150 and language preparation
Instrumentation: Math. 104, 148; Aero.-Eng. 171, 175
Materials: Chem.-Met. Eng. 122, 124, 125, 126, 136; Eng. Mech. 126
Nuclear: Nuc. Eng. 190, 191
Polymers: Chem.-Met. Eng. 125, †232; Phys. 179
Petroleum: *Geol. 98, 237; Chem.-Met. Eng. †235
Protective coatings: Chem.-Met. Eng. 135, 137, †266

SUGGESTED SCHEDULE‡

For common first-year schedule see page 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Chem.-Met. Eng. 2	3
xChem. 20	3	Physics 46	5
Elective	3	xChem. 41	4
	15		16

SUMMER SESSION	
Eng. Mech. 5	4
Chem. 182	3
	7

FIFTH SEMESTER		SIXTH SEMESTER	
xChem. 61	6	xChem. 161R	2
Chem.-Met. Eng. 16	3	Chem.-Met. Eng. 113	4
Chem.-Met. Eng. 111	3	Chem.-Met. Eng. 118	3
Chem. 183	3	Econ. 173	3
	15	Eng. Mech. 3	3
		Electives	3
			18

SEVENTH SEMESTER		EIGHTH SEMESTER	
Chem.-Met. Eng. 117	3	Chem.-Met. Eng. 129	3
Chem.-Met. Eng. 115	3	Chem.-Met. Eng. 121	3
Elec. Eng. 5	4	Chem.-Met. Eng. 130	3
Econ. 153	3	English, Group III	2
Electives	3	Electives	5
	16		16

* Acceptable as nontechnical electives.
† Courses which may be substituted for Chem.-Met. Eng. 130 in the chemical engineering program.
‡ 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. 20 during the first year will permit advancing the courses marked x by one semester.

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 as well, will find that they must add Chem-Met. Eng. 13, 119, and 124 and elect Chem.-Met. Eng. 127 and 128 rather than Chem.-Met. Eng. 117 for a total of thirteen hours for additional courses. Students in the metallurgical program who desire to earn a degree in chemical engineering as well must elect Chem. 41, Chem. 61 and 161R instead of 61R, Chem.-Met. Eng. 113 and 115 instead of Chem.-Met. Eng. 114, and Chem-Met. Eng. 130 in addition for a total of fourteen extra hours.

CHEMICAL ENGINEERING AND CHEMISTRY

Advisers: College of Literature, Science, and the Arts, Assistant Professor Taylor; 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 students and of industry 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 23, 24	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.		

	HOURS	HOURS
MATHEMATICS AND SCIENCE GROUP		61 (to 69)
Chemistry 3, 8, (or 3, 4, 20), 41 (4 or 5 hrs), 61, 141 (4 or 5 hrs), 161, 182, 183, 185, 186, 191........	39 (to 43)	
Physics 45, 46	10	
Math. 13, 14, 53, 54; or 17, 18, 54......................	16 (or 12)	
SOCIAL SCIENCES GROUP*		12
Econ. 53, 54, 173	9	
Electives	3	
ENGINEERING COURSES		53
Eng. Mech. 3, 5....................................	7	
Elec. Eng. 5..	4	
Drawing 1, 2..	6	
Chem.-Met. Eng. 1, 2, 111, 113, 115, 117, 118, 121, 129, 130, Mech. Eng. 2..............................	33	
Elective in engineering or mathematics................	3	
ELECTIVES		9
Not more than 44 hours of courses in the Department of Chemistry may be counted toward the degree.		
Total	153 to 161	

CIVIL ENGINEERING

Program Adviser: Professor Boyce, 304 West Engineering

Civil Engineering, originally named to distinguish it from military engineering, has always covered a wide field of engineering practice. 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 of the civil engineer's work requires that he not only have a broad basic foundation in the physical sciences, but also that he be alert to the economic and social significance of what he plans and builds. This aspect of his educational foundation has been a strong contributing factor in qualifying him for positions of leadership in both industry and government. In the junior and senior years the curriculum provides an opportunity for elective courses in one of the following areas which exemplify the more important fields of civil engineering:

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

Construction. The methods and techniques of modern construction; fundamental principles of construction applicable to all types of engineering structures; business and legal principles of contracting as applied in the field of construction.

Geodesy and Surveying. Theory and practical applications of surveying and surveying techniques; theoretical and applied geodesy, figure of the earth, local and extended control surveys; precise measurements and the adjustment of observations; design and execution of municipal surveys, topographic mapping projects, boundary surveys and land subdivision; industrial applications of surveying techniques; research in fields of instrumentation, computation, mapping and photogrammetry, and the problems of land surveying and route location.

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

Hydraulic. 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.

Meteorology. Courses in meteorology offered under the sponsorship of the Department of Civil Engineering are of general interest to, and may be elected by, qualified students from all branches of engineering and physical science.

Railroad. 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. The planning, construction, and operation of water works, 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; principles and standards of ventilation.

Soils. Soil mechanics: evaluation of soil properties and environmental conditions in foundations of earth-supported structures; mass stability in excavations and subsurface construction. Soil Engineering: use of soil characteristics and properties and soil classification in design and construction of highways, railways, airports, and other surface facilities.

Structural. 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.

Traffic. Methods of increasing the efficiency and safety of traffic movement; street and off-street parking; traffic surveys, geometrical design of urban and rural highways, traffic control devices, and other means of regulating and controlling the use of highways.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Civ. Eng. 1, 2, 3, Surveying	10
English, Group II and Group III	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials I	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. Eng. 13, Heat-Power Engineering	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. 52, Water Supply and Treatment	3
Civ. Eng. 53, Sewerage and Sewage Treatment	2
Civ. Eng. 65, Transportation Engineering	3
Civ. Eng. 121, Reinforced Concrete	3
Civ. Eng. 135, Engineering Properties of Soil	3
Civ. Eng. 140, Hydrology	3
Civ. Eng. 141, Hydraulics	2
Civ. Eng. 180, Specifications and Contracts	2
Geol. 98	4
Econ. 153, 173*	6
Nontechnical electives	2
Group options and electives†	9
Total, professional subjects and electives	87

The group option requirement will be satisfied by the completion of course work representing a sequence in some area of civil engineering activity and additional electives for a total of nine hours subject to the approval of the option adviser. As early as practicable the student should select that field 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. Groupings of courses which meet the group option requirement are available in the following areas:

1. Construction—Adviser: Associate Professor Alt
2. Geodesy and Surveying—Adviser: Professor Berry
3. Highway—Adviser: Assistant Professor Cortright
4. Hydraulic—Adviser: Professor Brater
5. Meteorology—Adviser: Professor Hewson

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

† A maximum of 4 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

6. Railroad—Adviser: Assistant Professor Heimbach
7. Sanitary—Adviser: Associate Professor Borchardt
8. Soils—Adviser: Professor Housel
9. Structures—Adviser: Professor Maugh
10. Traffic—Adviser: Professor Kohl

Other combinations can be formulated and approved by the program adviser in accordance with the special interest of the student.

SUGGESTED SCHEDULE

For common first-year schedule see page 18.

SUMMER SESSION (at Camp Davis)

	HOURS
Civ. Eng. 1	4
Geol. 98	4
	8

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

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

FIFTH SEMESTER	HOURS
Civ. Eng. 30	1
Civ. Eng. 140	3
Eng. Mech. 4	3
Civ. Eng. 22	3
Civ. Eng. 65	3
Civ. Eng. 20	2
	15

SIXTH SEMESTER	HOURS
Civ. Eng. 121	3
Civ. Eng. 23	3
Civ. Eng. 141	2
Civ. Eng. 52	3
Eng. Mech. 3	3
Elective	2
	16

SEVENTH SEMESTER	HOURS
Civ. Eng. 135	3
Elec. Eng. 5	4
Econ. 173 (53)	3
Civ. Eng. (53)	2
Electives	4
	16

EIGHTH SEMESTER	HOURS
Civ. Eng. 180	2
Mech. Eng. 13	4
Engl. Group III	2
Econ. 153 (54)	3
Electives	5
	16

COMBINED PROGRAM WITH COLLEGE OF LITERATURE, SCIENCE AND THE ARTS

Advisers: College of Literature, Science, and the Arts, Assistant Professor John A. Dorr; College of Engineering, Associate Professor Robert B. Harris

As one of the combined programs referred to on page 9, 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.

This program is designed to meet the desires of those who wish to have a broader background in the humanities and liberal arts than can be offered in the regular four-year civil engineering curriculum. Many civil engineers find a need for a humanistic and liberal arts background in their professional work, particularly as they relate their designs and constructions to the economic and social demands of society.

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 of 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 full requirements 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. The complete program is as follows:

	HOURS	HOURS
HUMANITIES GROUP		37
English 23, 24, 45	9	
Fine Arts 3	4	
Foreign language or Soc. Sci.*	16	
Speech 61	2	
Philosophy 31 or 34, 33	6	
MATHEMATICS AND SCIENCE GROUP		34 (to 39)
Math. 13, 14, 53, 54, or 17, 18, 54	16 (or 12)	
Chem. 3, 4, or 5E and Psych. 31	8 (or 9)	
Geology (at Camp Davis)	4	
Physics 45, 46	10	
SOCIAL SCIENCE GROUP		9
Economics 53, 54, 173	9	
ENGINEERING GROUP		82
Drawing 1, 2	6	
Chem.-Met. Eng. 1	3	
Eng. Mech. 1, 2, 2*a*, 3, 4	14	
Elec. Eng. 5	4	
Mech. Eng. 2, 13	6	

* The College of Literature, Science, and the Arts requires that during his fourth semester the student demonstrate by examination proficiency in a foreign language. If a student satisfies this requirement prior to the completion of 16 hours of language course work, he will take the remaining language in foreign language literature or the social sciences.

	HOURS	HOURS
Civil Eng. 1 (at Camp Davis), 2, 3, 20, 22, 23, 30, 52, 53, 65, 121, 135, 140, 141, 180, group options	49	
ELECTIVES IN COLLEGE OF L.S. & A.		5
Total		167–172

ELECTRICAL ENGINEERING

Program Adviser: Professor Holland, 2511 East Engineering.

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 streetcars, 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 program in electrical engineering emphasizes basic theory and provides the student with a broad and fundamental background. A student may achieve, however, by careful selection of elective courses, a measure of specialization even within the basic undergraduate program. Extensive specialization should be reserved for graduate study.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Math. 103 or 104, Differential Equations	3
English, Group II and Group III	4
Econ. 53, 54*, Principles of Economics	6

* Econ. 153 and 173 or Econ. 153 and three additional hours of nontechnical electives also will satisfy this requirement.

	HOURS
Eng. Mech. 5, Statics and Stresses	4
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. Eng. 13, Heat-Power Engineering	4
Mech. Eng. 83, Machine Design	3
Elec. Eng. 3, Circuits I	4
Elec. Eng. 4, DC Machinery	2
Elec. Eng. 10, Principles of Electricity & Magnetism	3
Elec. Eng. 100, Circuits II	4
Elec. Eng. 101, Networks and Lines	3
Elec. Eng. 110, Electromagnetic Fields and Waves	3
Elec. Eng. 120, Radio Communication I	4
Elec. Eng. 130, Electrical Measurements	3
Elec. Eng. 141, Economic Applications in Electrical Engineering	2
Elec. Eng. 150, AC Machinery	4
Elec. Eng. 160, Electrical Design	4
Elec. Eng. 180, Electron and Semiconductor Devices I	4
Nontechnical electives	6
Group options and electives†	11
Total, professional subjects and electives	87

SUGGESTED SCHEDULE

For common first-year schedule, see page 18.

THIRD SEMESTER	HOURS
Math. 53	4
Physics 45	5
Elec. Eng. 10	3
Electives	3
	15

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
Eng. Mech. 5	4
Math. 103 or 104	3
Econ. 53*	3
	16

SIXTH SEMESTER	
Elec. Eng. 141	2
Elec. Eng. 150	4
Elec. Eng. 180	4
Eng. Mech. 3	3
Econ. 54*	3
	16

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

* Econ. 153 and 173 or Econ. 153 and three additional hours of nontechnical electives also will satisfy this requirement.

† A maximum of 4 hours of advanced air, military, or naval science (300 or 400 series) may be used as electives in this group.

SEVENTH SEMESTER	HOURS
Elec. Eng. 101	3
Elec. Eng. 120	4
Eng. Mech. 4	3
Electives	7
	17

EIGHTH SEMESTER	HOURS
Elec. Eng. 110	3
Elec. Eng. 160	4
English, Group III	2
Mech. Eng. 83	3
Electives	4
	16

ENGINEERING MECHANICS

Program Adviser: Associate Professor S. K. Clark, 201 West Engineering.

The purpose of the program in engineering mechanics is to prepare men for theoretical and research work in engineering fields. Although most men trained in this field of engineering are engaged in technical work, many, like other engineers, find their way into supervision and management. Men with this training are sought by the research and development laboratories of the large utilities, automotive and aircraft industries, and the federal government. Representative problems given to these men include analysis of stresses due to static or dynamic loading, thermal changes, or drawing of metals; studies in photoelasticity; problems in instrumentation; analysis of fluid motion with applications to engineering problems; vibration analysis and elimination; problems in heat conduction; and the thermodynamics of 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.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Math. 103, Differential Equations	3
Math. 147, Modern Operational Mathematics	2
Math. 150, Advanced Mathematics for Engineers	4

	HOURS
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, or Eng. Mech. 103, Experimental Mechanics, or Aero. Eng. 172, Instrument Dynamics	3
Mech. Eng. 105, Thermodynamics	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials I	4
Eng. Mech. 2*a,* Strength of Materials Laboratory	1
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, Fluid Mechanics II	3
Eng. Mech., approved advanced courses	7
Economics 153	3
Nontechnical electives	5
Group options and electives*, see following paragraph	23
Total, professional subjects and electives	87

Every student is required to elect a complete group option of 12 to 14 hours from some other program in the College of Engineering in order that his theoretical training may be correlated with engineering practice in that field. Electives, 9 to 11 hours, selected in conference with the adviser, will complete this group of requirements.

Suggested group options are:

- Aerodynamics
- Aeromechanics
- Chemical Engineering
- Electrical Power
- Electronics
- Hydraulics
- Instrumentation
- Internal Combustion
- Metallurgy
- Naval Architecture
- Nuclear Engineering
- Structures

Details of these can be obtained from the program adviser and options in other areas can be arranged in conference with him.

INDUSTRIAL ENGINEERING

Program Adviser: Professor Allen, 231 West Engineering

The industrial engineer is primarily interested in the structure of business problems as an adviser to major management. His principal task is the establishment of an uninterrupted flow of production at the lowest cost. He may be called upon to devise entire plans for management control systems; and, through a consideration of cost, quality, and quantity elements, to evaluate existing systems against predetermined standards. When to take corrective action, and to what extent such action should be taken

* A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

as results vary from the standards established, must be determined by an analysis of the human, the economic, and the mechanical elements of the management control plan. He may be called upon to devise alternate plans as resources used in the business vary in their availability.

Operating elements in the planning and control functions of management are many. The industrial engineer may be asked to devise means which will ensure quality in the product; to evaluate wage rates and production standards; to establish economical methods for the layout of processes and the handling of material; to determine inventory policies; to develop adequate production control plans for loading the plant effectively; to devise adequate means of communication between management and the working force. These are examples of the elements with which the industrial engineer must be concerned in over-all systems design. Preparation for proficiency in this area involves familiarity with the basic sciences, with technical engineering, with business administration, and with the technique of industrial engineering.

REQUIREMENTS

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

	HOURS *Schedule T*	HOURS *S*
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED		
Total, normally (see page 21)	44–53	47–49
B. PROFESSIONAL SUBJECTS AND ELECTIVES		
Chem.-Met. Eng. 1 and Mech. Eng. 2, Engineering Materials	–	5
Drawing 33	2	–
English, Group II and Group III	4	4
Econ. 153*	3	3
Eng. Mech. 1, Statics	3	–
Eng. Mech. 2, Strength and Elasticity 1	4	–
Eng. Mech. 12, Strength of Materials	–	4
Eng. Mech. 3, Dynamics	3	–
Eng. Mech. 13, Dynamics	–	3
Chem.-Met. Eng. 107, Metals and Alloys	3	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4	4
Sci. Eng. 110, Thermodynamics	–	3
Mech. Eng. 13, Heat-Power Engineering	4	–
Mech. Eng. 14, Heat-Power Laboratory	1	1
Mech. Eng. 32, Manufacturing Processes	3	3
Mech. Eng. 83, Machine Design	3	3
Mech. Eng. 86, Machine Design II	3	3
Mech. Eng. 132, Manufacturing Engineering	3	3
Ind. Eng. 100, Industrial Management	3	3
Ind. Eng. 110, Plant Layout and Materials Handling	3	3

* Econ. 53 and 54 may be substituted for Econ. 153 and three hours technical elective.

	HOURS Schedule T	HOURS S
Ind. Eng. 120, Motion and Time Study	3	3
Ind. Eng. 130, Wage Incentives and Job Evaluation	2	2
Ind. Eng. 140, Production Control	2	2
Ind. Eng. 150, Engineering Economy	2	2
Ind. Eng. 160, Operations Research	3	3
Bus. Ad. 11, 14,* Cost Accounting	6	6
Bus. Ad. 142, Personnel Administration	3	3
Math. 161, 162, Statistical Methods for Engineers	6	6
Nontechnical electives	5	5
Group options and electives†	6	6
Total, professional subjects and electives	87	86

SUGGESTED SCHEDULES

For common first-year schedule, see page 18.

THIRD SEMESTER	HOURS Schedule T	S
Math. 53	4	–
Math. 55	–	4
Physics 45	5	–
Chem. 15	–	4
Draw. 33	2	–
Eng. Mech. 1	3	–
Eng. Mech. 12	–	4
Eng. Mech. 13	–	3
English, Group II	2	–
	16	15

FOURTH SEMESTER	HOURS Schedule T	S
Math. 54	4	–
Math. 56	–	4
Physics 46	5	–
Physics 54	–	4
Eng. Mech. 2	4	–
Chem.-Met. Eng. 1	–	3
Mech. Eng. 2	–	2
Mech. Eng. 13	4	–
Sci. Eng. 110	–	3
	17	16

SUMMER SESSION	T	S
English, Group II	–	2
Eng. Mech. 3	3	–
Elec. Eng. 5	4	4
	7	6

FIFTH SEMESTER	T	S
Mech. Eng. 14	1	1
Math. 161	3	3
Chem.-Met. Eng. 107	3	3
Mech. Eng. 83	3	3
Ind. Eng. 100	3	3
Bus. Ad. 11	3	3
	16	16

SIXTH SEMESTER	T	S
Mech. Eng. 86	3	3
Mech. Eng. 32	3	3
Math. 162	3	3
Ind. Eng. 120	3	3
Bus. Ad. 14	3	3
Elective	2	2
	17	17

* Bus. Ad. 12 and 111 may be substituted for Bus. Ad. 14 and three hours of technical elective.
† Advanced courses in air, military, or naval science (300 and 400 series) may be used for these electives.

SEVENTH SEMESTER	HOURS	
English, Group III	2	2
Econ. 153	3	3
Mech. Eng. 132	3	3
Ind. Eng. 110	3	3
Ind. Eng. 130	2	2
Electives	3	3
	16	16

EIGHTH SEMESTER	HOURS	
Ind. Eng. 150	2	2
Ind. Eng. 160	3	3
Ind. Eng. 140	2	2
Bus. Ad. 142	3	3
Electives	6	6
	16	16

MATERIALS ENGINEERING

Program Adviser: Associate Professor Van Vlack, 4215 East Engineering.

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 one of the following programs:

	HOURS Schedule T	HOURS S
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED		
Total, normally (see page 21)	44–53	47–49
B. PROFESSIONAL SUBJECTS AND ELECTIVES		
Math. 103, Differential Equations	**3**	**–**

	HOURS Schedule *T*	HOURS *S*
Math. 150, Adv. Math. for Engineers, or Math. 161, Statistical Methods I	–	4 or 3
Eng. Mech. 1, 2, 3, Statics Strength and Elasticity, Dynamics, or Eng. Mech. 5, 3, 126, Statics and Stresses, Dynamics, and Stress Analysis	10 and 9	–
Eng. Mech. 12, 13, Strength of Materials, Dynamics	–	7
Eng. Mech. 4, Fluid Mechanics I, or equivalent	3	3
Chem. 20, Qualitative, or Chem. 23, Analytical	3 or 4	3 or 4
Chem. 61, Organic	6	6
Chem. 182, 183, Physical	6	6
Sci. Eng. 110, or Chem.-Met. Eng. 111, or equivalent, Thermodynamics	3	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits*	4	4
Chem.-Met. Eng. 16, or Chem.-Met. Eng. 124, or Elec. Eng. 136, Laboratory Measurements	3	3
Chem.-Met. Eng. 118, Structure of Solids, or equivalent	3	3
Chem.-Met. Eng. 122, Ceramic Materials	4	4
Chem.-Met. Eng. 125, Introduction to High Polymers	4	4
Chem.-Met. Eng. 127, 128, Physical Metallurgy	7	7
Electives in English, Anthropology, Classical Studies, Economics, Geography, Fine Arts, History, Journalism, Music, Languages, Political Science, Psychology, Sociology, Speech. One course in English and others in at least two of the departments named	16	16
Group Options	9	9
Electives†	4 or 2	5–3
Total, professional subjects and electives	87	86

In satisfying the group option requirement, courses are to be elected within one engineering area with the advance approval of the program adviser.

SUGGESTED SCHEDULES‡

For common first-year schedule, see page 18.

THIRD SEMESTER	HOURS Schedule *T*	*S*
Math. 53	4	–
Math. 55	–	4
Phys. 45	5	–
Chem. 15	–	4
Eng. Mech. 1	3	–
Eng. Mech. 12	–	4
Elective	3	3
	15	15

FOURTH SEMESTER	HOURS Schedule *T*	*S*
Math. 54	4	–
Math. 56	–	4
Phys. 46	5	–
Phys. 54	–	4
xChem. 20	3	3
Eng. Mech. 2	4	–
Eng. Mech. 13	–	3
Elective	–	3
	16	17

* If group options are chosen in the electrical area, Elec. Eng. 10 (4) or Elec. Eng. 11 (4) should be elected in place of Elec. Eng. 5 (4).

† Advanced courses in air, military, or naval science (300 and 400 series) may be used for these electives.

‡ 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. 5E and 20 during the first year will permit advancing the courses marked x by one semester.

SUMMER SESSION	HOURS	
Elec. Eng. 5	4	4
Elective	4	4
	8	8

FIFTH SEMESTER		
Math. 103	3	–
Math. 161	–	3
xSci. Eng. 110	3	3
xChem. 61	6	6
xChem. 182	3	3
Eng. Mech. 3	3	–
	18	15

SIXTH SEMESTER	HOURS	
Chem.-Met. Eng. 118	3	3
Chem. 183	3	3
Chem.-Met. Eng. 16	3	3
Eng. Mech. 4	3	3
Options	3	3
	15	15

SEVENTH SEMESTER		
Chem.-Met. Eng. 125	4	4
Chem.-Met. Eng. 127	4	4
Electives and options	9	7
	17	15

EIGHTH SEMESTER		
Chem.-Met. Eng. 122	4	4
Chem.-Met. Eng. 128	3	3
Electives and options	9	10
	16	17

MATHEMATICS

Program Adviser: Professor Bartels, 274A West Engineering.

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, page 161.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Eng. Mech. 1, Statics	3

	HOURS
Eng. Mech. 2, Strength and Elasticity of Materials I	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D. C. and A. C. Apparatus and Circuits	4
Eng. Mech. 142, or Chem.-Met. Eng. 111, or Mech. Eng. 105, Thermodynamics	2 or 3
Electives in mathematics	12
Electives in engineering analysis and design	15
Electives in science, engineering science	15
Nontechnical electives	6
Electives*	19 or 18
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

Program Adviser: Professor Evaldson, 230A West Engineering.

The mechanical engineer is concerned with the generation and use of power, the design and development of a wide variety of products and machinery, and the methods and operations of manufacture. As such, he engages in the design and manufacture of automobiles and other transportation means; internal combustion engines and gas and steam turbines; fluids machinery; production and materials handling machinery and equipment; heating, ventilating, air-conditioning and refrigeration equipment; consumer goods such as home appliances; and many more items. He is responsible for the development, selection, and operation of manufacturing processes. He plays a significant role in the development of nuclear power and in the operation of power plants.

The mechanical engineer is employed in all industries. The automotive, machine tool, and home appliance firms are obvious examples. Perhaps somewhat less obviously, the mechanical engineer is engaged in large numbers in the aircraft, chemical, basic materials, and electrical industries.

The varied nature of mechanical engineering demands a strong foundation in the basic sciences of mathematics, physics, and chemistry. To this the program adds study in the engineering sciences: thermodynamics and heat transfer, solid and fluid mechanics, electricity and electronics, and materials. These fundamentals are then applied to the design, heat

* A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

and power, and manufacturing aspects of mechanical engineering through a group of lecture, laboratory, and design courses required of all mechanical engineering students. In addition, as indicated below, the student undertakes study in an area of particular interest to himself through the selection of a sequence of "Group Options and Electives."

The particular interest of a mechanical engineering student may make it desirable for him to work toward a second bachelor's degree in another engineering program, simultaneously with his work toward the degree in mechanical engineering. The requirements governing work toward two degrees are presented on page 161. The mechanical engineering program is readily adaptable to these requirements; interested students should consult the program adviser.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Econ. 53 and 54; or Econ. 153 and Ind. Eng. 150; or Econ. 153 and three hours nontechnical elective	5 or 6
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials I	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Math. 103 or 104, Differential Equations	3
Mech. Eng. 17, Mechanical Engineering Laboratory	2
Mech. Eng. 32, Manufacturing Processes	3
Mech. Eng. 80, Dynamics of Machinery	2
Mech. Eng. 82, Machine Design I	3
Mech. Eng. 86, Machine Design II	3
Mech. Eng. 104, Fundamentals of Fluids Machinery	3
Mech. Eng. 105, Thermodynamics I	3
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 111, Heat Transfer I	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Elec. Eng. 7, Motor Control and Electronics	4
Chem.-Met. Eng. 107, Metals and Alloys	3
Nontechnical electives	6
Group options and electives*	19 or 18
Total, professional subjects and electives	87

* A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

The group options and electives requirement permits the student to pursue a sequence of courses reflecting his interest in a particular field such as automotive, air conditioning, design, fluids machinery, heat power (automotive and stationary power plants, including turbines, rockets, nuclear energy, etc.), instrumentation and control, manufacturing, mathematics and science, refrigeration, etc. The student who does not wish to emphasize any particular field may distribute his selections in a broader manner.

The student is encouraged to formulate his own sequence of group option and elective courses, with the advice and subject to the approval of his adviser; example elective sequences for the fields listed above are available. A student interested in the automotive area, for example, may wish to emphasize body and chassis work or engine and transmission aspects, or he may elect courses in each. As another example, a student interested in the mechanical engineering aspects of the chemical industry may wish to select some electives in the chemical engineering area.

SUGGESTED SCHEDULE

For common first-year schedule, see page 18.

THIRD SEMESTER	HOURS
Math. 53	4
Phys. 45	5
Eng. Mech. 1	3
Nontechnical electives	4 or 3
	16 or 15

FOURTH SEMESTER	HOURS
Math. 54	4
Phys. 46	5
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Nontechnical electives	2 or 3
	16 or 17

SUMMER SESSION	
Eng. Mech. 3	3
Mech. Eng. 105	3
	6

FIFTH SEMESTER	
Mech. Eng. 32	3
Mech. Eng. 80	2
Mech. Eng. 106	3
Eng. Mech. 4	3
Chem.-Met. 107	3
Nontechnical electives	3
	17

SIXTH SEMESTER*	
Mech. Eng. 17	2
Mech. Eng. 82	3
Mech. Eng. 111	3
Elec. Eng. 5	4
Math. 103	3
	15

SEVENTH SEMESTER*	
Mech. Eng. 86	3
Mech. Eng. 104	3
Elec. Eng. 7	4
Econ. 153	3
Group options and electives	3
	16

EIGHTH SEMESTER*	
Group options and electives	15
English, Group III	2
	17

* The most appropriate schedule for any student will depend upon his area of Group Option and Electives interest. The student should develop the desired modifications to the above basic schedule with the advice and approval of his counselor.

METALLURGICAL ENGINEERING

Program Adviser: Professor Flinn, 4305 East Engineering.

Metals and alloys possessing carefully defined properties are required by manufacturers of electronic equipment, aircraft, reactors, as well as in structures. In many cases the discoveries of science cannot be usefully applied until metals of the required characteristics are developed.

The metallurgical engineer is concerned, therefore, with the conversion of ores into metals and combinations of metals which possess specified qualities such as higher strength, increased resistance to extreme temperatures, greater hardness or ductility. In common with other engineers he is required to have a thorough background of the physical and engineering sciences, as well as a knowledge of casting and of other metallurgical operations. The nature and control of metal structures are studied by modern methods, such as X-ray diffraction and the use of the electron and light microscopes, as also are the structural transformations resulting from heat treatment.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Economics 153, 173	6
Eng. Mech. 5, Statics and Stresses	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D.C. and A. C. Apparatus and Circuits	4
Mech. Eng. 83, Machine Design	3
Chemistry 23, Analytical	4
Chemistry 61R, Organic	4
Chemistry 182, 183, Physical	6
Chem.-Met. Eng. 2, Engineering Calculations	3
Chem.-Met. Eng. 13, Processing of Cast Metals	2
Chem.-Met. Eng. 16, Measurements Laboratory	3
Chem.-Met. Eng. 111, Thermodynamics	3
Chem.-Met. Eng. 114, Unit Operations	4
Chem.-Met. Eng. 118, Structure of Solids	3
Chem.-Met. Eng. 119, Metallurgical Process Design	4

	HOURS
Chem.-Met. Eng. 121, Design of Process Equipment	3
Chem.-Met. Eng. 124, X-ray Studies of Engineering Material	3
Chem.-Met. Eng. 127, Physical Metallurgy I	4
Chem.-Met. Eng. 128, Physical Metallurgy II	3
Chem.-Met. Eng. 129, Engineering Operations Laboratory	3
Nontechnical electives	6
Group options and electives*	5
Total, professional subjects and electives	87

SUGGESTED SCHEDULE†

For common first-year schedule, see page 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Chem.-Met. Eng. 2	3
Chem. 23	4	Physics 46	5
Econ. 173	3	Eng. Mech. 5	4
	16		16
SUMMER SESSION			
Chem. 182	3		
Eng. Mech. 3	3		
Electives	2		
	8		
FIFTH SEMESTER		SIXTH SEMESTER	
Chem. 183	3	Chem. 61R	4
Chem.-Met. Eng. 114	4	Chem.-Met. Eng. 127	4
Chem.-Met. Eng. 16	3	Chem.-Met. Eng. 13	2
Chem.-Met. Eng. 111	3	Mech. Eng. 83	3
Chem.-Met. Eng. 118	3	Electives	3
	16		16
SEVENTH SEMESTER		EIGHTH SEMESTER	
Chem.-Met. Eng. 128	3	Chem.-Met. Eng. 121	3
Chem.-Met. Eng. 119	4	Chem.-Met. Eng. 129	3
Elec. Eng. 5	4	English, Group III	2
Econ. 153	3	Chem.-Met. Eng. 124	3
Electives	2	Electives	4
	16		15

* Advanced courses in air, military, or naval science (300 and 400 series) may be used for these electives.

† The program may be completed in eight semesters if seventeen- or eighteen-hour semester schedules can be carried successfully and the sequences are carefully planned.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Program Adviser: Professor Adams, 448B West Engineering.

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 turbine, gas 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 naval architecture and 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 years. 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 experimental ship model basin. The University also has an operating nuclear reactor and an extensive nuclear engineering graduate program. Thus upon completion of the requirements for a B.S.E. (Naval Architecture and Marine Engineering) the student may continue with a nuclear engineering graduate program.

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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Draw. 33	2
Math. 57	2
English, Group II and Group III	4
Econ. 153	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials I	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 136, Theory of Vibrations	3
Mech. Eng. 17, Heat-Power Laboratory	2
Mech. Eng. 82, Machine Design I	3
Mech. Eng. 80, Dynamics of Machinery	2
Mech. 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 Propulsion Machinery	2
Nav. Arch. 147, Marine Auxiliary Machinery	2
Nav. Arch. 151, Resistance, Power, Propellers	3
Nontechnical electives	6
Group options and electives	23
Total, professional subjects and electives	86

One of the following groups should be selected by the student before beginning the junior year:

1. NAVAL ARCHITECTURE. Adviser: Professor Adams

For those principally interested in ship design and hull construction:

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, Ship Model Theory	3
Electives*	2

* Advanced courses in air, military, or naval science (300 and 400 series) may be used for these electives.

2. MARINE ENGINEERING. Adviser: Assistant Professor West

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

	HOURS
Chem.-Met. Eng. 10, Fuels	1
Civ. Eng. 21, Theory of Structures	3
Mech. Eng. 104, Fundamentals of Fluids Machinery	3
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 108, Mechanical Engineering Laboratory	3
Mech. Eng. 111, Heat Transfer I	3
Nav. Arch. 144, Design of Marine Power Plants II	3
Nav. Arch. 146, Design of Marine Power Plants I	2
Electives*	3

SUGGESTED SCHEDULE

For common first-year schedule, see page 18.

THIRD SEMESTER	HOURS
Math. 53	4
Eng. Mech. 1	3
Physics 45	5
Nav. Arch. 11	2
Draw. 33	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	
Eng. Mech. 3	3
Mech. Eng. 105	3
Math. 57	2
	8

FIFTH SEMESTER	*Option* 1	*Option* 2
Nav. Arch. 21	3	3
Nav. Arch. 141	2	2
Eng. Mech. 4	3	3
Mech. Eng. 17	2	2
Mech. Eng. 80	2	2
Nav. Arch. 13	3	–
Mech. Eng. 106	–	3
Electives	2	2
	17	17

SIXTH SEMESTER	*Option* 1	*Option* 2
Nav. Arch. 22	2	–
Mech. Eng. 82	3	3
Civ. Eng. 21	–	3
Nav. Arch. 147	2	2
Elec. Eng. 5	4	4
Nav. Arch. 152	3	–
Mech. Eng. 111	–	3
Eng. Mech. 136	3	3
	17	18

* Advanced courses in air, military, or naval science (300 and 400 series) may be used for these electives.

SEVENTH SEMESTER	HOURS Option 1	2
Nav. Arch. 131	3	–
Nav. Arch. 137	3	–
Econ. 153	3	3
Nav. Arch. 146	–	2
Chem.-Met. Eng. 10	–	1
Mech. Eng. 104	–	3
Mech. Eng. 108	–	3
Eng. Mech. 127	4	–
Electives	3	3
	16	15

EIGHTH SEMESTER	HOURS Option 1	2
English, Group III	2	2
Nav. Arch. 151	3	3
Nav. Arch. 132	4	–
Nav. Arch. 144	–	3
Electives	3	4
	12	12

PHYSICS

Program Adviser: Professor Wolfe, 4063 Randall.

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, page 161.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Modern language	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 of Materials I	4
Eng. Mech. 3, Dynamics, or Physics 171, Intermediate Mechanics	3
Elec. Eng. 3, Circuits I	4
Elec. Eng. 100, Circuits II	4

	HOURS
Mech. Eng. 105, or Eng. Mech. 142, or Chem.-Met. Eng. 111, Thermodynamics	3 or 2
Physics 147, Electrical Measurements	4
Physics 165, Electron Tubes	3
Physics 196, Atomic and Molecular Structure	3
Group options and electives	33 or 34
Total, professional subjects and electives	87

Group options and electives are to be selected with the advice and consent of the program adviser in accordance with the distribution of hours as listed below. For the group of engineering electives, each student is expected to complete a planned sequence from the offerings of one of the following departments: Aeronautical Engineering, Chemical and Metallurgical Engineering, Civil Engineering, Electrical Engineering, or Mechanical Engineering.

	HOURS
Physics	9
Mathematics	3
Engineering electives (engineering analysis, design, and engineering systems)	12 or 13
From economics, geography, history, philosophy, political science, or sociology	6
Electives*	3

SCIENCE

Program Adviser: Professor White, 2038 East Engineering.

Modern trends in engineering are characterized by increasing emphasis upon science. During recent years, engineering has expanded in spectacular fashion into many new fields such as nuclear engineering, instrumentation and control, and operations analysis. Also many revolutionary advances have been made in establishing the scientific bases of the older fields of engineering.

The science engineering program is excellent preparation for postgraduate work in engineering or applied science as well as for immediate employment in the expanding fields of engineering research and development.

A student completing the science engineering program has a background in physical, chemical, and engineering science equivalent to that required in many of the programs leading to the master's degree, but is not required to complete the specialized engineering courses necessary for the bachelor's degree in the other engineering programs. Any student enrolled in the science engineering program, however, can transfer into one of the specialized programs at the end of the fourth semester (second year) if such interests develop.

* Advanced courses in air, military, or naval science (300 and 400 series) may be used for these electives.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Science) are required to complete the program outlined below. The student will be encouraged to formulate his own sequence of subjects, including a number of integrated courses in an area of particular interest to him, with the advice and approval of the program adviser.

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21, Schedule S)	47–49
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Engineering science, including engineering materials, strength of materials, dynamics, fluid mechanics, thermodynamics, electromagnetics and energy conversion, network analysis, electronics and systems, rate processes, modern physics	35
Electives in engineering	17
Electives in mathematics	6
Electives in English, literature, fine arts, or philosophy	6–10
Electives in anthropology, economics, geography, history, journalism, political science, psychology, or sociology	14–10
Electives*	8
Total, professional subjects and electives	86

SUGGESTED SCHEDULE

For first-year schedule see page 18.

THIRD SEMESTER	HOURS
Math. 55	4
Chemistry 15	4
Eng. Mech. 12	4
Sci. Eng. 110	3
	15

FOURTH SEMESTER	HOURS
Math. 56	4
Physics 54	4
Eng. Mech. 13	3
Elec. Eng. 9	3
Elective	3
	17

FIFTH SEMESTER	
Modern Physics	3
Eng. Mech. 14	4
Elec. Eng. 11	4
Elective (Math.)	3
Elective	4
	18

SIXTH SEMESTER	
Elec. Eng. 87	4
Engineering Materials	4
Elective (Math.)	3
Elective (Engineering)	4
Elective	3
	18

* A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

SEVENTH SEMESTER	HOURS
Sci. Eng. 112	3
Electives (Engineering)	5
Electives	9
	17

EIGHTH SEMESTER	HOURS
Electives (Engineering)	8
Electives	9
	17

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. Many of these special fields have been specifically mentioned under the various degree programs. Information regarding these fields and others in which the student may be interested will be made available upon request. Program advisers will assist any student in preparing a program to fit his particular desires.

INSTRUMENTATION ENGINEERING

The recent developments in the broad engineering application of the principles of measurement, communication, and control, as exemplified by the extensive use of telemetry, computer simulation, and automatic control, make desirable the education of men in this important field. It appears that the best preparation can be achieved at present by completing the requirements for one of the undergraduate B.S.E. degree programs, the science engineering program being the most appropriate, followed by special work in instrumentation at the graduate level. (See page 65.

Undergraduate students may start these special studies by electing one or more of the following courses: Aero. Eng. 172, Introduction to Instrument Dynamics (*2*); Aero. Eng. 174, Principles of Automatic Control (*4*); Aero. Eng. 177, Probability in Instrumentation (*2*); Elec. Eng. 108, Networks and Electron Tube Circuits (*4*), or 128, Electronics and Radio Communication (*4*); Mathematics 148, Operational Methods for Systems Analysis (*4*).

METEOROLOGY

The importance of weather and climate as factors in human life and activities has become increasingly apparent. There has been a corresponding demand for education in meteorology and its applications. The program of teaching and research emphasizes not only engineering meteorology, but also applied phases in such fields as medicine, public health, forestry, botany, etc. A bachelor's degree in any field, with basic physics and mathematics through calculus, is required preparation for specialization in meteorology and its applications at the graduate level. Recommended courses for those who wish to start studies in meteorology while undergraduates are: Civ. Eng. 90, Introductory Meteorology: Weather (*4*); Civ. Eng. 190, Physical Meteorology (*2*); and Civ. Eng. 191, Dynamic Meteorology (*3*). See Graduate School *Announcement* for advanced degree program.

NUCLEAR ENGINEERING

The new developments in nuclear energy have required engineers to design, construct, and operate the essential facilities. The implications and effects of nuclear energy demand the attention of engineers with backgrounds from all fields; and a special undergraduate or B.S.E. degree program in this field is not considered desirable at this time. Such specialization in nuclear engineering is offered at the graduate level (see page 66). Undergraduates desiring only a one-semester course of nuclear engineering should elect Nuclear Engineering 190, Elements of Nuclear Engineering. Seniors who wish to start on the advanced program should elect Nuclear Engineering 191, Introduction to Nuclear Engineering.

RESERVE OFFICERS' TRAINING CORPS

Each male student enrolled in the University of Michigan who meets certain requirements has the opportunity to enroll in the Army ROTC, the Navy ROTC, or the Air Force ROTC. Enrollment is voluntary, but the University and the armed forces expect each student who volunteers to enroll in ROTC to meet the full obligations accepted.

The objective of the ROTC is to train well-qualified reserve officers for the armed forces. Each student who voluntarily enrolls in any one of these three officer training corps accepts the obligation of: (1) continuing his studies in the ROTC, unless excused by regulations of the Army, Navy, or Air Force, until graduation; (2) serving as an officer for specified times.

By voluntarily enrolling in ROTC, each student adds to his own degree requirement the completion of the freshman-sophomore program in the Army and the Air Force. At the beginning of the junior year, the Army or Air Force student may apply to continue in ROTC. If accepted, he adds to his degree requirement the completion of the junior and senior years. Students accepted in the Navy ROTC program commit themselves as freshmen to a four-year program as a degree requirement.

Since there are variations among the three services, interested students are requested to write to Professor of Military Science and Tactics for further information about the Army; Professor of Naval Science for further information about the Navy; and Professor of Air Science for information about the Air Force.

AIR SCIENCE

Professor Belsma; Assistant Professors Knapp, Middlebrook, Schatz, and Smith; Instructors Brown, Friedwald, Ivey, Lodigiani, and Lowery. Department office, 150 North Hall.

The Department of Air Science offers a four-year generalized course of study designed to develop in selected engineering students those attributes of character, personality, and leadership which are essential to a commissioned officer of the USAF, and to provide the students with a broad knowledge and understanding of national and international defense structures in relation to the global mission of the USAF. A qualified student who is selected for the AFROTC program and who successfully completes a four-year program with an engineering major acceptable to the USAF will, upon graduation from the University, be considered for a commission as second lieutenant in the USAF Reserve. No specific major is required for students desiring flight training. A limited number of commissions will be granted to students who qualify for nonflying engineering specialties. Throughout the program both the theoretical and the practical phases of modern air power are emphasized. The course of study is so organized and developed that the student acquires an understanding of strategic and tactical air power, air operations, aerodynamics and propulsion, aerial navigation, meteorology, administration and logistics, principles of leadership, personnel management, international tensions and security organizations, instruments of national military security, elements of aerial warfare, applied air science, communications process and Air Force correspondence, military aviation and the art of war, and military aspects of world political geography.

Pay and allowances are offered to students who are formally enrolled in the advanced course (third and fourth years), approximating $275 for each of these two years. An additional amount of approximately $75, plus all expenses and life insurance, is earned while at summer camp.

Any Air Force ROTC student who is designated as a distinguished AFROTC student and who graduates from the University as a distinguished AFROTC graduate may apply for a commission in the regular Air Force.

Students who are commissioned will be required to serve on active duty for three years.

The Department of Air Science sponsors a rifle team, drill team, newspaper, and an Air Force band. There is also on campus a chapter of the National Arnold Air Society, which is sponsored by the Department of Air Science.

Qualified members of the unit may participate in the Scabbard and Blade and Pershing Rifles.

COURSES OFFERED IN AIR SCIENCE

101, 102 Airplane and the Air Age. (*2*).
201, 202 Elements and Potentials of Air Power. (*2*).
301, 302 Air Force Officer in the Air Age. (*3*).
401, 402 Leadership and Air Power Concepts. (*3*).

MILITARY SCIENCE AND TACTICS

Professor Woodman; Assistant Professors Boswell, Farrell, and Henderson. Department Office, 212 Temporary Classroom Building.

The Department of the Army offers a four-year program designed to produce junior officers who, by their education, training, and inherent qualities, are suitable for continued development as officers in the United States Army. ROTC graduates, if otherwise qualified, are commissioned as second lieutenants in the Army Reserve on attainment of a baccalaureate degree. Distinguished military graduates are offered direct commissions in the Regular Army. Each student, by voluntarily enrolling in the Army ROTC for the basic course (freshman and sophomore years) or the advanced course (junior and senior years), makes the completion of that course a degree prerequisite, unless excused by Army regulations. Students in the basic course are not required to sign draft deferment agreements. Each student in the basic course who signs a draft deferment agreement accepts the obligations of (1) continuing his studies in ROTC, unless excused by Army regulations, until graduation, (2) accepting a commission on graduation, if tendered, and serving his military obligation in accordance with the law. The military obligation may be served, in accordance with the needs of Department of the Army, in one of two ways: (1) active duty as an officer for two years, followed by three years as an officer in an Army Reserve or a National Guard unit, and one year on inactive reserve duty, for a total of six years; or (2) active duty as an officer for six months followed by seven and one-half years as an officer in an Army Reserve or National Guard unit, a total of eight years. The method of serving the military obligation of officers is determined by the needs of the Department of the Army for officers on active duty.

At the end of the sophomore year, students who successfully complete the basic ROTC course are screened for entrance into the advanced course in the junior year. Selection for the advanced course is made on demonstrated leadership potential and inherent qualities, proficiency in the ROTC and academic curriculums, and desires of students for entrance into the advanced course. Those students selected and enrolled in the advanced ROTC course make completion of the course, attendance at summer camp, and acceptance of a Reserve commission, if tendered, a degree prerequisite, unless excused by higher Army Headquarters in accordance with Army regulations.

Army ROTC students who maintain prescribed standards will be deferred from military service until the ROTC curriculum has been completed.

Duration of the complete course of instruction comprises four years with not fewer 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. Attendance at a six-week ROTC summer camp is mandatory, normally during the summer between the junior and senior years. The complete course of instruction is organized into four major subcourses: American Military History; Operations, Tactics and Techniques; Logistics and Materiel; School of the Soldier and Exercise of Command. These four subcourses are concerned with four broad and distinct areas of military knowledge and skill. The instructional objective of the Department of Military Science and Tactics is to integrate the instruction under the four areas of military knowledge and skill into the progressive development of self-confidence, initiative, sense of responsibility, high moral standards, and leadership among ROTC students.

BASIC COURSE	HOURS
Military Science I	
Organization of the Army and ROTC	5
American Military History	30
Individual Weapons and Marksmanship	25
School of the Soldier	30
Military Science II	
Crew-Served Weapons and Gunnery	30
Map and Aerial Photograph Reading	20
School of the Soldier	30
Role of the Army in National Defense	10

ADVANCED COURSE	
Military Science III	
Small Unit Tactics and Communications	55

	HOURS
Organization, Function, and Mission of Arms and Services	30
Military Teaching Methods	20
Leadership	10
Pre-Camp Orientation	5
Exercise of Command	30

Military Science IV

Logistics	20
Operations	50
Military Administration and Personnel Management	30
Service Orientation	20
Exercise of Command	30

Branch assignments. During the senior year cadets will be classified for assignment as officers on graduation to one of the following branches in accordance with their leadership, aptitude, University curriculum, interest, and the needs of the Army: Arms: Armor, Artillery, Infantry. Technical and Administrative Services: Adjutant General's Corps, Army Security, Chemical, Corps of Engineers, Finance Corps. Medical Service Corps, Military Intelligence, Military Police Corps, Ordnance Corps, Quartermaster Corps, Signal Corps, Transportation Corps. Completion of the ROTC course does not lead to commission in: Medical Corps, Dental Corps, Chaplains' Corps, Judge Advocate General's Corps, or Veterinary Corps.

Pay and allowances. These begin with the enrollment in the third year of the military science course and amount to approximately $265 for each of the last two years. In addition, the student receives approximately $117, plus travel expenses to and from camp for the six-week summer camp held between the third and fourth years of the military science course. All ROTC students are furnished uniforms without charge.

Prior servicemen. Credit for prior active duty enlisted service is allowable. Satisfactory ROTC participation for men with prior active service can be substituted for the Ready Reserve obligation. On graduation and commissioning prior servicemen assume a second military obligation.

The new four-year obligation requires six months on active duty, unless urgent necessity requires more, and the remainder as a member of a Ready Reserve unit. Interested students should consult the Department of Military Science and Tactics.

The Department of Military Science and Tactics sponsors a rifle team and the ROTC Marching Band. The two national honorary military societies — Scabbard and Blade and Pershing Rifles — have active chapters on the campus.

NAVAL SCIENCE

Professor Mothersill; Associate Professor Banfield; Assistant Professors Epps, Griffith, Hirsch, Lambert, Riley, and Van Malsen; Instructors Benson, Browning, Durham, Fleming, Moshgat, Turner. Department office, North Hall.

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

Objectives. The objectives of the Department of Naval Science in carrying out the above mission at the University of Michigan are:

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).

Officers Candidates. Officer candidates in the NROTC are of two types:

a) Regular NROTC Students. These students, after selection by nationwide 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 four years on active duty after being commissioned as ensigns, United States Navy, or as 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. They are not entitled to the compensation or benefits paid regular NROTC students except that they are entitled to the uniform issue, naval science textbooks and equipment, 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 six weeks duration between the junior and senior years. After graduation, they are commissioned as ensigns, USNR, or second lieutenants, USMCR, and called to two years' active duty. They may then apply, if they desire, for retention in the service.

Candidates must be between seventeen and twenty-one years of age. In special cases Contract students sixteen years of age may be enrolled. All must pass the Navy physical examination. Height must be between 64 and

78 inches and general physical development good. Vision must be 20/20 uncorrected by glasses.

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 Navy Supply Corps commissions complete four semesters of general naval science subjects and four semesters of Navy Supply Corps subjects.

Regular NROTC students participate in three summer cruises of six to eight weeks' duration; Contract NROTC students participate in one six-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 trigonometry in high school or by the end of their sophomore year in college. Regular NROTC students must also complete one year of college physics by the end of their sophomore college year.

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

Courses Offered in Naval Science

101. Naval History. I. *(3).*
A study of the history of sea power and its influence in shaping world affairs socially, economically, and politically.

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, employment, and control of naval weapons, includng radar and sonar. Employment of the Combat Information Center in ship organization. Fundamental operation and principles of guided missiles.

301. Naval Engineering. I. *(3).*
Provides a broad general concept of the fundamentals of naval engineering installation including steam, diesel, nuclear power, gas turbines, and auxiliary plants, and ship stability.

301S. Navy Supply. I. *(3).*
For Navy Supply Corps candidates only. Naval finance, organization, logistics, and naval accounting methods.

301M. Study of Evolution of Art of War. I. *(3).*
For Marine Corps candidates only. Analysis of decisive battles of history according to Principles of War and evolution of weapons.

302. Navigation. II. *(3).*
Thoroughly acquaints the student with the theory of dead reckoning, piloting, and celestial methods of navigation. Practical problem solution is stressed during summer cruises.

302S. Navy Supply. II. *(3)*.
For Navy Supply Corps candidates only. Supply organization and administration afloat.

302M. Modern Strategy and Tactics. II. *(3)*.
For Marine Corps candidates only. Study of European and U. S. military policies and strategies and fundamental infantry tactics.

401. Naval Operations. I. *(3)*.
Provides a broad understanding of basic naval tactics, tactical communications, relative motion, and the rules of the nautical road.

401S. Naval Administration. II. *(3)*.
For Navy Supply Corps candidates only. Supply problems with emphasis on ship's store, clothing, and basic commissary management and operation.

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

402. Naval Administration. II. *(3)*.
Develops a thorough understanding of the principles of leadership, good personnel management, and naval justice.

402S. Navy Supply. II. *(3)*.
For Navy Supply Corps candidates only. Procurement, receipt, storage, issue, and accounting for all commissary operations and management (15 sessions only; remaining 30 sessions combined with Naval Science 402 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 (15 sessions only; remaining 30 sessions deals with study of naval justice and Marine Corps 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 preparaton 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.

Students contemplating graduate work should consult with the program adviser or the advisory committee for the desired program.

AERONAUTICAL ENGINEERING

Advisory Committee: Professors Kuethe, Peery, and Howe; Associate Professors Broadwell, Adamson, and Isakson

A candidate for this degree may, through suitable selection of courses, put emphasis on any of the following fields: aerodynamics, structures, aeroelasticity, propulsion, design, and instrumentation. Ordinarily the candidate may include three to four hours of nontechnical studies but 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 and the graduate requirements.

CHEMICAL ENGINEERING

Advisory Committee: Professors Churchill, Banchero, and Martin; Associate Professors Ragone, Van Vlack, and Young.

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.

A full range of courses is available for those interested in many special fields, particularly: food processing, materials, petroleum refining or production, plastics and elastomers, process and equipment design, protective coatings.

CIVIL ENGINEERING

Program Adviser: Professor Boyce

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: construction, geodesy and surveying, highway and traffic, hydraulics, municipal, railway, sanitary, structures, and soil mechanics.

CONSTRUCTION ENGINEERING

Program Adviser: Associate 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 Advisers: Professors Holland and Macnee

A candidate for this degree must have satisfactorily completed the undergraduate electrical engineering program of the University of Michigan or its equivalent. Normally, a minimum of thirty credit hours of advanced graduate work is required for this degree, which must include 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: communications engineering, computer engineering, electrical engineering design, electrical measurements and instrumentation, electric power engineering, electronics, illumination engineering, and industrial electronics and control.

ENGINEERING MATERIALS

Advisory Committee: Professors Churchill, Banchero, and Martin; Associate Professors Ragone, Van Vlack, and Young.

A candidate for this degree is required to have a background essentially equivalent to that represented by the program leading to the degree of Bachelor of Science in Engineering (Materials Engineering) at the University of Michigan. This includes chemistry, through organic and physical, structure of materials, mechanics of materials, and thermodynamics. Thirty semester hours of additional work are required, which are to be selected with the approval of the advisory committee of the program and which will include Chemical and Metallurgical Engineering 208 or 218.

ENGINEERING MECHANICS

Advisory Committee: Professors Ormondroyd, Naghdi, and Dodge; Associate Professors Masur and Yih.

Candidates may be admitted to the degree program from any of the undergraduate engineering curriculums if accepted by the advisory committee.

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

Program Adviser: Associate Professor Steffy

A candidate for this degree must have completed satisfactorily the undergraduate industrial engineering program of this College, or its equivalent, and must complete in residence a minimum of thirty hours of recognized graduate work approved by the adviser. The course selections necessary for this degree are rather flexible but it is expected that approximately fifteen hours of course study will be in the industrial engineering area.

INSTRUMENTATION ENGINEERING

Advisory Committee: Professors Rauch, Kaplan, Macnee, Williams; Associate Professor Parkinson.

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 Mathematics 148, Electrical Engineering 108 and 128, Aeronautical Engineering 172, 174 and 177, and other courses approved by the advisory committee. The systems-engineering concept is emphasized throughout the program.

MECHANICAL ENGINEERING

Program Adviser: Professor Porter

The degree of Master of Science in Engineering (Mechanical) is offered in the following fields: aeronautical propulsion, air conditioning, automotive, fluids machinery, heat power, land locomotion, machine design and manufacturing.

An applicant for the master's degree in any of the above-mentioned fields must complete at least fifteen hours in the department of specialization and at least two cognate subjects totaling five or more credit hours in other than mechanical engineering. Details of course requirements will be furnished by the department upon request.

Students majoring in mechanical engineering will not be given graduate credit for courses equivalent to any which they have been required to take for the bachelor's degree or for courses required in the undergraduate curriculum of this department.

METALLURGICAL ENGINEERING

Advisory Committee: Professors Churchill, Banchero, and Martin; Associate Professors Ragone, Van Vlack, and Young.

The requirements for this degree include Chemical and Metallurgical Engineering 211, 218, and 210 (4 hours), and a minimum of one course from each of the following groups of courses: Chemical and Metallurgical Engineering 207, 217, 241, 244, 251; Chemical and Metallurgical Engineering 216, 219, 240, 243; and Chemical and Metallurgical Engineering 224, 228, 242, 328.

Other courses are to be selected as approved by the Graduate Committee. Each student is encouraged to design his program to satisfy his special interests.

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 equivalent engineering courses for 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.

It is also possible to obtain a combined degree Master of Science in Engineering (Marine and Nuclear). The Graduate School requirements for such a degree are a minimum of forty hours of graduate level courses and the approval of the candidate's program by the Dean of the Graduate School.

NUCLEAR ENGINEERING

Advisory Committee: Professors Gomberg, Brownell, and Ohlgren; Associate Professors Borchardt, Howe, and Kerr; Assistant Professor West.

Candidates may be admitted to the program from any of the undergraduate engineering curriculums if accepted by the advisory committee. The requirements for the degree include nineteen hours of course work in the nuclear engineering field (see p. 54) plus electives which meet with the approval of the committee, and the preparation of a thesis.

Opportunities for thesis work may be found in theoretical problems or in experimental areas, making use of the extensive radiation source and tracer laboratory facilities now available or the 1000 kw Ford Nuclear Reactor.

SANITARY ENGINEERING

Program Adviser: Associate Professor 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.
INDUSTRIAL ENGINEER—I.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 areas 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. 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. Substitutions for the French or German request may be made under certain conditions which are defined in the *Announcement* of the Graduate School.

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

Description of Courses

The courses offered by the College of Engineering, with certain closely associated departments of other units of the University, are listed with a brief description for each.

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)* denotes credit to be arranged.

AERONAUTICAL ENGINEERING

1. General Aeronautics. *Prerequisite: completion of freshman year in College of Engineering, or equivalent.* I and II. *(1).*

An introduction to aeronautical engineering. Elementary problems designed to orient the student in the program of aeronautical engineering, together with a discussion of the current state of aeronautical developments and the role of the engineer. Recitations and demonstrations.

72. Instrument and Control Systems. *Prerequisite: Math. 54 and Eng. Mech. 3, or equivalent.* I and II. *(3).*

Static sensitivity of instrument systems, null principle of measurement, random and systematic errors, dynamic errors, dynamics of instrument systems, such as accelerometers and vibrometers, elements of feedback control. Statistical properties of random errors, propagation of errors in instrument systems, least squares analysis of data. The laboratory includes measurement of temperature, pressure, strain, vibration, and parameters of physical systems, as well as the use of the electronic differential analyzer for study and simulation of dynamic instrument and control systems. Lecture and laboratory.

101. Airplane Design I. *Prerequisite: preceded or accompanied by Aero. Eng. 141 and 130.* I and II. *(3).*

Design procedure, including layouts and preliminary structural design; preliminary performance, stability and control; subsonic and supersonic designs. Emphasis on design techniques and systems approach. Lecture and laboratory.

102. Pilotless Aircraft Design II. *(To be arranged).*

Primarily for graduates.

103. Airplane Design II. *Prerequisite: Aero. Eng. 101. (2).*

Design procedure, including layouts and preliminary structural design; stress analysis and detail design. Lectures and drawing.

110. Aerodynamics I. *Prerequisite: preceded or accompanied by Eng. Mech. 3 and Math. 103.* I and II. *(4).*

Development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Calculation of the forces and moments acting on wings and bodies in compressible inviscid flow and comparison with experiment.

114. Aerodynamics II. *Prerequisite: Aero. Eng. 110, and preceded or accompanied by Aero. Eng. 163.* I and II. *(4).*
Continuation of Aerodynamics I. Viscous and compressible fluid theory applied to the calculation of the forces and moments on wings and bodies and comparison with experiment. Loads on an airplane. Lectures and laboratory.

115. Theory of Thin Airfoils. *Prerequisite: Aero. Eng. 110 or equivalent. (3).*
Application of complex variables and mapping theory to the thin airfoil in arbitrary motion; quasi-steady theory of cambered airfoils; apparent mass and wake effects, nonstationary flow equations. Aerodynamic forces and moments are developed in a form suitable for use in the gust and flutter problems.

116. Applied Fluid Mechanics. *Prerequisite: Eng. Mech. 4 or equivalent. (3).*
The physical aspects of various problems of viscosity and compressibility and their application in aeronautical and other branches of engineering. Not open to students who have elected Aero. Eng. 114.

117. Theory of Propellers and Fans. *Prerequisite: Aero. Eng. 110 and Mech. 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. Experimental Aerodynamics. *Prerequisite: Aero. Eng. 119. (2).*
Covers the work presented in the experiments in Aero. Eng. 114 but with more attention to detail and more elaborate discussion of the advanced theories and methods used in this field. Lectures and laboratory.

119. Intermediate Aerodynamics. *Prerequisite: Aero. Eng. 114 or 116 or a course in advanced calculus. (3).*
Aerodynamics of viscous and compressible fluids. Equations of motion and energy, high subsonic, transonic, and supersonic flow, shock waves, characteristics, boundary layers, turbulence, unsteady flow. Theoretical aspects of subject are stressed.

121. Turbulence and Diffusion. *Prerequisite: a course in advanced calculus and Aero. Eng. 114 or Eng. Mech. 4. (To be arranged).*
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.

122. Theory of Supersonic Wings and Bodies. *Prerequisite: Aero. Eng. 114 or a course in advanced calculus. (3).*
The linearized theory of finite wings of arbitrary planform and cross section in supersonic flow. Linearized body theory, flow field around wings and bodies, interference effects. A companion course to Aero. Eng. 119 that is directed toward aerodynamic aspects of the design of supersonic aircraft and missiles.

130. Aircraft Structures I. *Prerequisite: Eng. Mech. 2, and preceded or accompanied by Eng. Mech. 3. (3).*
Fundamentals of aircraft structural design and stress analysis. Application of statics, dynamics, and properties of materials to simple aircraft structures.

131. Aircraft Structures II. *Prerequisite: Aero. Eng. 130 or by special arrangement for students from other departments. (4).*
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. Laboratory 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. Aircraft Structures III. *Prerequisite: Aero. Eng. 131. (3).*
Complete strength and deflection analysis of built-up wing structures with effective and ineffective skin. Effects of differential bending, warping of cross-sections, and shear lag are discussed.

134. Structures at Elevated Temperatures. *Prerequisite: Aero. Eng. 131 or 135. (3).*
Aerodynamic heating of high-speed aircraft. Steady and transient conditions of thermal stresses. Properties of materials and structures under conditions of temperature and load.

135. Aircraft Structural Analysis and Design. *Prerequisite: Eng. Mech. 2. (3).*
Loading conditions, stress distribution, design of typical components. Not open to students taking Aero. Eng. 130 or 131.

141. Mechanics of Flight I. *Prerequisite: Aero. Eng. 114 and Math. 103, and preceded or accompanied by Aero. Eng. 164 and Eng. Mech. 3. (3).*
Longitudinal and lateral static stability of aircraft, control power, steady state maneuvers, hinge moments, and control forces. Power-required and power-available characteristics of aircraft on a comparative basis, calculation of performance characteristics.

142. Mechanics of Flight II. *Prerequisite: preceded or accompanied by Aero. Eng. 141 or equivalent. (3).*
Dynamic analysis of systems with many degrees of freedom, dynamic stability and response of the rigid aircraft, use of servo controls, influence of structural elasticity in airplane dynamics, aeroelastic stability problems.

143. Aircraft Control Systems. *Prerequisite: preceded or accompanied by Aero. Eng. 142. (3).*
Analysis of linear control systems; Routh-Hurwitz and Nyquist stability criteria; static and dynamic characteristics of aircraft instruments; airplane transfer functions; analysis and introduction to synthesis of autopilot and powerplant control systems; use of the analog computer in the laboratory for simulation. Two lectures and one laboratory.

144. Aeroelasticity I. *Prerequisite: Aero. Eng. 142. (3).*
Description of the deformation characteristics of aircraft structures. Deformations of aircraft structures under dynamic loads; differential equation, integral equation, energy methods of analysis. Wing divergence, control surface effectiveness, aeroelastic effects on load distribution, flutter.

145. Performance of Aircraft. *Prerequisite: a course in differential equations. (3).*
Summary of the material in Aero. Eng. 141 and 142. Primarily for graduate students.

150. Rotary Wing Aircraft. *Prerequisite: Aero. Eng. 114, and preceded or accompanied by Aero. Eng. 141. (3).*
Rotating-wing aircraft development. Performance analysis, rotor blade stall, stability, vibration. Applications to various types of vertical take-off and landing aircraft.

163. Aircraft Propulsion I. *Prerequisite: Mech. Eng. 105, Aero. Eng. 110 or Mech. Eng. 106. (3).*
Introduction to aerothermodynamics and applications to problems in aircraft

propulsion. Discussion of the momentum theorem, one-dimensional flow systems with heat addition, shock waves, diffusers, compressors, and turbines.

164. Aircraft Propulsion II. *Prerequisite: Aero. Eng. 163 or equivalent. (3).*
Performance and analysis of aircraft propulsion systems including the reciprocating engine-propeller, reciprocating engine-rotor, turboprop, turbojet, ramjet, pulse-jet, and rocket.

165. Introduction to Aircraft Propulsion. *Prerequisite: Mech. Eng. 105, 106, or equivalent. (3).*
Review of those phases of thermodynamics used in the analysis of compressible flow and propulsion systems; turbojet and ramjet; rocket and pulse-jet.

166. Aircraft Propulsion Laboratory. *Prerequisite: preceded by Aero. Eng. 163. (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 pulse-jet, turbojet, ramjet, and rocket motors.

167. Aircraft Propulsion III. *Prerequisite: Aero. Eng. 164 or equivalent. (3).*
Continuation of Aero. Eng. 164. Further treatment of aircraft engine performance, including off-design operation, and study of selected problems in the field of propulsion.

168. Topics in Gas Dynamics. *Prerequisite: Aero. Eng. 114 or permission of instructor. (2).*
The role of transport phenomena in gas dynamics problems is stressed. The subjects covered include simplified gas kinetics, definition of transport properties, general conservation equations, laminar boundary layer and mixing problems with heat transfer and diffusion.

170. Seminar on Electronic Analog Computers. *Open only to graduates and seniors who receive special permission. (To be arranged).*
Study of selected topics in design and application of electronic analog computers.

172. Introduction to Instrument Dynamics. *Prerequisite: Eng. Mech. 3, Elec. Eng. 3 or 5. (2).*
Treatment of instrument response and errors including static, steady-state, and transient behavior; gyros, accelerometers, seismic instruments, and other measuring devices. Dynamic and steady-state response of first, second, and n-th order linear systems. Laboratory experiments with physical systems; application of the electronic differential analyzer to the solution of instrumentation problems. Lecture and laboratory.

173. Wind Tunnel Instrumentation. *Prerequisite: Aero. Eng. 172 or equivalent. (2).*
Study of the role of schlieren, shadow, and interferometric techniques in aerodynamic research and a comparison of their relative accuracy and effect in data reduction; pressure and temperature measurements. Lecture and laboratory.

174. Principles of Automatic Control. *Prerequisite: Eng. Mech. 3, Elec. Eng. 3 or 5, and a course in differential equations. (4).*
Transient and steady-state analysis of linear feedback control systems; transfer functions and operational calculus. Stability analysis of single and multiple-loop systems using the Nyquist criterion. Synthesis of control systems using Nyquist plots, attenuation methods, and root-locus diagrams. Use of the electronic differential analyzer in the laboratory for simulation and as a design tool.

175. Application of the Electronic Differential Analyzer I. *Prerequisite: a course in differential equations. (2).*
Basic theory and principles of operation of electronic differential analyzers. Applications to one- and two-degree-of-freedom vibration problems, automatic control systems, heat flow, eigenvalue problems, nonlinear vibration problems, and other selected topics. Lecture and laboratory. Laboratory consists of the solution of problems on the electronic differential analyzers of the Department of Aeronautical Engineering.

176. Flight Testing. *Prerequisite: Aero. Eng. 141 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.

177. Probability in Instrumentation. *Prerequisite: a course in differential equations. (2).*
Probability basis of measurement errors and random events; probability distributions; precision indices and their propagation; confidence intervals; tests for distributions; least squares fitting; linear correlation; discrete and continuous time series.

178. Design of Electronic Analog Computers. *Prerequisite: Elec. Eng. 108 or equivalent. (3).*
Theory of operational amplifiers, including stability, reliability, and drift-effects and their influence on d.c. amplifier circuitry. Drift-stabilized d.c. amplifiers. Design of integrators, summers, and operational analog circuits. Design of servomultipliers, time-division multipliers, function-generators, drift-stabilized power supplies, and other selected topics. Lectures and laboratory.

179. Gyrokinetics. *Prerequisite: a course in differential equations. (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.

181. Directed Study. *(To be arranged).*
Individual study of specialized aspects of aeronautical engineering.

182. Research. *(To be arranged).*
Specialized individual or group problems of research or design nature supervised by a member of the staff.

185. High-Altitude Studies. *Prerequisite: a course in differential equations. (3).*
Upper atmosphere pressure, density, temperature, winds, composition. Rarified gas dynamics; solar constant and spectrum; the ionosphere; techniques and results of rocket research; characteristics of research vehicles; the earth satellite.

201. Dynamics of Viscous Fluids. *Prerequisite: Aero. Eng. 119 or permission of instructor.*
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. 119. (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, transonic and supersonic airfoil theory.

210. Advanced Engineering Measurements. *Prerequisite: Aero. Eng. 172 and 177, Elec. Eng. 108, 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.

212. Control and Guidance of Missiles. *Prerequisite: Aero. Eng. 248 or Elec. Eng. 256, Math. 148. (3).*
Analysis and synthesis of missile autopilot systems. Navigational homing systems; inertial and celestial navigation systems. Trajectories of ballistic missiles. Lectures and laboratory. Laboratory consists of simulation of missile control and guidance systems with the electronic differential analyzer.

214. Information Theory and Radio Telemetry. *Prerequisite: Aero. Eng. 172 and 177, Elec. Eng. 120, Math. 148. (2).*
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; transducers and various methods of data recording.

215. Radio Telemetry Laboratory. *Prerequisite: to be taken concurrently with or following Aero. Eng. 214. (1).*
Laboratory experiments involving the various modulation and multiplex methods and associated instrumentation described in Aero. Eng. 214.

230. Structural Analysis of Thin Wings. *Prerequisite: Aero. Eng. 131 or equivalent, Math. 150. (3).*
Application of the theorem of minimum potential and complementary energy, Galerkin's method, finite difference approximations, and relaxation procedures to the deformation and stress analysis of low aspect ratio wings.

244. Aeroelasticity II. *Prerequisite: Aero. Eng. 144. (3).*
Static and dynamic aeroelastic problems relative to swept wings and wings of low aspect ratio. Transient aeroelastic response problems. Aeroelastic effects on aircraft flying qualities.

248. Feedback Control. *Prerequisite: Aero. Eng. 174 or Elec. Eng. 255 or equivalent. (3).*
Analysis and synthesis of a.c. carrier systems. Operational amplifiers as control elements. Analysis and synthesis of elementary nonlinear control systems and sampled data. Behavior of linear systems in the presence of noise; introduction to autocorrelation methods; the Wiener-Hopf equation for optimum linear system design. Lectures and laboratory.

250. Theory of Oscillation of Nonlinear Systems. *Prerequisite: Math. 104 and a knowledge of elementary matrix theory. (2).*
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 to redevelopment of linear ordinary differ-

ential 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: preceded or accompanied by 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.

262. Combustion and Flame Propagation. *Prerequisite: permission of instructor. (2).*
The fluid dynamic and thermodynamic relationships governing the propagation of combustion waves are derived and applied to deflagrations and detonations. Emphasis is placed on the close connection that exists between the hydrodynamics of burning mixtures and the heat release of chemical reactions.

273. Theory of Linear Time-Variant Systems. *Prerequisite: Math. 148. (2).*
Linear time-variant systems with a finite number of degrees of freedom; general theory of linear dynamical systems, Green's function, adjoint systems, perturbation equations and methods, Floquet theory, the Brillouin-Wentzel-Kramers method, matrix methods, the time-variant impulse response and transfer function, operational methods, and computer techniques. Applications to automatic control and filtering. Use of the electronic differential analyzer for the solution of problems is demonstrated.

275. Applications of the Differential Analyzer II. *Prerequisite: Aero. Eng. 175 or equivalent. (2).*
Differential analyzer solutions of a wide variety of static and dynamic engineering problems. Solution of linear and nonlinear automatic control problems. Simulation of the six degree-of-freedom dynamic rigid body equations. Solution of linear and nonlinear partial differential equations using eigenvalue and difference techniques. Error analysis of differential analyzer solutions. Lecture and laboratory.

310. Seminar in Aerodynamics. *(Arranged).*

330. Seminar in Structures. *(Arranged).*

340. Seminar in Mechanics of Flight. *(Arranged).*

360. Seminar in Propulsion. *(Arranged).*

370. Seminar in Instrumentation. *(Arranged).*

BACTERIOLOGY*

Professor Nungester, Associate Professors Gerhardt and Kempe; Assistant Professors Blumenthal, Johnson, Merchant, Murphy, Preston, Rajam, and Wheeler; Instructors Callahan, Garrison, Heath, and Whitehouse.

109. Bacteriology for Engineers. *Prerequisite: Org. Chem. 61.* I. *(4-2).*
Lectures and laboratory. Principles and techniques of microbiology with an introduction of their application to the several fields of engineering.

151. Bacterial Physiology. II. *(4-2).*
Lectures and laboratory. Study of the composition and function of bacterial cells.

156. Bacterial Metabolism. *Prerequisite: Bact. 101 and Biochem. 110. (4-2).*
Lectures and laboratory. Presentation of principles and methods for study of bacterial metabolism.

160. Industrial Bacteriology. *Prerequisite: Bact. 109.* II. *(2).*
Lectures and laboratory to illustrate the applications of microbiology in industry.

BUSINESS ADMINISTRATION†

Professors Dixon, Dykstra, Moore, Schlatter, and Woodworth; Associate Professors Gardner and Rewoldt; Assistant Professors Pilcher and Southwick; Lecturer Hann 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:

1. No student shall elect courses in the School of Business Administration who does not have at least third-year standing (sixty credit hours). This does not apply to B.A. 11 and B.A. 12, which are listed as sophomore-level courses in the economics department.
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. *(3).*
12. Principles of Accounting. *(4).*
14. Industrial Cost Accounting. *(3).*
22. Statistical Method. *(3).*
61. Money and Banking. *(3).*
62. Financial Principles. *(3).*

* Medical School.
† School of Business Administration.

105. Business Law. *(3).*
106. Business Law. *(3).*
141. Production Management. *(3).*
142. Personnel Administration. *(3).*
151. Marketing Principles and Policies. *(3).*

CHEMICAL AND METALLURGICAL ENGINEERING

1. Engineering Materials and Processes. *Prerequisite: Chem. 3 or one year of high school chemistry validated by a satisfactory grade on the chemistry placement test given during orientation period, or Chem. 4. Preceded or accompanied by Math. 13 or 33. (3).*

An introductory course of study of materials used by the engineer. Attention is given to the factors such as structure and service conditions which govern the properties and behavior of metallic, ceramic, and plastic materials. Required of all engineering students in the "T" schedule. Two lectures and two recitations.

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.

11. Cast Metals. *Prerequisite: preceded or accompanied by Math. 54. (2).*

For mechanical and industrial engineering students. Melting and refining of cast metals including charge calculations and cost analysis; development of proper mold design based upon heat transfer calculations. Quality control exercises using magnaflux and radiographic inspection. Precision casting methods, foundry layout, and operation are also investigated. One lecture and one three-hour laboratory period.

12. Processing of Cast Metals. *Prerequisite: preceded or accompanied by Math. 54. (3).*

For students in other than metallurgical engineering. Quantitative study of the operations of melting, molding, cleaning, as well as exercises in quality control. Melting experiments include investigation 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.

13. Processing of Cast Metals. *Prerequisite: preceded or accompanied by Math. 54. (2).*

For metallurgical engineering students. Quantitative study of the operations of smelting, 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.

16. Measurements Laboratory. *Prerequisite: Chem. 23, preceded or accompanied by Chem. 182. (3).*
Physicochemical 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: Chem.-Met. Eng. 107. (2).*
Survey of fundamental mechanisms controlling the properties of metallic solids; their crystallography; elastic and plastic properties; electrical, thermal, and mechanical properties.

103. Research in Cast Metals and Foundry Processes. *Prerequisite: Chem.-Met. Eng. 11, 12, or 13. (3).*
An opportunity for the student to participate in research in problems of importance to the cast metals industry. Both short individual investigations and 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.

104. Air Pollution by Combustion Processes. *Prerequisite: enrollment in Air Pollution Curriculum or permission of program adviser.* I. *(2).*
Combustion of fuels of all types and effects of combustion variables and chemical constituents on exhaust products.

105. Fuels and Chemical Equilibrium in Combustion. *Prerequisite: Mech. Eng. 105 or Chem.-Met. Eng. 2. (3).*
Chemical properties of jet fuels, rocket fuels, and oxidizers, computation of propulsive performance under equilibrium conditions, kinetics of reactions.

107. Metals and Alloys. *Prerequisite: Chem.-Met. Eng. 1 and Mech. Eng. 2. (3).*
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.

107a. Metals and Alloys Laboratory. *(1).*
May be elected only in conjunction with Chem.-Met. Eng. 107. One laboratory period of three hours.

111. Thermodynamics. *Prerequisite: Chem.-Met. Eng. 2 and Math. 54. (3).*
Laws of energy applied to continuous or flow processes, chemical equalibria, properties of materials and solutions, heat, work, and the concept of availability.

113. Unit Operations I. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 111. (4).*
Equipment and theory of unit operations and their applications.

114. Unit Operations. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 111. (4).*
Unit operations in the field of metallurgical engineering.

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

116. Measurements and Instrumentation for Pollution Control. *Prerequisite: enrollment in Air Pollution Curriculum or permission of program adviser.* II. *(3).*
A study of methods of sampling, identification, and measurement of the constituents of air pollution.

117. Metals and Alloys. *Prerequisite: Chem.-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. 182. (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: Chem.-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 Chem.-Met. Eng. 115 or 119. (3).*
The student designs and estimates cost of selected equipment.

122. Ceramic Materials. *Prerequisite: physical chemistry or permission of instructor. (4).*
The nature, preparation, and properties of ceramic materials. Lectures, recitations, and laboratory.

123. Survey of the Unit Operations. *Prerequisite: calculus, senior or graduate standing. (2).*
A survey of the unit operations of chemical engineering, including fluid flow filtration, distillation, heat transfer, and mass transfer. Not open to students in chemical or metallurgical engineering.

124. X-ray Studies of Engineering Material. *Prerequisite: Chem.-Met. Eng. 16 and 118. (3).*
Radiography, investigation of welds and castings; diffraction studies of metals and alloys. Lectures, recitations, and laboratory.

125. Introduction to High Polymers. *Prerequisite: organic chemistry, physical chemistry, or permission of instructor. (4).*
Preparation, properties, and utilization of polymeric materials. Lectures, recitations, and laboratory.

126. Electron Microscopy. *Prerequisite: Chem.-Met. Eng. 16 or senior or graduate standing in engineering or science. (3).*
Theory, techniques, and applications of electron microscopy. Laboratory instruction in the preparation of specimens, operation of the microscope, and interpretation of micrographs. An opportunity will be provided for laboratory work on problems of interest to individual students.

127. Physical Metallurgy I. *Prerequisite: Chem.-Met. Eng. 118. (4).*
Structures and properties of metals as related to composition and thermal and mechanical treatment. Lectures, recitations, and laboratory.

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

129. Engineering Operations Laboratory. *Prerequisite: Chem.-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: Chem.-Met. Eng. 115 and 117. (3).*
Application of chemistry and the unit operations to the design of chemical processes.

131. Industrial Processes and Wastes. *Prerequisite: enrollment in Air Pollution Curriculum or permission of program adviser.* II. *(2).*
Discussion and problems concerning industrial process variables which influence the emission of air contaminants; modification of waste products and by-products by changes in process equipment and its operation.

136. Protective Coating—Pigments. *Prerequisite: Chem. 61R and 183.* II. *(3).*
Pigments, stains, and dyes, their manufacture, properties, and use in protective coatings.

137. Protective Coatings—Vehicles and Driers. *Prerequisite: Chem. 61 and 183.* I. *(3).*
Production, properties, and uses of natural and synthetic oils, thinners, and diluents.

147. Metals for Process Equipment. *Prerequisite: physical chemistry. (3).*
Structures and properties as affected by composition and mechanical or thermal treatment; their resultant mechanical properties and behavior in service.

148. Metallurgy of Joining. *Prerequisite: Chem.-Met. Eng. 117 or 127 or 147. (3).*
The effects of the joining of metals on the mechanical, physical, and chemical properties of the structures. Special emphasis on the roles of solid phase transformations, liquid state reactions, properties of metallic surfaces, and residual stresses in joining processes.

202. Advanced Chemical Engineering Calculations. *Prerequisite: Chem.-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.

204. Polymerization Processes. *Prerequisite: Chem.-Met. Eng. 125. (3).*
Mechanisms of polymerization, copolymerization, and degradation; effects of reaction variables on molecular weight, molecular weight distribution, branching, and crosslinking. Lectures, recitations, and laboratory.

205. Combustion. *Prerequisite: Chem.-Met. Eng. 105 or 115 or Mech. Eng. 112. (3).*
Fundamentals of deflagration and detonation, with emphasis on the chemical aspects. Applications of combustion to industrial processes and propulsive devices.

207. Metals at High Temperatures. *Prerequisite: Chem.-Met. Eng. 107, 117, or 127. (3).*
Fundamental principles determining the behavior of metals at high tem-

peratures and the selection and performance of alloys in such applications as jet-propulsion engines, gas turbines, chemical industries, and steam power plants.

208. Structures and Properties of High Polymers. *Prerequisite: Chem.-Met. Eng. 125. (3).*
Properties of polymeric materials in relation to the molecular and structural characteristics of the polymer, the behavior of compounding agents, and the conditions of fabrication. Lectures, recitations, and laboratory.

209. Thermodynamics of Metallurgical Processes. *Prerequisite: Chem.-Met. Eng. 111. (3).*
Laws of thermodynamics and statistical mechanics applied to metallurgical systems. Emphasis on nonideal solid solutions, order-disorder transformations, and multicomponent systems.

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: Chem.-Met. Eng. 111. (3).*
Principles of the laws of energy as applied to chemical and metallurgical engineering problems.

212. Equilibrium Stage Operations. *Prerequisite: Chem.-Met. Eng. 115, preceded or accompanied by Chem.-Met. Eng. 121. (3).*
Design of multicomponent separation systems, including liquid-liquid extraction, distillation, and gas absorption, with primary emphasis on the equilibrium stage concept.

213. Rate Operations. *Prerequisite: Chem.-Met. Eng. 115. (4).*
Chemical reactions, transport of material, heat transfer, mass transfer, and momentum transfer.

215. Rate Operations Design. *Prerequisite: Chem.-Met. Eng. 213. (3).*
Simultaneous rate operations and process design.

216. Engineering Experiments and Their Design. *Prerequisite: Chem.-Met. Eng. 129. (3).*
Economical design of experiments, analysis of experimental data, errors of measurement, limitations of equipment. Subjects considered involve procedures of particular interest to chemical and metallurgical engineers, such as optical and electron microscopy, determination of properties of high polymers, particle size measurements, micro-hardness tests, pyrometry, endurance, chemical and spectroscopic analysis. Lecture, recitation, laboratory.

217. Corrosion and High-Temperature Resistance of Metals. *Prerequisite: Chem.-Met. Eng. 107 or 117. (3).*
Fundamentals involved in choosing a metal for use in oxidizing or corroding media or at elevated temperatures.

218. Theoretical Metallurgy. *Prerequisite: Chem.-Met. Eng. 124. (3).*
Electron theory of metals, zone theory of metals, theory of alloying, rate processes, dislocation and imperfection theories, diffusion, polygonization and recrystallization, grain boundaries, nucleation and growth.

219. Metallurgical Operations. *Prerequisite: Chem.-Met. Eng. 107 or 127. (3).*
Rolling, forging, extrusion, piercing, drawing, and straightening.

220. Chemical Plants, Design, Operations, and Production Control. *Prerequisite: Chem.-Met. Eng. 130 or by special permission. (3).*
The evaluation of research and development data, integration, and selection of optimum unit operations for chemical plants, preparation of equipment design calculations. Design data, utilities requirements, plant operating instructions, plant startup, operation and shutdown, and engineered control of production costs. Lectures, problems, and recitations.

221. Equipment Design for Advanced Engineering Students. *Prerequisite: Chem.-Met. Eng. 115. (3).*
The design of chemical and petrochemical process equipment involving heat transfer and mass transfer. Process computations, stress considerations, corrosion problems and material selections, fabrication methods, assembly and maintenance problems. Equipment evaluation and estimates. Lectures, designs, and reports.

224. X-ray Studies of Engineering Materials. *Prerequisite: Chem.-Met. Eng. 124.* II. *(3).*
Application of X-ray methods to the study of age hardening, cold working, and phase changes.

227. Nuclear Metallurgy. *Prerequisite: Chem.-Met. Eng. 117 or 127 or 147. (3).*
The physical process and mechanical metallurgy of the primary metals used in nuclear reactors: uranium, plutonium, thorium, and their fission products. Container metals, fuel elements, moderators, control elements, liquid metals.

228. Nonferrous Metals. *Prerequisite: Chem.-Met. Eng. 128. (3).*
Ternary systems, solution and precipitation, plastic deformation, recrystallization, grain growth. Lectures, recitations, and laboratory.

231. Explosives. *Prerequisite: Chem. 161R and Chem.-Met. Eng. 130. (3).*
Manufacture of commercial and military explosives and pyrotechnic materials, their properties and uses.

232. Process Engineering of Polymer Plants. *Prerequisite: Chem.-Met. Eng. 114 or 115 and 117, or permission of instructor. (3).*
Processing methods for production of polymers from raw materials. Design of plants for manufacture of materials such as polystyrene, cellulose plastics, nylon, and rubbers.

235. Petroleum Engineering. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 130.* I. *(3).*
Properties of petroleum gases and liquid under pressure, the production and processing of natural gas and crude oil.

237. Synthetic Resins and Emulsions. *Prerequisite: Chem.-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 pharma-

ceuticals and industrial chemicals, and industrial waste disposal. Lectures, seminars, and field trips.

239. Food Processing. *Prerequisite: organic chemistry and Chem.-Met. Eng. 115 or permission of instructor. (3).*
Chemistry of food and food processing methods. Lectures, seminar, and field trips.

240. Metal Reactions in Melting and Refining. *Prerequisite: Chem. 183, Chem.-Met. Eng. 119. (4).*
Experiments concerning reactions during melting, refining, and solidification of ferrous and nonferrous metals. Experiments include gas-metal and refractory slag-metal reactions in a variety of furnaces including cupola, direct arc electric, vacuum induction, as well as vacuum fusion analyses. Lectures, calculations, and laboratory.

241. Cast Iron and Steel. *Prerequisite: Chem.-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 gray irons; selection of cast metals for specific purposes.

242. Steels. *Prerequisite: Chem.-Met. Eng. 128. (3).*
Theory and practice of alloy additions to steel and the effect of alloying elements on properties of steel.

243. Powder Metallurgy. *Prerequisite: Chem.-Met. Eng. 107, 117, or 127. (3).*
Characteristics and properties of metal powders, principles of compacting, physical metallurgy, and theories of sintering. Lectures, recitation, laboratory.

244. Cast Metals in Engineering Design. *Prerequisite: Chem.-Met. Eng. 117, 127, or permission of instructor. (3).*
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.

247. Nuclear Metallurgy Laboratory. *Prerequisite: Chem.-Met. Eng. 227. (3).*
The metallurgical examination and testing of radioactive materials by specialized remote techniques. Metallography, X-ray diffraction, mechanical, thermal, and electrical properties investigations.

251. Furnace Design and Construction. *Prerequisite: Chem.-Met. Eng. 114 or 115. (3).*
Furnace atmosphere, refractory materials, and their application in the design of furnaces.

254. Heavy Chemicals. *Prerequisite: Chem.-Met. Eng. 129 and 130.* I. *(3).*
Design study of selected heavy chemical manufacturing processes and the design of major equipment.

255. Petrochemical and Refining Processes. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 211. (4).*
Designs and economic studies of selected petrochemical and refining processes.

256. Small Particles and Suspensions. *Prerequisite: Chem.-Met. Eng. 113 or 123, or Eng. Mech. 4, or permission of instructor. (3).*
Physical and chemical properties of small particles, properties and flow of

suspensions, and engineering principles of equipment for handling such material. Includes measurement techniques, conveying and separation equipment, sprays, and dusts.

258. Electrochemical Operations. *Prerequisite: Chem. 183 and Chem.-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 Chem.-Met. Eng. 136 or 137.* I. *(4).*
Analysis, physical testing, and manufacture. Conferences and laboratory.

311. Applied Thermodynamics. *Prerequisite: Chem.-Met. Eng. 211. (3).*
Advanced analytical study of chemical engineering processes from the standpoint of quantitative thermodynamics.

315. Advanced Distillation Calculations. *Prerequisite: Chem.-Met. Eng. 211. (3).*
Design of distillation equipment for multicomponent and nonideal separation processes.

328. Physical Metallurgy Seminar. *Prerequisite: Chem.-Met. Eng. 228. (2).*

336. Paint, Varnish, and Lacquer Formulation. *Prerequisite: Chem.-Met. Eng. 237. (5).*
Economic formulation, manufacture, and uses.

337. Varnish. *Prerequisite: Chem.-Met. Eng. 237.* I. *(3).*
Formulation, manufacture, and uses of natural and synthetic resin, varnish, and wax.

342. Applied Physical Metallurgy. *Prerequisite: Chem.-Met. Eng. 242.* I. *(3).*
Processing and service failures.

355. Petroleum Seminar. *Prerequisite: Chem.-Met. Eng. 235 or 255. (2).*
Individual study of advanced topics in production, commercial natural gas, refining and petrochemical processes. Seminar and reports.

363. Heat Transfer Seminar. *Prerequisite: Chem.-Met. Eng. 213. (2).*

365. Mass Transfer Seminar. *Prerequisite: Chem.-Met. Eng. 213. (2).*

CHEMISTRY*

Professors Anderson, Brockway, Elderfield, Elving, and Halford; Associate Professors Bernstein, Case, Meinke, Parry, Rulfs, Smith, Tamres, Vaughan, and Westrum; Assistant Professors Bigelow, Geiduschek, Nordman, Stiles, Taylor, and Weatherill; Dr. Atkinson, Dr. Berry, Dr. Gordus, Dr. Hartzler, Dr. Ireland, Dr. Jaselskis, Dr. Schilt, and Dr. Warnell.

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.

* College of Literature, Science, and the Arts.

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, metallurgical, or materials 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, 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, three recitations, and four hours of laboratory.

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 planning to enter the curriculum in chemical, metallurgical, or materials 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.

8. Inorganic Chemistry and Qualitative Analysis. *Prerequisite: Chem. 3 with a grade of A or high B.* II. *(5).*
Ionic equilibrium, descriptive chemistry of the metallic elements, and qualitative analysis of the metallic ions. Three lecture-recitation periods and eight hours of laboratory.

14. Unified Chemistry. *Prerequisite: Physics 53.* II. *(4).*
The properties of matter discussed from the viewpoint of dynamics: discussions of thermodynamic functions, kinetic theory, and chemical kinetics. Lectures, recitations, laboratory.

15. Unified Chemistry. *Prerequisite: Chem. 14 and Physics 54.* I. *(4).*
Properties of matter from the viewpoint of atomic structure, including periodic relationships; organic and inorganic chemistry. Lectures, recitations, laboratory.

20. Qualitative Analysis. *Prerequisite: Chem. 4 or 5E.* I and II. *(3).*
The physicochemical treatment of ionic equilibria with applications to the identification of inorganic substances. Recitation and laboratory.

23. Introductory Analytical Chemistry. *Prerequisite: Chem. 4.* 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. 8 or 20.* I and II. *(4 required).*
A survey of the theory and practice of volumetric, gravimetric, electrometric, and colorimetric analysis. Systematic analysis of complex materials. Two lectures, one recitation, and two four-hour laboratory periods.

61. Organic Chemistry. *Prerequisite: Chem. 3 and 4, or 5E and 20, or 8.* I and II. *(6).*
Survey of the whole field of organic chemistry. Four lectures, one recitation, and seven hours of laboratory.

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. 183.* I. *(2).*
Elementary treatment of the fundamentals of the subject. Two lectures.

182. Physical Chemistry. *Prerequisite: Chem. 41, Physics 26, and Math 54.* I and II. *(3).*
Atomic concepts of matter and energy, nature of the gaseous, liquid, solid states, thermochemistry and thermodynamics. Lecture.

183. Physical Chemistry. *Prerequisite: Chem. 182.* I and II. *(3).*
Homogeneous and heterogeneous equilibria, kinetics, electrochemistry, solution theory, photochemistry, and colloids. Lecture.

188. Physical Chemistry. *Prerequisite: Chem. 20 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.

235. Nuclear Chemical Techniques. *Prerequisites: Chem. 107 and 183 or Physics 197 or Nuclear Engineering 191 or permission of instructor.* II. *(2).*
A laboratory course illustrating measurement, manipulatory, and safety techniques and equipment used with radioactive isotopes at the microcurie, millicurie, and multicurie levels: includes radiochemical separations, weak beta emitter (C^{14}) work, typical tracer experiments and use of high-level handling facilities.

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. Basic Surveying. *Prerequisite: Math. 13.* Camp Davis. S.S. *(4).*
Care, adjustment, and use of basic surveying instruments; leveling, taping, horizontal angle measurement, traverse surveys; circular curve theory and applications, co-ordinate computation, use of calculating machines.

2. Route Surveying. *Prerequisite: Civ. Eng. 1 or 4 and preceded or accompanied by Math. 14.* I and II. *(3).*
Vertical and horizontal alignment, including parabolic curves and spiral easement curves, sight distances, etc., developed from basic mathematical principles and applied to specific problems in modern practice; earthwork principles and practice; study of topographic mapping, including applications of photogrammetry to route location.

3. Advanced Surveying. *Prerequisite: Civ. Eng. 2.* I and II. *(3).*
Triangulation, local control surveys, astronomical observations, Public Land surveys. Computation and adjustment, field observations.

4. **Basic Surveying.** *Prerequisite: Math. 13.* I and II. *(2).*
For noncivil engineering students or those having permission of program adviser. Care, adjustment, and use of basic surveying instruments; leveling, taping, horizontal angle measurement, traverse surveys; circular curves, computation, use of calculating machines.

5. **Surveying Problems.** *Prerequisite: Civ. Eng. 4 or approximate equivalent.* I and II. *(2).*
A short course for students with surveying experience to prepare them for further work in surveying, such as Civ. Eng. 2 or 3.

12. **Surveying.** *Prerequisite: Math. 13. (3).*
Similar to Civ. Eng. 1. Designed for forestry students.

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.

21. **Theory of Structures.** *Prerequisite: Eng. Mech. 2.* I and II. *(3).*
Not open to civil engineering students. Analysis of stresses in simple and continuous structures; calculation of reactions, shear, and bending moment due to fixed and moving loads; design of steel, reinforced concrete, and wood structures. Discussion of framing plans.

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.

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, drawing work, and laboratory experiments.

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.

52. **Water Supply and Treatment.** *Prerequisite: Eng. Mech. 4. (3).*
Sources of water supply, quality and quantity requirements, design fundamentals of works for development, collection, purification and distribution of water.

53. **Sewerage and Sewage Treatment.** *Prerequisite: Civ. Eng. 52. (2).*
Requirements of residential and municipal sewerage systems, procedures for the design and construction of sewerage and sewage treatment works.

65. **Transportation Engineering.** *Prerequisite: Civ. Eng. 2.* I and II. *(3).*
Planning, location, design, construction, and maintenance of inland transportation facilities. Introduction to transportation economics.

90 **(formerly Civ. Eng. 80). Introductory Meteorology — Weather.** *Prerequisite: preceded or accompanied by Math. 7 or equivalent.* I and II. *(4).*
Wind and storm systems, cloud and precipitation, and other weather processes as revealed by meteorological research, with an elementary discussion of weather instruments and forecasting. Lectures, laboratory, and field trips.

91 **(formerly Civ. Eng. 81). Introductory Meteorology — Climate.** *Prerequisite: Civ. Eng. 90.* I and II. *(4).*
Climatic elements, controls, and regimes with a discussion of their distribution, classification, and fluctuation, and of the significance of climatic influences in the modern world. Lectures and laboratory.

92 (formerly Civ. Eng. 82). Weather, Climate, and Life. *Prerequisite: not open to first-semester freshmen nor to students who have taken Civ. Eng. 90.* I and II. *(4).*
An elementary description of the atmosphere, its characteristics and behavior; weather and climate as basic factors in life and civilization.

101. Geodesy. *Prerequisite: Civ. Eng. 3. (3).*
Introductory course; history; elements of modern practice and its application to several branches of surveying.

102. Geodesy. *Prerequisite: Civ. Eng. 101. (2).*
Methods employed and field covered by the United States Coast and Geodetic Survey.

105. Least Squares. *Prerequisite: Math. 54. (2).*
Theory of least squares; adjustment and comparison of data.

106. Advanced Surveying. *(To be arranged).*
Special advanced work can be provided for those who have received credit in Civ. Eng. 3.

107. Municipal Surveying. *Prerequisite: Civ. Eng. 3. (2).*
Surveys for streets, grades, paving, sewers, property lines, subdivisions.

113. Aerial Photogrammetry and Mapping. *Prerequisite: preparation in trigonometry and physics. (2).*
Map projections and map making from aerial photographs.

115. Boundary Surveys. *Prerequisite: Civ. Eng. 1 or equivalent. (3).*
Problems relating to the establishment of land boundaries, including study of special legal phases which confront the land surveyor; basic principles of the U. S. Public Land System.

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: Civ. Eng. 22.* I and II. *(3).*
Properties of materials; stress analysis and design of reinforced concrete structures; introduction to prestressed concrete and ultimate strength analysis. Lectures, problems, laboratory.

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.

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.

125 (formerly Civ. Eng. 230). Prestressed Reinforced Concrete. *Prerequisite: Civ. Eng. 23 and 121.* II. *(2).*
Fundamental principles of prestressing; prestress losses due to shrinkage, elastic action, plastic flow, creep, etc.; stress analysis and design of prestressed concrete structures.

127. Timber Construction. *Prerequisite: Civ. Eng. 23.* I. *(1).*
Physical characteristics of structural woods; grading rules; design of timber structures.

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.

132. Construction Methods and Equipment. II. *(3).*
Open to seniors and graduates. Contractors' organizations; plant selection and layout; equipment studies; methods of construction.

133. Estimating Practice. *Prerequisite: preceded or accompanied by Civ. Eng. 131.* I. *(1).*
Laboratory practice in the estimating and pricing of construction work. Quantity surveys, unit costs of labor and material, indirect costs.

135. Engineering Properties of Soil. *Prerequisite: Eng. Mech. 2 and 4.* 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; highway and airport construction.

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, Atterberg limits, shrinkage and expansion; measurement of physical properties, direct shear, unconfined and triaxial compression and internal stability; compaction characteristics; soil surveys and soil mapping.

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.

141. Hydraulics. *Prerequisite: Eng. Mech. 4.* I and II. *(2).*
Hydrostatic stability; orifices and weirs; Venturi meters; cavitation; pump characteristics; flow in pipes and fittings; unsteady-uniform flow; steady-nonuniform flow. Lecture, laboratory, and computation.

142. Water-Power Engineering. *Prerequisite: Eng. Mech. 4.* II. *(2).*
Design factors in turbines; fundamental principles of water-power development; selection of turbines; storage and pondage; surge in pipe lines; water hammer.

143. Flow in Open Channels. *Prerequisite: Civ. Eng. 141 or equivalent.* I and II. *(3).*
Laminar and turbulent flow; rapidly varied flow; subcritical and supercritical flow; transitions; channel controls; gradually varied flow; translatory waves.

144. Advanced Hydraulics. *Prerequisite: Civ. Eng. 141, preceded or accompanied by Civ. Eng. 143.* I. *(3).*
Two-dimensional potential flow; the flow net; percolation and hydrostatic uplift; side-channel spillways; boundary-layer; hydraulic similitude; hydraulic models; stilling pools.

145. Seminar in Hydraulic Engineering. *Prerequisite: Civ. Eng. 140 and 143.*
Lectures, assigned reading, and student reports on problems selected from the field of hydraulic engineering.

146. Hydraulic Engineering Design. *Prerequisite: Civ. Eng. 121 and 140; preceded or accompanied by Civ. Eng. 143.* II. *(3).*
Design of hydraulic structures such as diversion dams, head gates, control works, silt traps, siphon spillways, side-channel spillways, earth canals, and other structures involving accelerated flow, backwater, hydraulic jump, sedimentation, and erosion.

152. Water Purification and Treatment. *Prerequisite: Civ. Eng. 52 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 objectives. Lectures, library reading, and visits to municipal water purification plants.

153. Sewerage and Sewage Disposal. *Prerequisite: Civ. Eng. 53 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, 52, and 53. (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.

156. Sanitary Engineering Laboratory. *Prerequisite: Civ. Eng. 52, 53 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 permission 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. 65.* 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. 65.* I. *(3).*
Sources, production, and testing of highway materials; specifications; minor research problems.

162. Bituminous Materials and Pavements. *Prerequisite: Civ. Eng. 65.* II. *(2).*
Selection of bituminous materials for various uses; pavement types; design of mixtures; construction and maintenance methods.

163. Soils in Highway Engineering. *Prerequisite: Civ. Eng. 135 and 136. (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 materials surveys.

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. *Prerequisite: restricted to senior and graduate students. (2).*
Characteristics of highway traffic and driver behavior, traffic control and regulation, highway safety, traffic organization and administration.

166. Traffic Engineering. *Prerequisite: Civ. Eng. 65, or permission of instructor.* II. *(3).*
Principles of highway traffic flow, traffic surveys and planning, analysis and presentation of data, traffic design.

167. Highway Economics. *Prerequisite: Civ. Eng. 65.* II. *(2).*
Principles of engineering economics applied to highway planning, location and design; highway finance, taxation and administration.

169. Highway Design. *Prerequisite: Civ. Eng. 65.* I and II. *(3).*
Studies of highway capacity, alignment, profiles, intersections, interchanges, and grade separations.

172. Railroad Maintenance. *Prerequisite: Civ. Eng. 65.* II. *(3).*
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. 65. (3).*
Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities.

174. Airport Design and Construction. *Prerequisite: Civ. Eng. 135 and 136. (To be arranged).*
Selected problems in 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.

176. Economics of Railroad Construction and Operation. *Prerequisite: Civ. Eng. 65.* 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.

178. Transportation. *Prerequisite: principles of economics.* I. *(3).*
Transportation facilities, services, and policies, with emphasis on comparative performance of the various agencies of transport.

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, discussion.

183. Public Utility Problems. II. *(2).*
Nature of public service corporations; organization; ownership; valuation; depreciation; accounting; regulations; taxation; rates.

190 (formerly Civ. Eng. 185). Physical Meteorology. *Prerequisite: Math. 54 and Physics 26 or equivalent.* I. *(2).*
Composition of the atmosphere; atmospheric statics; thermodynamic diagrams; solar and terrestrial radiation; the heat balance of the earth; cloud and precipitation physics; thunderstorm structure and electricity. Lectures, recitation, and problems.

191 (formerly Civ. Eng. 188). Dynamic Meteorology. *Prerequisite: Math. 54 and Physics 46 or equivalent.* II. *(3).*
The stratification of the atmosphere; the hydrostatic equation; virtual temperature; the equations of motion; barotropy and baroclinicity; stream function; circulation and vorticity; gradient wind; thermal and isallobaric wind components; local change of pressure; atmospheric turbulence and turbulent transfer processes; the jet stream; weather prediction by high-speed computing methods.

192 (formerly Civ. Eng. 281). Synoptic Meteorology. *Prerequisite: Civ. Eng. 190 or 191. (3).*
Air mass analysis, representative and conservative properties, types of hydrometeors; detailed three-dimensional structure of fronts and pressure systems; principles of construction of prognostic pressure charts; procedures for forecasting the weather elements; the verification of weather forecasts. Lectures and problems.

193 (formerly Civ. Eng. 282). Laboratory in Synoptic Meteorology. *Prerequisite: preceded or accompanied by Civ. Eng. 192. (3).*
Application of air mass analysis principles to the preparation of weather maps at various levels in the atmosphere; the use of thermodynamic diagrams in forecasting problems; the construction of prognostic pressure charts and atmospheric cross sections; practice weather forecasts and their verification.

194 (formerly Civ. Eng. 184). Micrometeorology I. *Prerequisite: restricted to senior and graduate students.* I. *(3).*
The physical processes which govern microweather and microclimate; temperature, humidity, and wind near the ground in relation to height, time, soil, vegetation, and topography. Lectures and field experiments.

195 (formerly Civ. Eng. 187). Physical Climatology. *Prerequisite: Civ. Eng. 90 and 91, or 190 or 191.* I. *(3).*
A survey of the general circulation of the atmosphere; the physical processes governing climate; solar radiation and the terrestrial heat balance; influence of

large scale condensation and evaporation processes; the formal classification of climates according to zones and types; the application of climatic concepts. Lectures and exercises.

196 (formerly Civ. Eng. 186). Applied Meteorology. *Prerequisite: Civ. Eng. 90 or 190.* II. *(2).*
Topics in applied meteorology, selected in accordance with the requirements of the class. Representative topics: meteorological aspects of atmospheric pollution; wind and snowloading of buildings and bridges; weather and climate as elements in plant, animal, and human ecology; weather in business and industry.

198 (formerly Civ. Eng. 189). Meteorological Instrumentation. *Prerequisite: Physics 26 or its equivalent. Restricted to seniors and graduate students.* I. *(3).*
Principles of meteorological instruments; methods of measurement of pressure, temperature, humidity, precipitation, evaporation, and wind. Lectures and laboratory exercises.

199. Micrometeorological Instrumentation. *Prerequisite: preceded or accompanied by Civ. Eng. 194 or 198.* II. *(2).*
Analysis of requirements for instrumentation; measurement of radiation, temperature, humidity, and wind velocity near the ground and of their fluctuations and vertical gradients; exposure and ventilation of instruments in relation to soil, terrain, vegetation, and water surfaces. Lectures, laboratory, and field studies.

210. Geodesy and Surveying Research. *Prerequisite: Civ. Eng. 101. (To be arranged).*
Assigned work in geodesy, or other special field in surveying of interest to the student and approved by the professor of geodesy and surveying.

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. (3).*
Design and analysis of special types of reinforced concrete structures.

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.

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. *Prerequisite: Civ. Eng. 124.* II. *(3).*
Continuous truss bents; hinged and fixed arches; rings; frames with curved members; flexible members including suspension bridges; frames with semirigid connections.

225. Structural Engineering Seminar. I and II. *(1).*
Preparation and presentation of reports covering assigned subjects.

226. Metal Structures. II. *(3).*
Yield, fracture, and fatigue failure of metals. Plastic or "limit" analysis and design of metal structures. Local buckling and the design of compression plate elements and stiffeners of columns and girders.

227. Bridge Engineering Design. *Prerequisite: Civ. Eng. 123.* II. *(3).*
History of bridges; selection of the proper bridge structure for a given location with regard to economics, underclearance, site, foundation, erection, maintenance, aesthetics, safety, and financing.

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.

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).*
Stress-strain relations; strain gaging and strain-rosette analysis; structural test methods. Numerical stress analysis. Bending of flat plate with numerical analysis of special plate problems.

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. 143. (To be arranged).*
Assigned work in hydraulic research; a wide range of matter and method permissible.

243. Applied Hydromechanics. *Prerequisite: Civ. Eng. 143 or equivalent.* I. *(2).*
Problems in laminar flow; viscometry; the mechanics of turbulent flow; sedimentation; waves; high velocity flow in open channels; variable flow in open channels.

250. Sanitary Engineering Research. *(To be arranged).*
Assigned work upon some definite problem related to public sanitation; a wide range of 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.

251. Public Water Supply. II. *(3).*
Conservation and protection of sources of water supply; laws governing ap-

propriation and use of water resources as affecting both quantity 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.

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 Research.** *Prerequisite: permission of instructor.* I and II. *(To be arranged).*
Individually assigned work in the field of highway engineering.

262. **Advanced Bituminous Materials and Flexible Pavement Design.** *Prerequisite: Civ. Eng. 162. (To be arranged).*
Conferences and special problems on new developments in bituminous materials, bituminous mixture design, and flexible pavement design for highways and airports. Conferences, assigned reading, laboratory investigations, reports.

264. **Industrial Transport Management.** *Prerequisite: Civ. Eng. 178 or Econ. 133, or permission of instructor. (4).*
Analysis of industrial transportation requirements; classification, rates and tariffs; management of private transport services; organization of traffic department; regulatory procedures and practices.

265. **Transportation Planning.** *Prerequisite: Civ. Eng. 165 and 173, or permission of instructor. (3).*
Analysis of supply and demand for transportation services, transport relationships to land use and other elements of regional and urban planning, and planning techniques applied to transportation problems.

270. **Transportation Engineering Research.** *Prerequisite: permission of instructor.* I and II. *(To be arranged).*
Individual research and reports on library, laboratory, or field studies in the areas of transportation and traffic engineering.

280. **Civil Engineering Research.** I and II. *(To be arranged).*
Assigned work in the field of public utilities, or engineering relations and ethics. To obtain credit, a thesis must be prepared which would be acceptable for publication.

294 **(formerly Civ. Eng. 284). Micrometeorology II.** *Prerequisite: Civ. Eng. 190 and 194 or permission of instructor.* II. *(3).*
Laminar and turbulent flow in the atmosphere; transfer of matter, momentum, and heat; eddy diffusion; evaporation from natural surfaces. Lectures and problems.

295 **(formerly Civ. Eng. 285). Meteorological Research.** *(To be arranged).*
Assigned work in meteorological research; may include field measurements, analysis of data, development in physical or applied meteorology.

296 **(formerly Civ. Eng. 283). Laboratory in Applied Climatology.** *Prerequisite: Civ. Eng. 190 and 196 or equivalent.* I. *(3).*
Realistic interpretation of climatic information; space and time interpolation and extrapolation of climatic factors; combined effects of weather elements;

methods of determining the specific applications of climatic knowledge. Lectures and the analysis of practical examples.

297 (formerly Civ. Eng. 286). Interdepartmental Seminar on Applied Meteorology. *Prerequisite: Civ. Eng. 90 or 190 or 191 and 196, or permission of instructor.* I and II. *(1-3).*
Reading, preparation of term papers, and seminar discussion on various areas of applied meteorology. Course credit assigned each student at registration.

501. Meteorology for Teachers. *Prerequisite: upperclass or graduate standing or permission of instructor. Not open to engineering students. (2–3).*
Lectures, discussions, and workshop in the introduction and organization of meteorology subject matter in the science curriculum. Emphasis will be on the place of meteorology in the total school program, the interrelationships with other subject-matter fields and the planning of courses, units, and projects to fit into various individual programs. Included will be a survey of the type and sources of supplementary materials and the designing and equipping of facilities for projects, demonstrations, and laboratory and field exercises.

DRAWING (ENGINEERING)

The first-year requirements in engineering drawing may be fulfilled by Drawing 1 and 2, or 11 and 12, or 21 and 22. The student will elect whichever sequence is advised by the classifier. Drawing 21 and 22 are primarily for Schedule *S*.

1. Engineering Drawing. I and II. *(3).*
Use of instruments; lettering, geometric constructions, principles of orthographic projection, pictorial drawing, auxiliary views, sectional views and conventions, threads and fasteners, dimensioning, detail and assembly drawings.

2. Descriptive Geometry. *Prerequisite: solid geometry and Eng. Draw. 1.* I and II. *(3).*
Orthographic projection applied to the representation of points, lines, and planes in all possible relative positions, and the solution of problems involving the measurement of distances and angles; intersections of straight or curved lines with plane or curved surfaces, intersections of surfaces, tangent surfaces; size and shape of plane areas and development of curved surfaces. Emphasis is placed on analytical processes and the importance of neatness, accuracy, and systematic notation in graphical solutions.

11. Drawing and Engineering Geometry. *Prerequisite: solid geometry.* I and II. *(3).*
Use of instruments, lettering, geometric constructions, multiview drawings, auxiliary views, basic principles of descriptive geometry.

12. Engineering Drawing and Graphical Methods. *Prerequisite: Eng. Draw. 11.* I and II. *(3).*
Intersection and development of surfaces; pictorial drawings, sectional views and conventions; fasteners, dimensioning, and tolerances; detail and assembly drawings, piping and circuit diagrams, flow and process diagrams, freehand sketching; integration of areas and volumes by graphical methods.

21. Graphics and Engineering Geometry. *Prerequisite: solid geometry, preceded or accompanied by Math. 33 and Physics 53.* (Primarily for Schedule *S.*) I and II. *(3).*

Use of instruments; graphical analysis of physical and mathematical problems, probable accuracy of graphical solutions, representation of three variable systems by orthogonal projection; pictorial drawing, basic principles of descriptive geometry; introduction to graphical mathematics including graphical calculus and vectors.

22. Graphics and Engineering Drawing. *Prerequisite: Eng. Draw. 21, preceded or accompanied by Math. 34 and Eng. Mech. 11.* (Primarily for Schedule *S.*) I and II. *(3).*

Graphical techniques; graphical mathematics including solution of simple differential equations; graphical statics including simple equilibrium problems and vector operations; detail and assembly drawings, sectional views; standards, conventions, dimensioning.

32. Graphical Presentation and Computation. *Prerequisite: Eng. Draw. 2, 12 or 22, or permission of instructor.* 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.

33. Advanced Engineering Drawing. *Prerequisite: Eng. Draw. 2 or equivalent.* I and II. *(2).*

Advanced work in orthographic and pictorial representation including engineering sketching, machine drawing, working drawings, both detail and assembly, with emphasis on auxiliary views and tolerance dimensioning; piping and structural layouts; creating and planning engineering devices.

35. Production Illustration. *Prerequisite: Eng. Draw. 1 or its equivalent. (2).*

Various methods of making the pictorial drawings; use of production illustration; lettering, orthographic, axonometric, oblique, and perspective projections; sectional views, exploded views, and assembly views to illustrate how things are to appear when manufactured.

41. Mechanical Drawing for Foresters. II. *(1).*

Use of instruments, geometric constructions, lettering practice, orthographic projection, dimensioning, and elementary working drawings. As far as possible, drawing assignments are taken from material with which the forestry student will later have contact.

101. Mechanical Drawing for Industrial Arts and Vocational Education Teachers. *Prerequisite: an understanding of the basic principles of mechanical drawing. Not open to engineering students. (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 Ackley; Professors Boulding, Dickinson, Haber, Katona, Musgrave, Paton, Peterson, Remer, and Stolper; Associate Professors Brazer, Lansing, Levinson, Morgan, Palmer, and Suits; Assistant Professor Rousseas; Lecturers Anderson and Hayes. Department office, 107 Economics Building.

Economics 53 and 54 are introductory courses designed especially for students in the College of Engineering and are the usual 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, 173, 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. *Prerequisite: 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.

71, 72. Accounting. *Prerequisite: Econ. 71 is prerequisite to Econ. 72.* 71, I and II *(3)*; 72, I and II *(4).*

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).*

The background, development, and current aspects of the major problems of wage earners and labor relations. Economics 121 considers the labor force, its employment and unemployment, wages, hours, social security, and an introduction to trade unions. Economics 122 deals with union history, union structure and organization, the development of collective bargaining, labor disputes, labor law, and the significant issues in labor relations.

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.

*** College of Literature, Science, and the Arts.**

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. May be used as prerequisite for advanced courses with permission of course instructor. 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 or 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 Math. 54. (4).*
Direct-current and alternating-current circuits. Kirchhoff's laws, loop and node equations, network theorems. Alternating-current wave forms, effective and average values, instantaneous and average power. Single phase circuits, resonance, complex operator, polyphase circuits, ideal transformers. Two lectures, one four-hour computing period, and one four-hour laboratory period.

4. **Direct-Current Machinery.** *Prerequisite: Elec. Eng. 3. (2).*
Dynamo structure, analysis of the magnetic circuit; motor and generator operating characteristics, losses and heating, armature windings, commutation; special d.c. machines such as the Rosenberg generator and the amplidyne. One lecture and one four-hour laboratory.

5. **Direct- and Alternating-Current Apparatus and Circuits and Electronics.** *Prerequisite: Math. 54 and Physics 46. (4).*
Electric circuits; direct- and alternating-current motors and generators; electron ballistics, tubes, and R-C coupled amplifiers. Three lectures and one three-hour laboratory period.

7. **Motor Control and Electronics.** *Prerequisite: Elec. Eng. 5. (4).*
Direct- and alternating-current motors and control equipment; electronic tubes and circuits including industrial types. Not open to electrical engineering students. Three lectures and one four-hour laboratory period.

8. **Circuits.** *(4).*
Review of direct-current and alternating-current circuits and machinery. A

special course for the guided-missile program. Not open to electrical engineering students.

9. Network Analysis. *Prerequisite: preceded or accompanied by Math. 56. (3).*
Analysis of resistive, inductive, and capacitive circuits, direct current, transient and sinusoidal steady-state solution. Phasor and complex number analysis techniques. Superposition and reciprocity; mesh and nodal analysis; Thevenin's and Norton's theorems; maximum power transfer. Coupled circuits and transformers; polyphase systems. Transmission lines.

10. Principles of Electricity and Magnetism. *Prerequisite: preceded or accompanied by Math. 53. (3).*
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. Two lectures and one three-hour computing period.

11. Electromagnetics and Energy Conversion. *Prerequisite: preceded by Math. 56 and Physics 54. (4).*
Discussion of the physical quantities, electrical charge, and current. Analysis of phenomena dependent on these quantities in terms of the field concept. Electric and magnetic forces; introduction to electric and magnetic properties of materials, definition of circuit elements, transient and nonlinear phenomena; magnetic circuits and principles of energy conversion. Three lectures and one three-hour laboratory.

79. 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. 279 in that the instructor is in close touch with the work of the student. Elec. Eng. 279 is for graduates.

82. Introduction to Industrial Electronics I. *Prerequisite: Math. 8 and 13, or permission of instructor. (2).*
Discussion of force actions and energy relations of electrostatic and electromagnetic fields; capacitance and inductance of systems and conductors. Introduction of Kirchhoff's laws; network theorems; elementary treatment of electron ballistics and space-charge flow in cathode-ray and grid-controlled vacuum tubes; thermionic emission, gaseous conduction devices and electron tube characteristics. Introduction to rectifier circuits; elementary amplifier and oscillator circuits.

83. Introduction to Industrial Electronics II. *Prerequisite: Elec. Eng. 82 or permission of instructor. (2).*
Application of electron tubes and semiconductors as circuit elements. Amplifiers, oscillators, wave form generation, multivibrators and sawtooth generators, introduction to feedback theory as applied to amplifiers and elementary control systems. Study of electronic instruments. Introduction to electronic system design and operation.

87. Electronic Circuits and Systems. *Prerequisite: Elec. Eng. 11 and 9. (4).*
Introduction to electronic systems, block diagrams with identification of components. Analysis and design of rectifiers, amplifiers, waveform generators, and pulse circuits. Design and application of modulation and detection systems. Study of closed loop systems including transient and steady-state response. Discussion of electronic equipment and systems, computers, control systems, and special instruments and devices. Lectures and laboratory.

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.

101. Networks and Lines. *Prerequisite: Elec. Eng. 100. (3).*
General network analysis; artificial lines, attenuators, filters, equalizers; transmission of electric waves on lines; reflections at terminals. Lectures.

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 in power systems.

103. Electroacoustics and Ultrasonics. *Prerequisite: Math. 57 or 103 or 104 and Elec. Eng. 100, or permission of instructor. (3).*
Derivation of the equations for propagation of sound; electromechanical and electroacoustical systems in terms of equivalent electrical networks; loudspeakers and microphones; acoustic instrumentation and measurements. Lectures and laboratory.

108. Networks and Electronic and Transistor Circuits. *Prerequisite: Elec. Eng. 5 or equivalent. (4).*
Network analysis; vacuum tube and transistor circuits; amplifiers, mixers, modulators, and detectors. Not open to electrical engineering students. Lectures and laboratory.

109. Transistor Circuits. *Prerequisite: Elec. Eng. 5 or equivalent. (2).*
Not open to electrical engineering students. Basic semiconductor principles and transistor characteristics; the properties of small signal transistor amplifiers; bias considerations and temperature effects; power amplifiers, oscillators, and other circuits employing transistors; noise in transistors.

110. Electromagnetic Fields and Waves. *Prerequisite: Elec. Eng. 10 or equivalent. (3).*
Solutions of field problems. Elementary vector analysis — gradient, divergence, and curl, Poisson and Laplace equations. Maxwell's equations. Poynting's vector and energy relations. Plane waves in perfect and semiconducting dielectrics. Polarization of waves.

112. Materials in Electrical Engineering. *Prerequisite: Elec. Eng. 10 or permission of instructor. (2).*
Electric and magnetic properties of materials commonly used in the electrical engineering application. A discussion of insulators, semiconductors, conductors, dielectric and magnetic phenomena as affected by frequency, temperature, and other environmental factors. Nonlinear magnetic and dielectric materials. Characteristics of devices making use of these properties.

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 and preceded or accompanied by Elec. Eng. 101. (4).*
Wide band amplifiers; radio-frequency amplification; modulation and detec-

tion; transmitting and receiving circuits; radio-frequency transmission lines. Lectures and laboratory.

123. Pulse Circuits. *Prerequisite: Elec. Eng. 120. (3).*
Waveform generation; multivibrators, sawtooth generators, ringing oscillators, regenerative circuits, pulse-forming lines; pulse amplifier design; overshoot, sag, and applied transient analysis of linear amplifiers; use of maximally flat, linear phase, equal ripple, and other amplifier functions. Lectures and demonstrations.

128. Electronics and Radio Communications. *Prerequisite: Elec. Eng. 100. (4).*
Electron tubes and semiconductors as circuit elements; network theory including these elements; amplifiers, radio-frequency circuits. Amplitude, frequency and pulse modulation, frequency spectra. Radio receivers and transmitters, noise in communication circuits. Not open to electrical engineering students. 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.

131. Technical Electrical Measurements. *Prerequisite: Elec. Eng. 130 or equivalent. (2).*
Selected topics in technical electrical measurements; dielectric measurements by Schering bridge methods, watt-hour meter calibration, magnetic measurements. One lecture and one three-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.

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. *Prerequisite: Elec. Eng. 100 and 150, or permission of instructor. (3).*
Equipment for the generation and transmission of electric energy. Excitation systems, oil circuit breakers, substations, electrical and mechanical characteristics of transmission lines, and other associated topics.

141. Economic Applications in Electrical Engineering. *Prerequisite: preceded or accompanied by Elec. Eng. 150, or preceded by Elec. Eng. 5. (2).*
Corporate finance, cost of replacements, economic decay, obsolescence, plant location, and conductor section.

150. Alternating-Current Machinery. *Prerequisite: Elec. Eng. 4. (4).*
Theory and operating characteristics of transformers, polyphase synchronous and induction machines; various types of single-phase motors, selsyn devices. Lectures and laboratory.

151. Design of Induction Motors. *Prerequisite: Elec. Eng. 150. (3).*
Design and performance of polyphase and single-phase machines, especially induction motors. Lectures and computing period.

155. Automatic Control Systems. *Prerequisite: Elec. Eng. 150 and 180. (4).*
Study of the dynamic performance of d.c. and a.c. motors using automatic open-loop control. Characteristics of closed-loop control systems; transfer function analysis and conditions governing the stability of closed-loop control systems; applications to speed, voltage regulations, and process control systems. Lectures and laboratory.

157. Introduction to Servomechanisms. *Prerequisite: Math. 57 or 103 or 104 and Elec. Eng. 100 or permission of instructor. (2).*
A theoretical study of feedback control systems; transfer function analysis; conditions governing the stability of these systems; applications to position, speed, and process control systems.

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.

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.

174. Electric 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.

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.

180. Electron and Semiconductor Devices I. *Prerequisite: Elec. Eng. 3 or 5; preceded or accompanied by Elec. Eng. 10. (4).*
Electron tube and transistor characteristics; amplifiers, rectifiers, and equivalent circuits; electron ballistics and space-charge flow in cathode-ray and grid-controlled vacuum tubes; thermionic emission, gaseous conduction devices; energy-level diagrams for atoms, metals, and semiconductors; transistor physics. 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.

187. Seminar in Professional and Industrial Practices in Electrical Engineering. *Open to seniors and graduate students. (1).*
The nature of typical engineering decisions in electronic and other research, development, and production; organizational patterns and operating and personnel practices in major engineering establishments; the nature of operations research; stages in the growth of a new engineering field; compatibility between electronic and other devices and equipment; reliability, specifications; patents, origin and use of professional and commercial standards; functions of professional societies and trade associations; professional ethics; the consultant's function. Lectures, discussions, case reviews, and reports.

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 and Semiconductor Devices II. *Prerequisite: Elec. Eng. 180, or permission of instructor. (4).*
Conformal analysis of fields in space-charge control tubes; transit-time loading, electron transit-time principles; electron optics of cathode-ray focusing; secondary emission and photoelectric phenomena; television pickup and memory storage tubes; initiation of current in thyratrons, ignitrons, glow tubes, and circuit breakers; Paschen's law; radiation-counter tubes.

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.

205. Network Synthesis I. *Prerequisite: Elec. Eng. 101. (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 problem; synthesis for a prescribed time response; feedback amplifier design.

208. Network Analysis and Feedback Amplifier Design. *Prerequisite: Elec. Eng. 205 or permission of instructor. (3).*
Analysis and design of active networks; study of sensitivity for single- and multiple-loop networks; stability and physical reliability; contour integration and Nyquist's criterion for stability; design of single-loop stable amplifiers.

210. Electromagnetic Field Theory I. *Prerequisite: Elec. Eng. 110 or equivalent. (3).*
Advanced theory and problems in electric and magnetic fields, using vector methods which are introduced as required. Maxwell's equations, waves, and propagation of energy.

211. Electromagnetic Field Theory II. *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. Electric and Magnetic Properties of Materials. *Prerequisite: Elec. Eng. 110 or 112 or permission of instructor. (3).*
Structure of matter. Theory of dielectric constants; dielectric breakdown.

Ferroelectricity and ferromagnetism. Conductors and insulators. Electromagnetic waves in isotropic and anisotropic media. Discussion of selected solid-state devices.

215. **Methods of Solving Radiation and Scattering Problems.** *Prerequisite: Elec. Eng. 210 or equivalent. (3).*
Determination of approximate solutions of scattered electromagnetic fields from simple and complex shapes which have been illuminated by electromagnetic energy, such as radio waves. Solutions of various radiation problems are obtained by using the reciprocity theorem together with the techniques developed for the scattering problem. Simple and complex antenna shapes including slotted arrays are considered. The emphasis in this course will be on recent literature and in current research.

220. **Microwaves I.** *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, Propagation, and Antennas.** *Prerequisite: Elec. Eng. 120. (3).*
Fundamental theory; simple antennas, arrays, and reflecting systems; ionosphere; reflection, refraction, and diffraction; tropospheric propagation.

222. **Microwave Antenna Theory.** *Prerequisite: Elec. Eng. 210 and 221 or permission of instructor. (3).*
Methods of solution of microwave antenna design problems, reciprocity theorem, circuit relationships, impedance concept, reaction concept, slots, mutual coupling.

224. **Microwaves II.** *Prerequisite: Elec. Eng. 220 or permission of instructor. (3).*
General field theory for wave guides; the impedance concept and the application of network theory to microwave structures, general network theorems; analytical methods for determining equivalent circuits for microwave structures, the integral equation formulation, Green's function, variational techniques, and applications to typical boundary value problems; propagation in anisotropic media, nonreciprocal devices; the scattering matrix, and the analysis of multiport networks.

225. **Television.** *Prerequisite: preceded or accompanied by Elec. Eng. 121. (2).*
Basic principles, cathode-ray scanning devices and television receivers and transmitters.

228. **Microwaves, Radiation, and Propagation.** *Prerequisite: Elec. Eng. 128. (4).*
Transmission lines, standing waves, impedance transformation; Maxwell's equations, waves, wave guides, cavity resonators; antennas, arrays, radiation patterns; tropospheric and ionospheric propagation, radar equation, ducts. A special course for the guided-missile program.

232. **Analog and Digital Computer Technology.** *Prerequisite: Math. 57 or 103 or 104; Elec. Eng. 100 and 180, or permission of instructor. (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.

234. **Theory of Networks of Switching Elements.** *Prerequisite: Elec. Eng. 100 and Math. 57 or 103 or 104. (3).*
Analysis and synthesis of switching networks for performing counting, coding, computing, and similar functions. Lectures and laboratory.

235. Digital Computer Design Principles. *Prerequisite: Elec. Eng. 232. (3).*
Study of the logic of series and parallel type computers; logic circuits for computation and control; characteristics of pulse circuits, memory elements, and input-output systems.

238. Digital Computer Applications. *Prerequisite: Elec. Eng. 128 and Math. 148. (3).*
Logical structure and organization of digital computers; number systems, flow diagrams, and problem preparation; special topics in digital computer applications to simulation and system study. Lectures, and laboratory work on the University's computing facilities.

240. Generating Stations. *Prerequisite: Elec. Eng. 100 and 150. (2).*
Integrated performance of electrical equipment used in the generation of electrical energy. Electrical and mechanical transients of synchronous machines.

241. 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.

242. Electric Rates and Cost Analysis. *Prerequisite: Elec. Eng. 140. (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.

245. Power System Stability. *Prerequisite: Elec. Eng. 100 and 140. (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.

246. Analysis of Electric Power Systems. *Prerequisite: Elec. Eng. 102. (3).*
A study of the integrated power system, under steady-rate behavior, covering such topics as power and reactive volt-ampere distribution and control, system voltage regulation, frequency control and the application of tap changing and phase shifting transformers. Symmetrical component and alpha-beta-zero component impedances of synchronous machines and other elements of the power system. The application of the power network analyzer to the study of system performance.

247. Power System Protection. *Prerequisite: Elec. Eng. 140 and 150. (2).*
Theory of overcurrent, differential, distance, pilot wire and carrier current relaying systems and their application for the protection of power systems. System grounding and the ground fault neutralizer.

248. Power System Transients. *Prerequisite: Elec. Eng. 140 and 150. (2).*
A study of lightning and its effects on a power system. Insulation, and design for integrated protection. Transients due to lightning and system switching. Attentuation and reflection of traveling waves. Ground wires, counterpoise, and application of lightning arresters.

251. Alternating Current Apparatus. *Prerequisite: Elec. Eng. 150. (3).*
Advanced treatment of coupled circuits as applied to transformers and the induction machine. Generalized four terminal network theory and generalized circle diagrams. Space m.m.f. harmonics, rotating m.m.f. components, and harmonic iron losses of polyphase and single phase windings.

252. Synchronous Machinery. *Prerequisite: Elec. Eng. 150. (2).*
M.m.f. and flux distribution in the air gap and voltage wave shapes of non-salient and salient pole machines. Direct and quadrature reactances under steady-state and transient conditions.

255. Servomechanisms I. *Prerequisite: preceded or accompanied by Elec. Eng. 201 or Math. 147. (3).*
Design of automatic control systems, including mathematical theory. Laboratory work on the analysis of several control systems and their simulation on the differential analyzer. Two lectures and one four-hour laboratory period.

256. Servomechanisms II. *Prerequisite: Elec. Eng. 255 or equivalent. (3).*
Analysis and synthesis of linear control systems using log-modulus contour, root locus, zero-pole configuration, and analysis of nonlinear control systems using phase-plane techniques. Lectures and laboratory demonstrations on the differential analyzer.

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.

265. Large-Scale Systems Design I. *Prerequisite: Math. 150 and permission of instructor. (2).*
Tools of large-scale systems design, probability theory, mathematical statistics, operations analysis, computers and computing, simulation.

266. Large-Scale Systems Design II. *Prerequisite: Elec. Eng. 265. (2).*
Steps in system design; input measurement; measures of effectiveness, preliminary design; systems analysis; component choice, analysis and test; systems test and evaluation; other tools as needed.

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.

279. Research Work in Electrical Engineering. *Prerequisite: permission of program adviser. (To be arranged).*
Graduate 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 reports in the form of theses.

281. High-Voltage Experimental Techniques. *Prerequisite: Elec. Eng. 100 and 180. (1).*
Cathode-ray oscilloscope measurements of fast transient voltages such as occur on electric utility power lines, in automobile ignition systems, and in radar modulators; circuit breaker principles; surge generators; lightning arresters; insulation and corona problems. One four-hour laboratory period.

282. Electron Tube and Vacuum Techniques. *Prerequisite: Elec. Eng. 180 and permission of instructor. (1).*
Laboratory exercises and the techniques employed in vacuum-tube research and engineering and in physical electronics. One four-hour laboratory period.

283. Physical Electronics. *Prerequisite: Elec. Eng. 180 and Math. 150. (3 or 2).*
Theory of thermionic, photoelectric, and field emission; initial electron velocity effects; space-charge suppression of shot noise; high-density beam formulation, 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. Noise in Electronic Circuits and Devices. *Prerequisite: Elec. Eng. 100, Math. 57 or 103 or 104, and preceded or accompanied by Math. 152, or permission of instructor. (3).*
Probability and random processes; extension of Fourier analysis; sampling in the time domain; entropy of a random process; properties of a noise process; response of linear and nonlinear circuits to noise; noise factor; sources of noise in electronic circuits and devices.

285. Information Theory in Electrical Communication. *Prerequisite: Elec. Eng. 284 or equivalent preparation in probability and statistics. (2).*
Communication signals as random processes. Power spectra and correlation functions of various signals; entropy as a measure of information; optimum prediction and filtering; statistical inference applied to detection of signals in noise; components of communication channel; theoretical capacity of discrete and continuous channels; systems for encoding information into signals. Evaluation of amplitude, frequency and pulse modulation systems for transmission of information.

286. Microwave Electron-Beam Tubes. *Prerequisite: Elec. Eng. 210 or permission of instructor. May be elected for 2 hours credit without laboratory with permission of instructor. (3).*
Llewellyn-Peterson analysis; general induced-current theory; electron optics of high density beams, conservation of momentum, Busch's theorem, confined flow, Brillouin flow; space-charge wave analysis; velocity modulation, klystrons, small-signal traveling-wave tubes, backwardwave oscillators, magnetron oscillators and magnetron amplifiers. Lectures and laboratory.

287. Special Topics in Microwave Circuits and Tubes Seminar. *Prerequisite: Elec. Eng. 286 or permission of instructor. (2).*
Effect of magnetic field on space-charge wave propagation, electric and magnetic lenses, periodic magnetic focusing, Harris flow, electrolytic tanks; carcinotron theory; large-signal traveling-wave tubes, magnetrons; Omega-Beta diagrams, periodically loaded waveguides; energy theorems for electron streams. Lectures.

288. Semiconductors, Ferromagnetic and Ferroelectric Materials. *Prerequisite: Elec. Eng. 180 and Math. 57 or 103 or 104. (3).*
Structure of solids, metals, ionic crystals and valence crystals. Band theory of solids. Electron energy distribution; Fermi level, mean-free time, life and mobility of holes and electrons. Junctions; rectifiers, thermistors, transistors, and photoconductive cells. Ferromagnetism, ferroelectricity, and piezoelectricity. Domain structure; reversible and irreversible movements of domain walls. Metals, alloys, ferrospinels, barium titanate.

ENGINEERING MECHANICS

1. Statics. *Prerequisite: 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, hydrostatics, and centroids.

2. Strength and Elasticity of Materials I. *Prerequisite: 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.

2a. Laboratory in Strength of Materials. *Prerequisite: preceded or preferably 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; use of mechanical, optical, and electrical strain measuring instruments; tension, compression, torsion, bending, impact, and hardness tests; column experiments; demonstrations in photoelasticity and stress coat.

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.

4. Fluid Mechanics I. *Prerequisite: Eng. Mech. 1 and Math. 54.* I and II. *(3).*
The basic principles of mechanics are applied to liquid and gaseous fluids. Continuity, momentum, and energy relations are derived for typical problems. Special assumptions of ideal gases, nonviscous and viscous fluids are applied. Dynamic similitude is used as a means of solving problems and analyzing data. Special topics included are manometers, Venturi and orifice meters, equilibrium and stability of floating bodies, laminar and turbulent flow, resistance to flow, dissipation of mechanical energy into heat, circulation, lift, boundary layers, free-surface flow, adiabatic flow of ideal gases in conduits.

4a. 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 orifices, flow nozzles, Venturi meters; hydraulic jump and critical depth; resistance to flow, boundary layer, transition.

5. Statics 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, centroids, moment of inertia; 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.

11. Statics. *Prerequisite: Phys. 51, preceded or accompanied by Math. 34. (3).*
Basic principles of mechanics; laws of motion, concepts of statics, vectors

and vector addition and products; moments and couples; resultants and equilibrium of general force systems; free body method of analysis; applications to simple problems in all fields of engineering; elementary structures, cables, friction, centroids, hydrostatics, stability of floating bodies, virtual work, beams.

12. Strength of Materials. *Prerequisite: Eng. Mech. 11, preceded or accompanied by Math. 55. (4).*
Stress-strain relations, elastic and inelastic behavior of materials, combined stresses, introduction to theories of failure, statically determinate and indeterminate problems, axial stresses and strains including the thermal effect, torsion and bending of bars; shear center, deflection of beams, combined loading of a bar, buckling of columns, thick-walled cylinders under radially symmetric pressure.

13. Dynamics. *Prerequisite: Eng. Mech. 11, accompanied by Math. 55. (3).*
Kinematics, rectilinear and curvilinear motion, rotational kinematics, relative motion, Coriolis' acceleration, kinetics of particles and rigid bodies, d'Alembert's principle, momentum principle, conservation of energy, conservative and non-conservative systems, thermodynamical considerations, application to impact, dynamic stresses, propulsion; free and forced vibrations of rigid bodies, vibration of distributed masses, damping, vibrating mass systems, electrical and acoustical analogies, gyroscopes, balancing.

14. Fluid Mechanics. *Prerequisite: Eng. Mech. 13, accompanied by Math. 56. (4).*
Idealized fluid, Newtonian and non-Newtonian fluids, hydrostatic equilibrium; dynamics of fluids, incompressible fluid motion, Euler and Bernoulli equations, potential and stream functions, vortex motion, laminar and turbulent flows, momentum and energy relations, evaluation of energy losses; compressible fluid flow, equations of motion for ideal gas, thermodynamical considerations; dimensional analysis and similitude; flow of conduits, Reynolds criterion, flow in channels; lift and drag; deflection of jets by moving blades, reaction machines.

100. Seminar in Engineering Mechanics. *(To be arranged).*

102. Experimental Stress Analysis. *Prerequisite: Eng. Mech. 2 and 3.* I and II. *(2).*
Review of plane stress-strain relationships; mechanical, optical and electrical resistance strain-measuring techniques with applications to strain rosettes; dynamic, transient, and post-yield strain measurement: use of brittle coatings; fundamentals of photoelasticity with applications: similitude of models applied to structures. Recommended as a substitute for Eng. Mech. 2a.

103. Experimental Mechanics. *Prerequisite: Eng. Mech. 2, 3, and 4 and Elec. Eng. 5. (2).*
Analysis, design, and use of instruments for measuring and recording, under static and dynamic conditions, displacement, stress, strain, pressure, temperature, and viscosity; graphical and numerical methods of reducing experimental data and methods of determining the over-all accuracy of an experimental investigation.

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, plasticity, photoelasticity, structures, and materials.

122. Photoelasticity. *Prerequisite: Eng. Mech. 2 and Math. 57. (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 principal stresses. Models will be constructed to suit the interests of the students.

123. Strength and Elasticity of Materials II. *Prerequisite: Eng. Mech. 2. (3).*
Review of plane state of stress and strain; material properties, including the effects of temperature, fatigue, and creep; failure theories; selected stress analysis problems such as torsion of thin-walled open sections, rotating disk, and thick-walled cylinder; energy principles and elements of limit design with application.

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 prismatic 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, Math. 103 and 150. (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. Stress Analysis. *Prerequisite: Eng. Mech. 2 and 3. (2).*
Basic concepts of stress and strain in two-dimensions; bending of curved beams and beams on elastic foundations; fundamentals of elastic instability; an introductory analysis of plates and thin shells (membrane theory); problems of stress concentration, torsion, and curved bars under bending and axial load; fundamentals of photoelasticity.

127. Theory of Structures in Ship Design. *Prerequisite: Eng. Mech. 2. Not open to students in the engineering mechanics program. (4).*
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. Theory of Elastic Stability I. *Prerequisite: Eng. Mech. 2, Math. 103 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 and on elastic foundations; 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. (3).*
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. 57, 103, or 104. (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 shaft; self-induced vibration, stability.

132. Advanced Dynamics. *Prerequisite: Eng. Mech. 131, Math. 103, and 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. The influence of astronomical theories on the development of dynamics. *Mechanical Questions,* Aristotle; *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 reciprocating and turbo machinery; 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. 124 and 131, or permission of instructor. (3).*
Wave motion and vibration of elastic systems, including strings, bars, shafts, beams, and plates. Problems in free and forced vibrations with various end conditions and types of loading; effect of damping on the motion; application of Rayleigh-Ritz and other methods to the approximate calculation of frequencies and normal modes of nonuniform systems.

136. Theory of Vibrations, for Naval Architects. *Prerequisite: Eng. Mech. 3 and Math. 54. (3).*
General outline of vibration theory; vibration of masts, longitudinal vibration of propulsion machinery, torsional vibration of propulsion machinery; hull vibrations, vertical, lateral, longitudinal, and torsional; other selected problems.

137. Theory of Gyroscopes. *Prerequisite: Eng. Mech. 3, Math. 103 or 104, or permission of instructor.* I. *(2).*
General theory; rate gyros, freely gimbaled gyros, rate of turn gyros; gyrostabilization, gyro control, and other selected topics.

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. Mechanics of Inviscid Fluids I. *Prerequisite: Eng. Mech. 4 and Math. 150. (3).*
Equation of continuity, stream functions, vorticity and circulation, equations of motion, persistence of irrotationality, Bernoulli equation, Laplace equation, uniqueness theorem, kinetic energy and virtual mass, three-dimensional flows, images, two-dimensional motion, conformal mapping, free streamlines. Blasius theorems; vortex motion, Poisson's equation, shear flows, elements of wave motion.

143. Mechanics of Viscous Fluids I. *Prerequisite: Eng. Mech. 141. (3).*
Stress and rate-of-deformation tensors, dissipation function, the Navier-Stokes equation, equation for diffusion of vorticity, exact solutions of the Navier-Stokes equations, boundary layers, very slow motion, energy equations; forced and free convections; elements of hydrodynamic stability; isotropic turbulence, turbulent boundary layers, jets, wakes.

200. Theory of a Continuous Medium. *Prerequisite: Eng. Mech. 124, 141, 142. (3).*
General theory of a continuous medium and its specialization to elastic, fluid, plastic, and other special media; 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, Math. 152 and 155. (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. 124. (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.

228. Theory of Elastic Stability II. *Prerequisite: Eng. Mech. 124, 128. (3).*
Investigation of various stability criteria (equilibrium, energy, dynamic, and others) and their interrelationship in various systems, including nonconservative systems; nonlinear considerations and discussion of post-buckling characteristics of redundant structures; buckling and post-buckling behavior of plates and cylindrical shells; general instability criteria in three-dimensional elasticity; survey of plastic buckling theories.

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. Mechanics of Inviscid Fluids II. *Prerequisite: Eng. Mech. 141 and 142; others by special permission. (2).*

Stream functions for general three-dimensional flows, maximum and minimum theorems, Taylor-Birkhoff theorem and Darwin's theory for virtual masses, Lagally theorem for forces and moments: stability of vortex streets and vortex sheets; long waves, method of characteristics, surface waves, group velocity, waves of finite amplitude, waves in flowing water; motion of rotating fluids, motion of stratified fluids in a gravitational field.

243. Mechanics of Viscous Fluids II. *Prerequisite: Eng. Mech. 143. (3).*

Stress and rate-of-deformation tensors in general co-ordinates. Navier-Stokes equations in general co-ordinates by tensor methods, solutions of Navier-Stokes equations; Gortler's series for the boundary layer; stability of rotating fluids, gravitational or thermal instability and its inhibition by rotation and magnetic field, Tollmien-Schlichting waves, in-stability of free-surface flows, applications of Chandrasekhar's method; statistical theories of turbulence, wave-number space, and the use of Fourier transform.

ENGLISH

The work offered in English prepares 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 Associate 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 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 speaking, both prepared and extemporaneous, 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; generally to be preceded or accompanied by English 12.*

35. The Technical Article. *Prerequisite: English 12. (2).*
An advanced composition course with special emphasis on the writing of technical and scientific articles for both professional and nonprofessional readers. The course includes some study of current scientific and technical articles from such periodicals as *The Scientific American.*

41. Public Speaking for Engineers. *(2).*
Preparation and delivery of persuasive speeches. Frequent opportunity for practice and class criticism.

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 drama 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.

155. American Folklore. *(2).*
A study of the life and spirit of the American people as reflected in their folk-songs and ballads, tales, legends, superstitions, proverbs and sayings, games, customs, and the like. Extensive use will be made of regional and type collections and of recordings.

157. Great Poetry. *(2).*
Reading and critical analysis of major poetry of the Western World from Homer to our own day, with the following as objectives: to acquaint the student with the worlds of belief, meaning, and beauty that have become a part of our Western tradition; to acquaint him with the nature and place of poetry by means of which he may more adequately understand and enjoy poetry, and to sharpen his powers of analysis and expression through writing assignments.

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 drama 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.

192. Major American Writers. *(2).*
An intensive study of the works of two or three major American writers with emphasis on their ideas, their relationship to their period, their form of expres-

sion, and their literary significance. Writers are chosen who make possible an integrated exploration of significant cultural developments.

193. Major European Writers. *(2).*
An intensive study of the works of two or three major European writers with emphasis on their ideas, their relationship to their period, their form of expression, and their literary significance. Writers are chosen who make possible an integrated exploration of significant cultural developments.

GEOLOGY*

Professor Wilson; Professors Arnold, Ehlers, Goddard, Hibbard, Hussey, Kellum, Landes, Stumm, and Turneaure; Associate Professors Belknap, Kesling, and Zumberge; Assistant Professors Briggs, Dorr, and Eschman; Dr. DeNoyer and Dr. Kelly.

11. Introductory Geology. I. *(4).*
Principles of physical geology. Lectures, recitations, laboratory, and excursions.

98. Geology for Engineers. II and S.S. *(4).*
Geologic processes with special emphasis on structural geology, ground water, soil genesis, and the relation of geology to engineering problems. Laboratory includes rock and mineral identification, and the interpretation of geologic and topographic maps and aerial photographs. Geology 98 is required of students in civil engineering and is open to others as an elective. Lectures, laboratory and field trips.

99. Geology and Man. II. *(4).*
Geologic processes and their effect on civilization. Lectures and demonstration.

For other courses in geology for 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, 90, Minerals and World Affairs, and 127, Ground Water Geology, are especially useful for engineering students.

INDUSTRIAL ENGINEERING

100. Industrial Management. *Prerequisite: junior standing.* I and II. *(3).*
Management problems and methods involved in the operation of manufacturing institutions, including location, layout, equipment, motion study, time study, methods of wage payment, inspection, organization procedures, production control, material control, and budgets. Lectures, recitations, and problems.

110. Plant Layout and Materials Handling. *Prerequisite: Ind. Eng. 100 and one semester of physics.* I and II. *(3).*
Analysis and planning of the layout of industrial plants. The study and selection of material handling equipment as influenced by material, processing, production equipment, building, and related factors.

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120. Motion and Time Study. *Prerequisite: Ind. Eng. 100.* I and II. *(3).*
Operating methods, work-center layout according to the laws of motion economy, and time-study techniques. Recitations, problems, and laboratory.

125. Human Engineering. *Prerequisite: Ind. Eng. 100.* I and II. *(3).*
The application by engineers of the basic data of vision, audition, physical movement and fatigue to the design of equipment, the improvement of operating efficiency with existing equipment, and the performance of complex tasks.

126. Human Engineering Problems. *Prerequisite: Ind. Eng. 125.* I and II. *(3).*
Problems and field exercises on the application of human engineering methods to engineering problems. Students will formulate problems, select the experimental or other procedures for their solution, and report the findings.

130. Wage Incentives and Job Evaluation. *Prerequisite: Ind. Eng. 120.* I and II. *(2).*
Principles and evaluations of major types of wage incentive systems. Appraisal of various job evaluating systems and use of job evaluation in developing equitable wage structures.

140. Production Control. *Prerequisite: Ind. Eng. 100.* 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.

150. Engineering Economy. *Prerequisite: Econ. 153.* I and II. *(2).*
Economic selection of equipment, consideration of cost, methods of financing, depreciation methods, and the planning of future production. Not open to students below junior year.

160. Operations Research. *Prerequisite: Math. 54 or permission of instructor.* I and II. *(3).*
Introduction to operations research; the methodology of mathematical models and its application to various industrial problems, including experimental design and analysis; introduction to queueing theory, game theory, linear programing, and computers.

165. Data Processing. *Prerequisite: one year of calculus.* I and II. *(3).*
Classes of digital computer machines available for industrial data processing; fundamentals of digital computer operation and sample programing of some elementary problems; the business data handling problem.

200. Study or Research in Selected Industrial Engineering Topics. *Prerequisite: senior or graduate standing and permission of instructor who will guide the work.* I and II. *(To be arranged).*
Individual or group study, design, or laboratory research is in field of interest to the student. Topics may be chosen from any of the areas of industrial engineering including management, work measurement, methods, organization, industrial sciences, industrial mathematics, systems and procedures.
Permission of the individual instructor should be obtained before classification. The course may be elected in more than one semester with approval of the adviser.

210. Industrial Engineering Problems. *Prerequisite: Ind. Eng. 100 or permission of instructor.* I and II. *(3).*
The study of problems and the application of the principles of industrial engineering, using the case method in solving typical management situations. The application of engineering methods to the study and analysis of management in an era of rapid scientific and technical advance.

220. **Industrial Management — Field Work.** *Prerequisite: Ind. Eng. 120.* I and II. *(3).*
Principles of production developed in Industrial Engineering 100 and 120 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.

230. **Industrial Procurement.** *Prerequisite: Ind. Eng. 100.* I. *(3).*
Inventory management, selection of sources, price analysis, standards and specification, organization of a purchasing department, buying policies.

240. **Seminar in Industrial Engineering.** *Prerequisite: Ind. Eng. 120 or permission of instructor.* II. *(2).*
Current topics in industrial engineering. Reading, research, and preparation of papers.

250. **Operations Research Seminar.** *Prerequisite: permission of instructor.* I and II. *(1 or 2).*
Case studies of methodology in operations research. Reading, research, and reports. Visiting lecturers on alternate weeks.

251. **Operations Research Seminar.** *Prerequisite: permission of instructor.* II. *(1 or 2).*
Continuation of Industrial Engineering 250.

MATHEMATICS*

Professor Hay; Professors Bartels, Bott, Carver, Churchill, Copeland, Craig, Dwyer, Fischer, Kaplan, Moise, Nesbitt, Rainville, Rothe, Samelson, Thrall, Wilder, and Young; Associate Professors Carr, Coburn, Darling, Dolph, Dushnik, Jones, LeVeque, Lohwater, Lyndon, Piranian, Reade, and Wendel; Assistant Professors Addison, Clarke, Conner, Gehring, Griffin, Harary, Higman, Kazarinoff, Leisenring, Mayerson, McLaughlin, Ritt, Shields, Titus, Ullman, Wesler, and Wright; Mr. Bedient, Mr. Brooks, Dr. Davison, Mr. Deal, Mr. Finney, Dr. Galler, Dr. Goldman, Dr. Greenstein, Dr. J. S. Griffin, Dr. Halpern, Dr. Hicks, Mr. Keisler, Mr. Korfhage, Mr. Kwun, Mr. Lyjak, Dr. Maxwell, Dr. Palermo, Dr. Parker, Mr. Raymond, Mr. Richardson, Mr. Speake, Mr. Stampfli, Mr. Woolf; Lecturers, Dr. Kao, and Dr. Kincaid.

6. **Solid Euclidean Geometry.** *Prerequisite: one year of plane geometry.* I and II. *(2).*
Postulates; basic constructions and propositions; original exercises; mensuration.

7. **Algebra and Trigonometry.** I and II. *(4).*
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.

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13. Algebra and Analytic Geometry (for Schedule T). 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.

13d. Mathematics Drill. *Prerequisite: one and one-half units of high school algebra, one and one-half units of geometry, one-half unit of trigonometry; Math. 13 or 33 must be taken concurrently.* I and II. *(No credit).*
A tutorial type course meeting for two hours a week and designed to assist students whose mathematics background is weak. Review of high school algebra and trigonometry, drill in elementary college algebra. Open to engineering freshmen only.

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 (for Schedule T). *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; bearing and fixes.

33. Mathematics I (for Schedule S). *Prerequisite: one and one-half years high school algebra, one year plane geometry, one-half year solid geometry, one-half year trigonometry.* I and II. *(4).*
Review of exponents, radicals, quadratic equations, binomial theorem; functions and graphs, the straight line; derivatives, differentiation of algebraic and trigonometric functions; indefinite and definite integrals.

34. Mathematics II (for Schedule S). *Prerequisite: Math. 33.* I and II. *(4).*
Arc length, volume and area of figures of revolution; inequalities, theory of equations; the straight line, curves, tangents, normals, Newton's methods, conics; trigonometric functions, logarithmic and exponential functions; integration.

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 (for Schedule T). I and II. *(4).*
Functions; limits; continuity; derivative; differentiation of trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; integration.

54. Calculus II (for Schedule T). *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.

55. Mathematics III (for Schedule S). *Prerequisite: Math. 34.* I. *(4).*
Integration; vectors, curvature; elementary probability and statistics; determi-

nants; planes, quadric surfaces, straight lines, curves in space; partial derivatives, tangent planes, total differentials; least squares, curve fitting.

56. **Mathematics IV** (for Schedule S). *Prerequisite: Math. 55.* II. *(4).*
Areas, volumes, centroids, inertia, pressure, work, multiple integrals, series, indeterminate forms, complex numbers, 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.

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.

113. **Introduction to Matrices.** *Prerequisite: Math. 62 or permission of instructor.* I and II. *(3).*
Vector spaces; linear transformations and matrices; equivalent of matrices and forms; canonical forms; application to linear differential equations.

117. **Introduction to Linear Algebra and Its Application.** *Prerequisite: one course beyond calculus or permission of instructor.* I. *(3).*
Boolean algebra and elements of set theory; matrix operation; equivalence, congruence, and similarity of matrices and forms; emphasis on applications. Intended primarily for students in engineering and the social sciences.

118. **Optimization in Linear Systems.** *Prerequisite: Math. 117 or permission of instructor.* II. *(3).*
Solution of linear equations; linear inequalities and convex geometry; linear programing; simplex method; two-person zero-sum games, n-person games. Emphasis on applications of these topics. Students in mathematics should elect Math. 227.

[141. **Theoretical Mechanics I.** Omitted in 1958-59.]

[142. **Theoretical Mechanics II.** Omitted in 1958-59.]

[145. **Celestial Mechanics.** Omitted in 1958-59.]

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 Math. 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 Mathematics 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.** Omitted in 1958-59.]

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. *(4).*
Basic probability and statistical concepts; univariate theory: calculational methods; distribution functions; binomial, normal, and Poisson distributions. Introduction to sampling theory. This course should be followed by Mathematics 164. Students cannot receive credit for both Mathematics 161 and 163.

164. Theory of Statistics II. *Prerequisite: Math. 163.* I and II. *(4).*
Significance tests and confidence limits for large samples; exact sampling theory including derivation and use of Student-Fisher t; variance ratio and χ^2, correlation and regression; the bivariate normal distribution; introduction to multivariate analysis. Students cannot receive credit for both Mathematics 162 and 164.

166. The Analysis of Variance and Experimental Design. *Prerequisite: Math. 163, 154, or permission of instructor.* I. *(3).*
Introduction to the theory of significance tests. Exact significance tests in samples from normal. The likelihood ratio principle; the method of least squares.

Randomized complete blocks, Latin squares, factorial designs; incomplete blocks. The analysis of covariance; variance components; principles of experimental design.

[172. **Graphical Methods and Empirical Formulas.** Omitted in 1958-59.]

173. **Methods in High-Speed Computation I.** *Prerequisite: one year of calculus.* I and II. *(3).*
Characteristics and logic of general purpose high-speed digital computers; introduction to logical design. Important computational methods such as linear systems, differential equations, and linear programing. Laboratory work in programing and operating the IBM Type 650 Magnetic Drum Computer.

174. **Methods in High-Speed Computation II.** *Prerequisite: Math. 103 and 113.* II. *(3).*
The mathematics used with high-speed electronic computing machines. Presents attacks on: integration of ordinary differential equations, solutions of large-scale linear systems, determination of eigenvalues and eigenvectors, integration of partial differential equations, function evaluation; coding and solution of problems on the IBM 650 Magnetic Drum Computer.

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. *(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.** Omitted in 1958-59.]

242. **Problems in Heat Conduction and Diffusion.** *Prerequisite: permission of instructor.* II. *(2).*
Problems illustrating methods used in analyzing transient and steady diffusion in solids. The use of Fourier and generalized Fourier series and integrals, integral transforms, Green's functions, conformal mapping, similarity transformations in the resolution of problems; properties of flow.

[243. **Mathematical Theory of Turbulence.** Omitted in 1958-59.]

244. **Compressible Fluid Flows.** *Prerequisite: Math. 150 and permission of instructor.* *(3).*
The Chaplygin method in two-dimensional subsonic flows; the Kármán-Tsien approximation and the resulting theory of flows; the method of characteristics in two- and three-dimensional supersonic flows and simple waves.

245. **Advanced Mechanics.** *Prerequisite: a course in intermediate mechanics.* I. *(3).*
The principles of virtual work, energy, least action, and Hamilton; Lagrangian method for holonomic and nonholonomic systems; ignorable co-ordinates; small oscillations of conservative systems; Hamiltonian method, including integral invariants, contact transformations and the Hamilton-Jacobi equation.

246. **Hydrodynamics.** II. *(3).*
General equations of motion of a fluid; irrotational motion of an incompressible fluid; two- and three-dimensional flow problems; transformation theory and adiabatic flow; viscosity.

247. **Mathematical Elasticity.** I. *(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 function and the biharmonic equation; thin plates and shells.

249. Methods in Partial Differential Equations. I and II. *(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).* Omitted in 1958-59.]

251. Modern Topics in Mathematical Physics. *Prerequisite: Math. 150 and 152.* I. *(3).*
Those parts of general operator and eigenvalue theory and representation theory which pertain to the applications in theoretical physics.

[**252. Advanced Fourier Analysis.** Omitted in 1958-59.]

255. Direct Methods in Calculus of Variations. I. *(3).*
The method of steepest descent in relaxation theory; Dirichlet and Raleigh-Ritz principles and their application to Sturm-Liouville systems and partial differential equations.

256. Nonlinear Differential Equations. *Prerequisite: Math. 103 and 151.* II. *(3).*
Systems of ordinary differential equations, existence and general properties of solutions. Two-dimensional problems: Bendixson's theorems, nature of singular points. Nonlinear springs, nonlinear electric circuits; general theory of nonlinear systems from the physical point of view.

257. Special Functions in Classical Analysis. *Prerequisite: permission of instructor.* II. *(3).*
Gamma, Bessel, Legendre, hypergeometric, and elliptic functions as treated in Whittaker and Watson's *Modern Analysis.* Generalized hypergeometric functions, Hermite and Laguerre polynomials.

259. Advanced Differential Equations. I. *(3).*
Existence theorems and properties of solutions of systems of differential equations in real and complex variables; theory of linear differential equations.

277. Tensor Analysis. II. *(3).*
Definition of tensors; tests for tensor character; manifolds; geodesics; absolute derivatives, covariant and contravariant derivatives; the curvature tensor; relative tensors; Cartesian tensors; applications to mechanics, elasticity, hydrodynamics, heat conduction, electricity, and magnetism.

MECHANICAL ENGINEERING

2. Engineering Materials and Manufacturing Processes. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 1.* I and II. *(2).*
Correlation of the structure of metals with their mechanical properties; control of mechanical properties by modifying the microstructure; mechanical properties of commonly used metals; failure by corrosion; mechanical properties of nonmetals such as cement and plastics. Relations between mechanical properties and the manufacturing processes of casting, welding, plastic working,

machining and heat-treating. One lecture, one problem period, and two hours of laboratory.

13. Heat-Power Engineering. *Prerequisite: Phys. 45 and Math. 53.* I and II. *(4).*
Introduction to thermodynamics, heat transfer, fuels and combustion; application to various forms of heat engines and equipment; elements of air conditioning; introduction to allied machinery. Not open to mechanical engineering students.

14. Heat-Power Laboratory. *Prerequisite: Mech. Eng. 13 or permission of instructor.* I and II. *(1).*
Laboratory in the application of thermodynamics and heat transfer to various types of machinery, equipment, and instrumentation. One three-hour laboratory period. Not open to mechanical engineering students.

17. Mechanical Engineering Laboratory. *Prerequisite: preceded or accompanied by Mech. Eng. 106 and 111.* I and II. *(2).*
Laboratory dealing with various areas of mechanical engineering. Demonstration and application of basic principles; instrumentation and the reliability of measurements; behavior and nature of typical machinery and equipment. One four-hour period.

22. Plastic Working of Metal. *Prerequisite: Chem.-Met. Eng. 1 and Mech. Eng. 2.* I. *(3).*
A basic study of plastic deformation of metals by rolling, drawing, stamping, pressing, forging, extrusion, etc. Evaluation of materials for such operations on a basis of their physical and mechanical properties. Survey of equipment and processes, relating theory to actual design and operation of metal-working equipment. Two recitations and one three-hour laboratory period.

32. Manufacturing Processes. *Prerequisite: Phys. 45 and Mech. Eng. 2.* I and II. *(3).*
The relationship between product design and the limitations imposed by the processes used in manufacture. Considers a variety of processes in the areas of machining, plastic-working, foundry and welding. Three recitations and one two-hour demonstration.

80. Dynamics of Machinery. *Prerequisite: Eng. Mech. 2 and 3, Eng. Draw. 2 or 12.* I and II. *(2).*
Application of dynamics to machinery. Analysis of velocities, accelerations and forces in machines; vibration analysis and balancing. Two two-hour periods.

82. Machine Design I. *Prerequisite: Eng. Mech. 2, and preceded or accompanied by Chem.-Met. Eng. 107 and Mech. Eng. 32.* I and II. *(3).*
Application of the principles of mechanics, materials and manufacturing to the design of machine elements. Two one-hour and one two-hour periods.

83. Machine Design. *Prerequisite: Eng. Mech. 2 and 3.* I and II. *(3).*
Introduction to machine design, for students not in Mechanical Engineering. Incorporates elements of Mech. Eng. 80 and 82. Three one-hour periods.

86. Machine Design II. *Prerequisite: Mech. Eng. 80 and 82.* I and II. *(3).*
Independent design of a machine, including layout, analysis, and critical review. Two four-hour periods a week.

104. Fundamentals of Fluid Machinery. *Prerequisite: Mech. Eng. 105 and Eng. Mech. 4.* I and II. *(3).*
Theory, construction, and operation of the principal types of fluids machinery.

105. Thermodynamics I. *Prerequisite: Phys. 45 and Math. 53.* I and II. *(3).*
Basic course in engineering thermodynamics. First Law, Second Law, properties of a pure substance, ideal gases, mixtures of ideal gases and vapors, availability.

106. Thermodynamics II. *Prerequisite: Mech. Eng. 105 and Math. 54.* I and II. *(3).*
Continuation of Mech. Eng. 105. Systems involving chemical reactions, with emphasis on combustion; power and refrigeration cycles; flow through nozzles and blade passages; general thermodynamic relations, equations of state, and compressibility factors; gaseous dissociation.

107. Applied Energy Conversion. *Prerequisite: Mech. 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. Eng. 17.* 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. One four-hour laboratory period.

111. Heat Transfer I. *Prerequisite: Mech. Eng. 105 and Eng. Mech. 4.* I and II. *(3).*
Study of the mechanisms of heat transfer processes. Steady and transient conduction in solids, numerical and graphical methods; heat exchanger design, performance, and economics; thermal radiation; convective processes, turbulent and laminar flow, steady and transient diffusion, mass transfer between phases.

112. Power Plant Combustion Processes. *Prerequisite: Mech. Eng. 106 or equivalent.* I. *(2).*
Mechanisms, kinetics, and chemical reactions of combustion processes. Ignition and propagation of flame reactions. Properties of fuels and oxidizers. Air-breathing and nonair-breathing power plant applications.

113. Steam Turbines. *Prerequisite: Mech. 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 propulsion; general principles of governing.

114. Internal-Combustion Engines. *Prerequisite: Mech. 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. Eng. 82, and preceded or accompanied by Mech. 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.

* Only one of the following courses may be taken for credit toward a degree: Mech. Eng. 116 and 162.

120. **Refrigeration and Air Conditioning.** *Prerequisite: Mech. 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.

123. **Industrial Air Conditioning.** *Prerequisite: Mech. Eng. 105 or 13.* I. *(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.

124. **Industrial Exhaust and Ventilation Laboratory.** *Prerequisite: preceded or accompanied by Mech. 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.

125. **Heating and Air Conditioning.** *Prerequisite: Mech. Eng. 105.* I and II. *(3).*
Theory, design and construction of warm-air, steam, hot-water, and fan-heating systems; central heating; air conditioning and temperature control.

126. **Design of Heating and Air-Conditioning Systems.** *Prerequisite: Mech. 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.

127. **Air-Conditioning Laboratory.** *Prerequisite: Mech. Eng. 17 and 125.* I. *(3).*
Advanced experimental study in the field of air conditioning.

128. **Heating and Ventilating.** I and II. *(3).*
Theory, design, and construction of warm-air, steam, hot-water, and fan-heating systems; air conditioning and temperature control. Lectures, recitations. For architects only.

132. **Manufacturing Engineering.** *Prerequisite: Mech. Eng. 32.* I and II. *(3).*
Application of fundamental principles to problems arising in manufacturing. Particular attention is devoted to planning operations, designing special equipment, operations research, statistical quality control, cost analysis and reduction, and similar functions which engineers perform in connection with manufacturing. Two one-hour recitations and two two-hour laboratory periods.

134. **Plastics Fabrication.** *Prerequisite: Mech. Eng. 31 or 32 and Eng. Mech. 4.* I. *(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.

135. **Die Casting and Powder Metallurgy.** *Prerequisite: Chem.-Met. Eng. 13 and 125, or Chem-Met. Eng. 107 and 11 or 12.* II. *(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.

136. Stamping. *Prerequisite: Chem-Met. Eng. 102 and Mech. Eng. 132.* II. *(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 design of a product to permit its manufacture by the stamping process. The operating characteristics of presses, dies, and auxiliaries are studied.

140. Tool Design. *Prerequisite: Mech. Eng. 132.* II. *(2).*
Studies of the application of theories of machinability and economics to cutting practice, design of jigs, fixtures, and small tools. Two lectures and one two-hour design period.

141. Dynamics and Thermodynamics of Compressible Flow. *Prerequisite: Mech. Eng. 106 and 111.* II. *(3).*
One-dimensional compressible flow involving change of area, normal shock, friction, and heat transfer. Two-dimensional subsonic and supersonic flow, method of characteristics, and oblique shocks.

142. Design Theory of Pumping Machinery. *Prerequisite: Mech. Eng. 104.* I. *(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.

143. Design of Pumping Machinery. *Prerequisite: Mech. Eng. 82 and 104 or equivalent and Mech. Eng. 142.* II. *(3).*
Calculations and drawings for a centrifugal or reciprocating pump. Special attention is given to the design of runners, casings, and valves.

144. Design for Production. *Prerequisite: Chem.-Met. Eng. 11 or 12, and Mech. Eng. 132.* I. *(2).*
Correlations between functional specifications of a product and process characteristics are developed. Emphasis is placed on the manner in which both the theoretical and the practical aspects of production processes tend to limit product design.

150. Automobiles and Motor Trucks. *Not open to students below senior level except by permission of instructor.* I and II. *(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. Process Instrumentation. *Prerequisite: Math. 54 and Physics 46.* I. *(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.

153. Automotive Power Trains. *Prerequisite: Mech. Eng. 82 and 150, or permission of instructor.* I. *(3).*
Theory and design of automotive clutches, mechanical and hydraulic transmissions, differentials and axles. Lectures, recitations, and calculations.

154. Automotive Chassis. *Prerequisite: Mech. Eng. 150 or permission of instructor.* I. *(3).*
Performance of automobile and truck suspension, steering, brakes, axles, and frames. Problems of cost, size, and weight reduction. Power-weight ratio, acceleration, gradability, stability, maneuverability, and ride comfort.

155. Automotive Laboratory. *Prerequisite: Mech. Eng. 17 and 114 or 150.* I and II. *(3).*

Experimental study of automobile and aircraft engines, including horsepower, fuel economy, thermal efficiency, mechanical efficiency, heat balance, indicator cards, carburetion, compression ratio, electrical systems, and road tests for car performance. Laboratory and reports. Four or five hours each week.

156. Automotive Frames and Bodies. *Prerequisite: Mech. Eng. 150 or permission of instructor.* II. *(3).*

Frames, bodies, and cabs in automobiles, trucks, and tractors; unit-body versus conventional frame and body construction; convertibles and hardtops, structural efficiency of frame and body components; design of cab and body mountings; effect of bending and torsional rigidity on the performance of the body; problems of road shocks, body shake, noise, and vibration. Three one-hour periods.

160. Aircraft Power Plants. *Prerequisite: Mech. Eng. 105.* II. *(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. Eng. 17 and 114 or 160.* I and II. *(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. Eng. 82 and 114.* I and II. *(3).*

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 four-hour periods.

164. Gas Turbines and Jet Propulsion. *Prerequisite: Mech. Eng. 106.* I and II. *(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. Eng. 106.* II. *(2).*

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. Eng. 106.* I. *(2).*

Construction and operation of diesel engines for marine, stationary, and automotive purposes, together with their auxiliaries.

171. Dimensional Quality Control. *Prerequisite: Mech. Eng. 32.* II. *(3).*

A study of standards, specifications, the nature of quality, inspection principles, measuring and gaging equipment, and quality control procedure.

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.

* See footnote in connection with Mech. Eng. 116.

172. Welding. *Prerequisite: Chem.-Met. Eng. 107 or 117 or 127 or permission of instructor.* I. *(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.

173. Gas Welding. *Prerequisite: Mech. Eng. 172 or permission of instructor.* I and II. *(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 aircraft tube welding. One hour class and one three-hour laboratory period.

174. Electric Welding. *Prerequisite: Mech. Eng. 172 or permission of instructor.* I and II. *(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.

180. Mechanical Vibrations. *Prerequisite: Mech. Eng. 80 or 83.* I and II. *(3).*

Analysis, reduction and isolation of machine vibrations. Mounting of machines and equipment; critical speeds and torsional vibrations of rotors; balancing of machines; vibration absorbers and dampers.

181. Design of Machine Tools. *Prerequisite: Mech. Eng. 82 and 32.* 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. Parts Processing. *Prerequisite: Mech. Eng. 132 or permission of instructor.* II. *(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.

186. Stress and Strength Considerations in Design. *Prerequisite: Mech. Eng. 82 or 83.* I and II. *(3).*

Treatment of stress and strength aspects of machine design. Analytic and experimental determination of stresses in machine members. Evaluation of strength under steady and fatigue loadings. Post-yield behavior, residual stresses, temperature and corrosion effects.

200. Study or Research in Selected Mechanical Engineering Topics. *Prerequisite: senior or graduate standing; permission of instructor who will guide the work should be obtained before classification.* I and II. *(Credit to be arranged).*

Individual or group study, design, or laboratory research in a field of interest to the student. Topics may be chosen from any of the areas of mechanical engineering including air conditioning, automotive engines, transmissions, chassis, suspensions, and bodies; design, stress and strength analysis, dynamics of machinery; design and interpretation of experiments; fluids machinery; heat and power; manufacturing; thermodynamics and heat transfer. The student will submit a report on his project.

The course may be elected in more than one semester with approval of the adviser.

203. **Advanced Instrumentation and Control.** *Prerequisite: a degree in engineering or permission of instructor.* II. *(3).*

Automatic controls; fluid metering; measurements of temperature, humidity, pressure, displacement, strain, speed, sound, etc.

205. **Advanced Thermodynamics.** *Prerequisite: Mech. 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.

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.

211. **Heat Transfer II.** *Prerequisite: Mech. Eng. 105 and 111.* II. *(3).*

Study of the nature of convective processes involving the transfer of heat, mass and momentum. Boundary layer theory for laminar and turbulent flow. Analogy between heat and momentum transfer, condensation and boiling phenomena, two-phase flow. Unsteady convective processes. Natural convective processes, thermal radiation through absorbing and non-absorbing media, view factors. Steady and transient diffusion, mass transfer between phases, simultaneous heat, mass and momentum transfer.

212. **Heat Transfer III.** *Prerequisite: Mech. Eng. 105 and 111, Math. 103.* I. *(3).*

Conduction heat transfer in both steady and transient state, including heat sources. Mathematical, numerical, graphical and analog methods of solution for rectangular, cylindrical, and spherical co-ordinate systems with steady and fluctuating boundary conditions. Occasional laboratory demonstrations. Thermal stresses. Isotropic and nonisotropic solids. Heat exchanger performance in steady and transient state. Dynamics of thermal instrumentation.

214. **Advanced Theory of Internal-Combustion Engines.** *Prerequisite: Mech. Eng. 114.* II. *(3).*

Balance and vibration; advanced thermodynamics of engines; chemical equilibrium and kinetics of combustion; theory and control of detonation; combustion analysis; principles underlying recent advances in engines.

240. **Theory of Land Locomotion.** *Prerequisite: Math. 103 or permission of instructor.* I. *(3).*

The mechanics of vehicle mobility; locomotion on wheels, tracks, etc.; soil properties as related to vehicle mobility; vehicle performance, trafficability, and economy in off-road operation.

242. **Land Locomotion Laboratory.** *Prerequisite: Mech. Eng. 240 or permission of instructor.* I and II. *(3).*

Measurements of soil properties as related to vehicle mobility; model testing in soil bins; relations between load, sinkage, and tractive effort in soils of various types under wheel and track loading. Two four-hour periods.

251. Automobile Engineering Seminar. I and II. *(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.

255. Advanced Automobile Testing and Research. *Prerequisite: Mech. Eng. 155 or 161, and permission of instructor.* I and II. *(3).*
Advanced experimental and research work. Laboratory, reports.

264. Advanced Working, Treating, and Welding of Metal. *Prerequisite: Chem.-Met. Eng. 107, or equivalent.* II. *(2).*
Special problems on these subjects may be elected by students interested in steel treatment and processing.

273. Machinability. *Prerequisite: Mech. Eng. 132.* II. *(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.

304. Fluids Machinery Seminar. *Prerequisite: graduate standing and permission of instructor.* Offered upon sufficient demand. *(Credit to be arranged).*
Reports and discussions on library study and laboratory research in selected topics.

305. Seminar in Thermodynamics. *Prerequisite: Mech. Eng. 205 or permission of instructor.* II. *(3).*
Thermodynamic analysis of rectification, low temperature phenomena equilibrium, metastable states, and compressible flow.

308. Heat Power Seminar. *Prerequisite: graduate standing and permission of instructor.* Offered upon sufficient demand. *(Credit to be arranged).*
Reports and discussions on library study and laboratory research in selected topics.

327. Air Conditioning Seminar. *Prerequisite: graduate standing and permission of instructor.* Offered upon sufficient demand. *(Credit to be arranged).*
Reports and discussions on library study and laboratory research in selected topics.

355. Automotive Seminar. *Prerequisite: graduate standing and permission of instructor.* Offered upon sufficient demand. *(Credit to be arranged).*
Reports and discussions on library study and laboratory research in selected topics.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

1. Introduction to the Design and Construction of Small Pleasure Craft. *Prerequisite: one year high school algebra. May not be elected for credit by students in the College of Engineering.* II. *(3).*
Nomenclature, delineation of hull form, displacement, initial stability and power to carry sail, metallic and plastic construction, powering, machinery and general arrangements.

11. Introduction to Practice. *Prerequisite: sophomore standing and Eng. Draw. 1 and 2.* I and II. *(2).*
Types of ships, nomenclature, methods and materials of construction, shipyard and drawing room practices. The lines of a vessel are faired, and drawings prepared for typical ship structures.

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; launching; and watertight subdivision.

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 length, and the determination of the location of watertight bulkheads.

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.

22. Structural Design II. *Prerequisite: 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, the dynamical stability, rolling, pitching, and seagoing qualities of ships; rudders, turning, and maneuvering.

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 preliminary design of a suitable ship, including form, power, and strength calculations; midship section, lines, inboard and outboard profiles, and arrangement plans.

135. Advanced Ship Drawing and Design. I and II. *(To be arranged).*

136. Small Craft Design I. *Prerequisite: Nav. Arch. 12.* II. *(2).*
Design of small commercial and pleasure craft.

137. Specifications, Contracts, and the General Arrangement of Vessels. *Prerequisite: senior standing or permission of instructor.* I. *(3).*
Principal features of ship specifications 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.

141. Marine Propulsion Machinery. *Prerequisite: Mech. Eng. 105 and preceded or accompanied by Eng. Mech. 4.* I. *(2).*
Principles of construction and operation of main propulsion machinery and auxiliary plant.

142. Design of Marine Steam Generators. *Prerequisite: Nav. Arch. 146.* I and II. *(3).*

Heat transfer calculations. Design and layout drawings are prepared for a marine steam generator.

143. Design of Marine Propulsion Machinery. *Prerequisite: Nav. Arch. 146 or permission of instructor.* I and II. *(3).*

Design calculations and principal drawings are prepared for either a steam or oil engine suitable for propelling a vessel.

144. Design of Marine Power Plants II. *Prerequisite: Nav. Arch. 146.* I and II. *(3).*

Design calculations to establish the heat balance of an approved machinery installation. A preliminary machinery arrangement and piping diagrams are prepared.

145. Advanced Reading and Seminar in Marine Engineering. I and II. *(To be arranged).*

146. Design of Marine Power Plants I. *Prerequisite: Nav. Arch. 147.* I and II. *(2).*

Calculations on performance and preliminary design of main and auxiliary machinery.

147. Marine Auxiliary Machinery. *Prerequisite: Nav. Arch. 141 and preceded or accompanied by Elec. Eng. 5.* II. *(2).*

Piping systems; electrical distribution; engine room auxiliary; deck machinery; steering gear; and emergency apparatus.

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.

152. Ship Model Theory. *Prerequisite: Eng. Mech. 4 and Nav. Arch. 12.* I and II. *(3).*

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.

153. Research in Ship Hydrodynamics. *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).* Omitted in 1958–59.]

156. Thesis Research. *Prerequisite: Nav. Arch. 132 or design course in Option 2 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.

NUCLEAR ENGINEERING

190. Elements of Nuclear Engineering. *Open to senior and graduate students, or others with permission of instructor.* I and II. *(3).*
An introductory survey of nuclear engineering for those in fields other than nuclear engineering. Elementary nuclear physics, neutron mechanics, the nuclear reactor, radiation shielding, instrumentation and control, chemical separation and processing, and nuclear power plant systems are the principal topics surveyed.

191. 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. Elementary particles, electromagnetic radiation, waves, quantization and energy levels, radioactivity, measurement of nuclear phenomena, nuclear disintegration and fission, nuclear reactors.

192. Measurement in Nuclear Engineering. *Prerequisite: Nuclear Eng. 191 or permission of instructor.* I and II. *(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 counters and related circuitry. Instruments are used to study fundamental nuclear phenomena and the characteristic properties of alpha, beta, gamma, and neutron radiation. Lecture and laboratory.

193. Applications of Nuclear Radiations. *Prerequisite: preceded or accompanied by Nuclear Eng. 191, 192, or permission of instructor.* I and II. *(3).*
Uses of nuclear radiation in industry and research. Procedures in the safe handling of radioactive materials, hazard evaluations, and design of radiation facilities. One hour lecture, demonstrations, and experiments with high-level sources.

291. Interaction of Radiation and Matter. *Prerequisite: Nuclear Eng. 191 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. Thomson scatter, Compton scatter, pair production, bremmstrahlung, Cerenkov radiation, Wigner effect. 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 is considered.

292. Nuclear Reactor Instrumentation and Control. *Prerequisite: Nuclear Eng. 191 and 192. (3).*
Reactor kinetics, reactor stability studies; measurement of reactor power level and period: automatic control methods for thermal and fast reactors; temperature effects; accident studies; the use of analog computers in studying reactor dynamics; the loaded reactor.

293. Radiation Shielding. *Prerequisite: Nuclear Eng. 191, 192, and 291. (3).*
A macroscopic study of the absorption of nuclear radiations in dense materials with applications to radiation shielding. Topics considered include radiation sources, permissible radiation levels, gamma ray attenuation, neutron attenuation, shield optimization, heat generation and removal in shields, and other related problems.

294. Wave Mechanics in Nuclear Engineering. *Prerequisite: Nuclear Eng. 191. (3).*

Formulation of wave description of matter through the Schroedinger wave equation. Application to box problem and hydrogen-like atom. Energy level transition probabilities. Finite thickness potential barriers and transmission problems — alpha decay model. Particle and particle-wave interaction.

295. Theory of Nuclear Reactors. *Prerequisite: Nuclear Eng. 191 and Math. 150. (3).*

Development of a neutron balance equation and its application in an investigation of the problems of criticality and controllability of homogeneous nuclear reactors.

296. Nuclear Reactor Fuels and Fuels Processing. *Prerequisite: Nuclear Eng. 191 or permission of instructor. (3).*

Origin, preparation, and refining of virgin and reprocessed reactor fuels. Basic nuclear reactions and processes for recovery of radioactive fission products.

298. Nuclear Reactor Laboratory. *Prerequisite: Nuclear Eng. 295.* I and II. *(3).*

Characteristics and operation of a nuclear reactor and the use of a reactor as a radiation source, using the one megawatt Ford Nuclear Reactor in the Phoenix Memorial Laboratory. Reactor start-up and operation, control rod calibration, temperature coefficient of reactivity, flux distribution within the reactor. Neutron and gamma-ray shielding, fission, absorption, and scattering cross sections for thermal neutrons, activation analysis, neutron damage of materials, neutron slowing down and diffusion. Lectures and laboratory sessions.

299. Directed Research. *(2–5).*

Individual or group investigations in a particular field or on a problem of special interest to the student. The program will be arranged at the beginning of each semester by mutual agreement between the student and the staff member. Attendance at a weekly seminar is required. The student will write a final report and may be required to make a seminar presentation.

395. Advanced Reactor Theory. *Prerequisite: Nuclear Eng. 295 and Math. 152. (3).*

General formulation of the transport problem with application to refinements of calculation techniques for studying neutron and gamma-ray distributions. Perturbation theory with applications to both steady state and time varying systems. Thermal problems such as thermalization of neutrons, the calculation of thermal parameters, estimates of the Doppler effect on resonances, and related problems. Neutron age theory, specialized formulations of the Boltzmann equations and their use in the study of fast reactor systems. The theory of multigroup calculations, the activation of probes.

PHYSICS*

Professor Dennison; Professors Case, Crane, Glaser, Hazen, Laporte, Luttinger, Sawyer, Uhlenbeck, Wiedenbeck, Wolfe; Associate Professors Hough, Katz, McCormick, Parkinson, Pidd; Assistant Professors Chagnon, Franken, Gilbert, Hecht, Jones, Krimm, Meecham, Meyer, Perl, Peters, Sands, Sherman, Terwilliger, Trilling; Dr. Bilaniuk, Dr. Fregeau, Dr. Johnson, Dr. Kadyk, Dr. Sinclair; Lecturer Siegel.

* College of Literature, Science, and the Arts.

45. Mechanics, Sound, and Heat. I and II. *(5).*
Calculus should be elected concurrently. Two lectures, three recitations, and one two-hour laboratory period.

46. Electricity and Light. *Prerequisite: Phys. 45.* I and II. *(5).*
Two lectures, three recitations, and one two-hour laboratory period.

53. Elementary Mechanics. *Prerequisite: preceded or accompanied by Math. 33.* I. *(4).*
Mechanics of particles, kinematics, Newton's laws of motion, wave motion in mechanical systems, special relativity. One lecture, three recitations, and one laboratory period.

54. Electricity, Light, and Modern Physics. *Prerequisite: Phys. 53 and preceded or accompanied by Math. 54 or equivalent.* II. *(4).*
Electricity and magnetism, physical optics, atomic and nuclear structure. One lecture, three recitations, and one laboratory period.

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).*
Discussion of fundamental experiments on the nature of light, electricity, and matter.

147. Electrical Measurements. *Prerequisite: Phys. 46 and Math. 54.* I and II. *(4).*
Direct, alternating, and transient currents; measurements of inductance, capacitance, and losses due to hysteresis. Two lectures and one four-hour laboratory period.

165. Electron Tubes. *Prerequisite: Phys. 147.* II. *(3).*
Characteristics of electron tubes and their functions as detectors, amplifiers, and generators. Two lectures and a four-hour laboratory.

166. Electron Circuits. *Prerequisite: Phys. 165.* I. *(3).*
Characteristics of high-frequency circuits and their radiations. Two lectures and one laboratory period.

171. Intermediate Mechanics. *Prerequisite: Phys. 46, Math. 103.* I and II. *(3).*
Statics and dynamics; the equations of d'Alembert, Poisson, Laplace, and Lagrange.

173. Introduction to Physics of the Solid State. *Prerequisite: Phys. 196 or permission of instructor.* II. *(3).*
Structure and properties of crystalline solids, metals, insulators, semi-conductors.

177. Applications of Physical Measurements to Biology. *Prerequisite: Phys. 46 and eight hours of biological science.* I. *(3).*

178. Introduction to Physics of Macromolecules. *Prerequisite: Math. 54 and Phys. 186, or permission of instructor.* II. *(3).*
A study of the physical principles underlying the behavior and characterization of macromolecular systems, with particular emphasis on applications to biological processes.

180. Intermediate Electricity and Magnetism. *Prerequisite: Phys. 147 and Math 150 or 154.* I. *(3).*
Principles of electrostatics and electromagnetism.

181. Heat. *Prerequisite: Phys. 46 and Math. 54.* I. *(2).*
Thermal expansion, specific heats, changes 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. 171 or 53 or permission of instructor.* I. *(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, dispersion.

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.* I and 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.* II. *(3).*
Suitable for advanced undergraduates and beginning graduate students. Development of the methods of Schroedinger and Heisenberg, with applications.

199. Laboratory in Nuclear Physics. II. *(2).*
To accompany or follow Physics 197. Measurements on the characteristics of various nuclear transformations.

205, 206. Electricity and Magnetism. *Prerequisite: Phys. 147 and Math. 150 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).*

225. Theory of Neutron Diffusion. I. *(3).*

231. Advanced Electromagnetic Theory with Application to Modern Diffraction Problems. I. *(2).*

233. Special Problems in Fluid Dynamics. I. *(3).*

234. Random Processes in Physical Theory and Computation. II. *(3).*

238. Nuclear Theory. I. *(3).*

256. Molecular Spectra and Molecular Structure. *(3).*

SCIENCE ENGINEERING

Certain courses have been and are being developed through interdepartmental co-operation specifically for the Science Engineering degree program. These courses may be taught by staff members of various departments of instruction. They are listed separately rather than placed among the offerings of any one department. They may be elected by any student who presents prerequisites equivalent to those stated in the course definitions.

110. Thermodynamics (formerly 2001). *Prerequisite: Math. 55 and Chem. 14. (3).*
Introduction to thermodynamics.

112. Rate Processes. *Prerequisite: Eng. Mech. 14, Math. 56, and a course in thermodynamics. (3).*
A unified study of heat, mass, momentum transfer and chemical reaction kinetics with emphasis upon the background of existing theories and applications to the design of equipment.

Committees and Faculty*

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G. V. EDMONSON, term, 1955-59
M. J. SINNOTT, term, 1956-60
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* Listed for the academic year, 1957-58.

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CIVIL ENGINEERING

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CLINTON LOUIS HEIMBACH, B.S.E., (Transp.), B.S.E. (Civil), *Assistant Professor of Railroal Engineering*

Eugene Andrus Glysson, M.S.E., *Assistant Professor of Civil Engineering*
George Moyer Bleekman, M.S.E., *Assistant Professor Emeritus of Civil Engineering*
Robert Oscar Goetz, M.S.E. (C.E.), *Instructor in Civil Engineering*
Wadi Saliba Rumman, M.S.E. (C.E.), *Instructor in Civil Engineering*
Glen Virgil Berg, M.S.C.E., *Instructor in Civil Engineering*
Gerald Clifford Gill, M.A., *Lecturer in Meteorology, Department of Civil Engineering and Associate Research Engineer, Engineering Research Institute*
Frank Rolland Bellaire, M.S., *Lecturer in Meteorology and Associate Research Engineer, Engineering Research Institute*
George Warren Reynolds, M.S., *Lecturer in Meteorology and Research Associate, Engineering Research Institute*
Donald James Portman, Ph.D., *Lecturer in Meteorology and Associate Research Meteorologist, Engineering Research Institute*
David Lloyde Jones, M.S., *Lecturer in Meteorology and Research Associate, Engineering Research Institute*
Floyd Chalmers Elder, M.S., *Lecturer in Meteorology and Research Assistant, Engineering Research Institute*

DRAWING (ENGINEERING)

Herbert Theodore Jenkins, M.S.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*
Frank Harold Smith, M.S.E., *Professor of Engineering Drawing*
Frank Richard Finch, Ph.B., *Professor Emeritus of Engineering Drawing*
Henry Willard Miller, B.S., M.E., *Professor Emeritus of Engineering Drawing*
Robert Carl Cole, A.M., *Professor Emeritus of Engineering Drawing*
Martin J. Orbeck, C.E., M.S.E., *Professor Emeritus of Engineering Drawing*
Philip Orland Potts, B.M.E., *Associate Professor of Engineering Drawing*
Maurice Barkley Eichelberger, B.S., *Associate Professor of Engineering Drawing*
Robert Horace Hoisington, M.S., *Associate Professor of Engineering Drawing*
Herbert Jay Goulding, B.S. (M.E.), *Associate Professor Emeritus of Mechanism and Engineering Drawing*
Albert Loring Clark, Jr., B.S.E. (M.E.), *Assistant Professor of Engineering Drawing*
Francis X. Lake, Ph.D., *Assistant Professor of Engineering Drawing*
Robert Seaton Heppinstall, M.S. (M.E.), *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*

RAYMOND CLARE SCOTT, M.Ed., *Assistant Professor of Engineering Drawing*

FINN CHRISTIAN MICHELSEN, B.S.E. (Math.), M.S.E. (Nav. Arch.), *Instructor in Engineering Drawing*

WILLIAM HAVILAND STEELE, B.S. (Ch.E.), B.S. (E.E.), *Instructor in Engineering Drawing*

THOMAS JOHN BLACK, M.S., *Instructor in Engineering Drawing*

JAMES ROBERT CAIRNS, B.S.E., *Instructor in Engineering Drawing*

ELECTRICAL ENGINEERING

STEPHEN STANLEY ATTWOOD, M.S., *Professor of Electrical Engineering, Chairman of the Department of Electrical Engineering, and Acting Dean, College of Engineering*

ARTHUR DEARTH MOORE, 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*

GUNNAR HOK, E.E., *Professor of Electrical Engineering*

HARRY H. GOODE, M.A., *Professor of Electrical Engineering*

HENRY JACOB GOMBERG, Ph.D., *Professor of Nuclear and Electrical Engineering, and Assistant Director, Michigan Memorial—Phoenix Project*

ALAN BRECK MACNEE, Sc.D., *Professor of Electrical Engineering*

HEMPSTEAD STRATTON BULL, M.S., *Professor of Electrical Engineering*

JOHN JOSEPH CAREY, M.S. (E.E.), *Professor of Electrical Engineering*

NORMAN ROSS SCOTT, Ph.D., *Professor of Electrical Engineering*

LOUIS JOHN CUTRONA, Ph.D., *Professor of Electrical Engineering*

JAMES CARLISLE MOUZON, Ph.D., *Professor of Electrical Engineering*

RAYMOND FRED MOSHER, S.M., *Professor of Electrical Engineering*

KEEVE MILTON SIEGEL, M.S., *Professor of Electrical Engineering and Lecturer in Physics*

JOSEPH HENDERSON CANNON, B.S. (E.E.) *Professor Emeritus of Electrical Engineering*

ALFRED HENRY LOVELL, M.S.E., *Professor Emeritus of Electrical Engineering*

EDWIN RICHARD MARTIN, E.E., *Professor Emeritus of Electrical Engineering*

RICHARD KEMP BROWN, Ph.D., *Associate Professor of Electrical Engineering*

FRED T. HADDOCK, M.S., *Associate Professor of Electrical Engineering, and Associate Professor of Astronomy, College of Literature, Science, and the Arts*

WALTER ALFRED HEDRICH, Ph.D., *Associate Professor of Electrical Engineering*

WILLIAM KERR, Ph.D., *Associate Professor of Nuclear and Electrical Engineering*

JOSEPH AUBREY BOYD, Ph.D., *Associate Professor of Electrical Engineering*

ERNST DONALD KLEMA, Ph.D., *Associate Professor of Nuclear Engineering*

RICHARD KENT OSBORN, Ph.D., *Associate Professor of Nuclear Engineering*

PAUL A. BROCK, Ph.D., *Associate Professor of Electrical Engineering*

LOUIS FRANK KAZDA, M.S.E., *Associate Professor of Electrical Engineering*

JOSEPH EVERETT ROWE, Ph.D., *Associate Professor of Electrical Engineering*

CHARLES BRUCE SHARPE, Ph.D., *Assistant Professor of Electrical Engineering*

JAMES RICHIE BLACK, B.A. (Chem.), *Assistant Professor of Electrical Engineering*

DALE MILLS GRIMES, Ph.D., *Assistant Professor of Electrical Engineering*

EDWARD ANTHONY MARTIN, Ph.D., *Assistant Professor of Electrical Engineering*

CHIAO-MIN CHU, Ph.D., *Assistant Professor of Electrical Engineering*

BEN FREDERICK BARTON, Ph.D., *Assistant Professor of Electrical Engineering*

HARVEY LOUIS GARNER, M.S., *Instructor in Electrical Engineering*

HAROLD BURR, M.S.E.E., *Instructor in Electrical Engineering*

WILBUR LAMOTTE STEINMANN, M.S. (E.E.), *Instructor in Electrical Engineering*

WILLIAM WOLSEY RAYMOND, M.S.E., *Instructor in Electrical Engineering*

DALE CARNEY RAY, M.S.E., *Instructor in Electrical Engineering*

ROBERT EMIL FRESE, M.S.E., *Instructor in Electrical Engineering*

CHARLES WILLIAM RICKER, M.S., *Instructor in Nuclear Engineering*

VICTOR LEW WALLACE, B.E.E., *Instructor in Electrical Engineering*

NELSON WARNER SPENCER, M.S.E. (E.E.), *Lecturer in Electrical Engineering and Research Engineer, Engineering Research Institute*

MURRAY HENRI MILLER, M.S.E. (E.E.), *Lecturer in Electrical Engineering and Research Associate, Engineering Research Institute*

HAROLD C. EARLY, M.S. (Phys.), *Lecturer in Electrical Engineering and Research Engineer, Engineering Research Institute*

HAL FREDERIC SCHULTE, JR., M.S.E., *Lecturer in Electrical Engineering and Research Associate, Engineering Research Institute*

WESTON EDWARD VIVIAN, M.S.E., *Lecturer in Electrical Engineering and Research Engineer, Engineering Research Institute*

ROBERT E. BURROUGHS, M.A., *Lecturer in Electrical Engineering and Assistant Director, Engineering Research Institute*

JOHN GALEN LEWIS, Ph.D., *Lecturer in Nuclear Engineering and Research Engineer, Engineering Research Institute*

ENGINEERING MECHANICS

RUSSELL ALGER DODGE, M.S.E., *Professor of Engineering Mechanics and Chairman of the Department of Engineering Mechanics*
JESSE ORMONDROYD, A.B., *Professor of Engineering Mechanics*
PAUL MANSOUR NAGHDI, Ph.D., *Professor of Engineering Mechanics*
RICHARD THOMAS LIDDICOAT, Ph.D., *Professor of Engineering Mechanics*
EDWARD LEERDRUP ERIKSEN, B.C.E., *Professor Emeritus of Engineering Mechanics*
FERDINAND NORTHRUP MENEFEE, C.E., D.Eng., *Professor Emeritus of Engineering Mechanics*
JAN ABRAM VAN DEN BROEK, Ph.D., *Professor Emeritus of Engineering Mechanics*
HOLGER MADS HANSEN, B.C.E., *Professor Emeritus of Engineering Mechanics*
CHARLES THOMAS OLMSTED, B.S. (C.E.), *Professor Emeritus of Engineering Mechanics*
FRANKLIN L. EVERETT, Ph.D., *Associate Professor of Engineering Mechanics*
ROBERT LAWRENCE HESS, Ph.D., *Associate Professor of Engineering Mechanics*
ERNEST FRANK MASUR, Ph.D., *Associate Professor of Engineering Mechanics*
CHIA-SHUN YIH, Ph.D., *Associate Professor of Engineering Mechanics*
SAMUEL KELLY CLARK, Ph.D., *Associate Professor of Engineering Mechanics*
HADLEY JAMES SMITH, Ph.D., *Assistant Professor of Engineering Mechanics*
EDWARD AXEL YATES, M.S.E., *Assistant Professor of Engineering Mechanics*
RAYMOND A. YAGLE, M.S.E., *Assistant Professor of Engineering Mechanics*
FRANKLIN ESSENBERG, JR., M.S.E., LL.B., *Assistant Professor of Engineering Mechanics*
WILLIAM LLOYD WAINWRIGHT, M.S.E., *Instructor in Engineering Mechanics*
TARIQ B. KHAMMASH, M.S., *Instructor in Engineering Mechanics*
BERTRAM HERZOG, M.S., *Instructor in Engineering Mechanics*
WILLIAM PAUL GRAEBEL, M.S., *Instructor in Engineering Mechanics*
JOSEPH E. MATAR, M.S., *Instructor in Engineering Mechanics*
LOUIS WILLIAM WOLF, M.S., *Instructor in Engineering Mechanics*
MOVSES JEREMY KALDJIAN, M.S., *Instructor in Engineering Mechanics*
BRUCE DOUGLAS GREENSHIELDS, Ph.D., *Lecturer in Engineering Mechanics and Traffic Engineer, Transportation Institute*
WILLIAM WALTER O'DELL, JR., M.S., *Lecturer 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*

CARL EDWIN BURKLUND, Ph.D., *Professor of English, College of Engineering*
IVAN HENRY WALTON, A.M., *Professor of English, College of Engineering*
WEBSTER EARL BRITTON, Ph.D., *Professor of English, College of Engineering*
GEORGE MIDDLETON MCEWEN, Ph.D., *Professor of English, College of Engineering*
WILFRED MINNICH SENSEMAN, Ph.D., *Professor of English, College of Engineering*
THOMAS FARRELL, JR., Ph.D., *Professor of English, College of Engineering*
JOSHUA MCCLENNEN, Ph.D., *Professor of English, College of Engineering*
JOSEPH RALEIGH NELSON, A.M., *Professor Emeritus of English, Counselor Emeritus to Foreign Students, and Director Emeritus of the International Center*
JESSE EARL THORNTON, A.M., *Professor Emeritus of English, College of Engineering*
WILLIAM HENRY EGLEY, A.M., *Associate Professor of English, College of Engineering*
ROBERT D. BRACKETT, A.M., *Associate Professor Emeritus of English, College of Engineering*
WILLIAM BYROM DICKENS, Ph.D., *Assistant Professor of English, College of Engineering*
THOMAS MITCHELL SAWYER, JR., Ph.D., *Assistant Professor of English, College of Engineering*
ROBERT PERCY WEEKS, Ph.D., *Assistant Professor of English, College of Engineering*
DONALD ARTHUR RINGE, Ph.D., *Assistant Professor of English, College of Engineering*
WILLIAM MCKENDREY JONES, Ph.D., *Assistant Professor of English, College of Engineering*
STEPHEN SADLER STANTON, Ph.D., *Assistant Professor of English, College of Engineering*
CHESTER FISHER CHAPIN, Ph.D., *Assistant Professor of English, College of Engineering*
FRANCIS MARION KELLY, JR., Ph.D., *Assistant Professor of English, College of Engineering*
RALPH ANDREW LOOMIS, Ph.D., *Assistant Professor of English, College of Engineering*
EDWARD MERL SHAFTER, JR., Ph.D., *Assistant Professor of English, College of Engineering*
NIEL KLENDENON SNORTUM, Ph.D., *Assistant Professor of English, College of Engineering*
W. HARRY MACK, A.M., *Assistant Professor Emeritus of 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*

ROGER MILLIKEN JONES, M.A., *Instructor in English, College of Engineering*

PETER ROBERTS KLAVER, M.A., *Instructor in English, College of Engineering*

RICHARD EMERSON YOUNG, M.A., *Instructor in English, College of Engineering*

INDUSTRIAL ENGINEERING

WYETH ALLEN, B.M.E., D.Eng., *Professor of Industrial Engineering and Chairman of the Departments of Industrial Engineering and Mechanical Engineering*

CHARLES BURTON GORDY, Ph.D., *Professor of Industrial Engineering*

MERRILL MEEKS FLOOD, Ph.D., *Professor of Industrial Engineering and Associate Director of the Engineering Research Institute*

ROBERT MCDOWELL THRALL, Ph.D., *Professor of Operations Analysis, Department of Industrial Engineering, and Professor of Mathematics, College of Literature, Science, and the Arts*

FREDERICK LEE BLACK, A.B., *Professor of Industrial Engineering, Assistant Director, College of Engineering Industry Program, and Director of Business Relations, School of Business Administration*

GEORGE ALFRED ELGASS, Ph.D., *Professorial Consultant in Industrial Engineering, College of Engineering and Assistant Professor of Marketing, School of Business Administration*

QUENTIN C. VINES, B.S.E. (E.E.), M.E., *Associate Professor of Industrial Engineering*

WILBERT STEFFY, B.S.E. (Ind.-Mech.), *Associate Professor of Industrial Engineering*

WILLIAM D. MCILVAINE, M.S., *Associate Professor of Industrial Engineering and Assistant to the Dean, College of Engineering*

JAMES A. GAGE, M.S., (M.E.), *Associate Professor of Industrial Engineering*

EDWARD LUPTON PAGE, M.S.E. (I.E.), *Assistant Professor of Industrial Engineering*

RICHARD WATSON BERKELEY, B.S.E. (M.&I.E.), *Assistant Professor of Industrial Engineering*

CLYDE WILMOUTH JOHNSON, A.B., *Assistant Professor of Industrial Engineering*

RICHARD CHRISTIAN WILSON, M.S., *Instructor in Industrial Engineering*

HERBERT WYCOFF HADCOCK, M.B.A., *Lecturer in Industrial Engineering*

DEAN H. WILSON, B.S.E. (E.E.), *Lecturer in Industrial Engineering and Research Engineer, Engineering Research Institute*
JOSEPH ELBERT HOAGBIN, M.S., *Lecturer in Industrial Engineering and Research Engineer, Engineering Research Institute*
ROGER RYAN CRANE, S.M., *Lecturer in Industrial Engineering*

MECHANICAL ENGINEERING

WYETH ALLEN, B.M.E., D.Eng., *Professor of Industrial Engineering, Chairman of the Departments of Mechanical Engineering 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*
EDWARD THOMAS VINCENT, B.Sc., *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, M.E., Ph.D., *Professor of Mechanical Engineering*
LESTER VERN COLWELL, M.S., *Professor of Mechanical Engineering*
FLOYD NEWTON CALHOON, M.S., *Professor of Mechanical Engineering*
JAY ARTHUR BOLT, M.S., M.E., *Professor of Mechanical Engineering*
GLENN VERNON EDMONSON, M.E., *Professor of Mechanical Engineering*
RUNE L. EVALDSON, Ph.D., *Professor of Mechanical Engineering*
CHARLES LIPSON, Ph.D., *Professor of Mechanical Engineering*
WILLIAM HORACE GRAVES, B.S.E. (Ch.E.), *Professor of Automotive Engineering*
JOHN ALDEN CLARK, Sc.D., *Professor of Mechanical Engineering*
JOHN RAYMOND PEARSON, M.Sc., M.E., *Professor of Mechanical Engineering*
GORDON JOHN VAN WYLEN, Sc.D., *Professor of Mechanical Engineering*
RANSOM SMITH HAWLEY, B.S. (E.E.), M.E., *Professor Emeritus of Mechanical Engineering*
ORLAN WILLIAM BOSTON, M.S.E., M.E., *Professor Emeritus of Mechanical Engineering and of Production Engineering*
ARNET BERTHOLD EPPLE, M.S., *Associate Professor of Mechanical Engineering*
KEITH WILLIS HALL, B.S.M.E., *Associate Professor of Mechanical Engineering*
JOSEPH REID AKERMAN, Ph.D., *Associate Professor of Mechanical Engineering*
HERBERT HERLE ALVORD, M.S.E., *Associate Professor of Mechanical Engineering*
JOSEPH DATSKO, M.S.E., *Associate Professor of Mechanical Engineering*
JOSEPH EDWARD SHIGLEY, M.S.E., *Associate Professor of Mechanical Engineering*

ROBERT CHARLES JUVINALL, M.S.M.E., *Associate Professor of Mechanical Engineering*

CHIN TSE YANG, Ph.D., *Associate Professor of Mechanical Engineering*

HAROLD RHYS LLOYD, M.A., *Associate Professor Emeritus of Mechanical Engineering*

LESLIE E. WAGNER, M.A., *Assistant Professor of Production Engineering, Department of Mechanical Engineering*

HOWARD REX COLBY, M.S.E., *Assistant Professor of Mechanical Engineering*

FREDERICK JOHN VESPER, M.S.E., *Assistant Professor of Mechanical Engineering*

JOSEPH ANTHONY SWEENEY, JR., B.S.E. (M.E.), *Assistant Professor of Mechanical Engineering*

KARL ERNST HANS MOLTRECHT, M.S.E., *Assistant Professor of Mechanical Engineering*

JOHN GRAHAM YOUNG, B.S.E. (M.E.), *Assistant Professor of Mechanical Engineering and Assistant to the Dean of the College of Engineering*

ROBERT MACORMAC CADDELL, M.S.E., *Assistant Professor of Mechanical Engineering*

WILLIAM MIRSKY, Ph.D., *Assistant Professor of Mechanical Engineering*

LELAND JAMES QUACKENBUSH, M.S.E., *Assistant Professor of Mechanical Engineering*

JULIAN ROSS FREDERICK, Ph.D., *Assistant Professor of Mechanical Engineering*

HARRY JAMES WATSON, B.M.E., *Assistant Professor Emeritus of Mechanical Engineering*

FREDERICK KENT BOUTWELL, M.S.E., *Instructor in Mechanical Engineering*

KENNETH C. LUDEMA, M.S.E., *Instructor in Mechanical Engineering*

JOSEPH CASMERE MAZUR, M.S.E., *Instructor in Mechanical Engineering*

IRVING JEROME STEWART, M.S.E., *Instructor in Mechanical Engineering*

FRANKLIN HERBERT WESTERVELT, M.S.E., *Instructor in Mechanical Engineering*

ISMAIL HUSEYIN HOYI, M.S.E., *Instructor in Mechanical Engineering*

RICHARD EDWIN SONNTAG, M.S.E., *Instructor in Mechanical Engineering*

WILLIAM TELFER, *Instructor Emeritus in the Working, Treating and Welding of Steel*

FREDERICK GNICHTEL HAMMITT, M.S., *Lecturer in Mechanical Engineering and Associate Research Engineer, Engineering Research Institute*

FRITZ B. HARRIS, M.S., *Lecturer in Mechanical Engineering*

NAVAL ARCHITECTURE AND MARINE ENGINEERING

RICHARD BAILEY COUCH, Ae.E., *Professor of Naval Architecture and Marine Engineering and Chairman of the Department of Naval Architecture and Marine Engineering*

HENRY CARTER ADAMS 2d, M.S., *Professor of Naval Architecture and Marine Engineering*

EDWARD MILTON BRAGG, S.B., *Professor Emeritus of Naval Architecture and Marine Engineering*

LOUIS A. BAIER, B. Mar. E., N.A., *Professor of Naval Architecture and Marine Engineering and Chairman of the Department of Naval Architecture and Marine Engineering.* On retirement furlough, 1957-58.

HARRY BELL BENFORD, B.S.E. (Nav. Arch. and Mar.E.), *Associate Professor of Naval Architecture and Marine Engineering*

GEORGE LAUMAN WEST, JR., B.S.E. (Nav. Arch. and Mar. E), *Assistant Professor of Naval Architecture and Marine 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 Associate 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

Health Service approval is a prerequisite for final admission. This approval is granted when the report of a physical examination is submitted by a physician of the applicant's choice upon a form provided by the University. It is not intended to establish standards of physical requirements for admission and the nature of the physician's report will not affect the eligibility of the applicant. However, it is essential that the Health Service be provided with information with respect to the physical condition of each student in the best interest of the student himself and his associates. Vaccination for smallpox and tetanus is strongly urged.

Physicians' examinations are not required of those applicants who intend to enroll only for the summer session or who are on campus for limited periods.

All new students will report to the Health Service for chest X-ray examination as a part of the normal registration procedure.

Students who have been out of residence for health reasons will go to the Health Service for clearance as will those students who have received notice that special Health Service approval is required for readmission.

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

Each student entering the University from a secondary school is required to complete satisfactorily a one-year course in physical education suited to his health condition.*

A transfer student with less than sixty hours of advanced credit and without a year of physical education elsewhere will be required to elect one year of physical education at the University unless excused by the Health Committee.*

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 from required physical education classes must be presented to the Waterman Gymnasium office for approval.

MENTOR SYSTEM

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 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.

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 students in his group definite information regarding their progress.

FRESHMAN ASSEMBLY

Attendance during the first semester at a weekly assembly is required of all freshmen. In the assemblies matters are discussed pertaining to the students' orientation to college life and the improvement of study habits,

* By Regents' action on 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.

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.

PLACEMENT MEETINGS

The College conducts a series of placement meetings which includes discussion of a variety of placement and professional subjects, such as the considerations for selecting an engineering position, the techniques for employment interviewing, legal registration of engineers, personal career management, continued education, and so forth.

Although these meetings are planned to be of primary concern to upperclassmen who will soon be starting their careers, they are open to all interested students in the College.

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, or more than eighteen hours unless his grade average for the preceding semester is at least 3.0. No credit will be allowed 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 Associate 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. Any student who fails to maintain a satisfactory proficiency in English in any of his work in the College of Engineering shall be reported to the Associate Dean. After consultation with the Department of English and the program adviser, the student may be required to elect further work in English as may be deemed necessary.

6. 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.

7. 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 and Design (see *a*, above)

8. Substitution of a course for one which is a requirement for graduation is possible only in accordance with the rules of the Committee on Curriculum.

9. 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.

10. 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 fulfills 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 Associate 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 Associate 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 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 Associate Dean.

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 or 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 Associate 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 Associate 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 Associate 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 Associate 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 Associate 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 13 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.

Registration Schedules

Each of the following groups of students is allotted a definite period for admission to the gymnasiums for registration. Come exactly on time, neither early nor late.

You will enable yourself and others to enter on time if you complete all registration forms distinctly and according to directions on the forms — *before you enter the gymnasiums.* Elections should be approved as specified in the *Announcement* of your school or college.

FIRST SEMESTER, 1958–1959

WEDNESDAY, SEPTEMBER 17, 1958

A.M.			P.M.		
8:00– 8:10	Aa	–Alc	1:00– 1:10	Cohf	–Con
8:10– 8:20	Ald	–Anderse	1:10– 1:20	Coo	–Cou
8:20– 8:30	Andersf	–Ark	1:20– 1:30	Cov	–Cro
8:30– 8:40	Arl	–Bab	1:30– 1:40	Crp	–Dam
8:40– 8:50	Bac	–Baq	1:40– 1:50	Dan	–Daz
8:50– 9:00	Bar	–Bas	1:50– 2:00	Db	–Deng
9:00– 9:10	Bat	–Bec	2:00– 2:10	Denh	–Din
9:10– 9:20	Bed	–Benr	2:10– 2:20	Dio	–Dou
9:20– 9:30	Bens	–Bes	2:20– 2:30	Dov	–Dup
9:30– 9:40	Bet	–Blac	2:30– 2:40	Duq	–Eg
9:40– 9:50	Blad	–Boe	2:40– 2:50	Eh	–En
9:50–10:00	Bof	–Bot	2:50– 3:00	Eo	–Fan
10:00–10:10	Bou	–Bra	3:00– 3:10	Fao	–Fil
10:10–10:20	Brb	–Brown, F.	3:10– 3:20	Fim	–Foc
10:20–10:30	Brown, G.	–Buc	3:20– 3:30	Fod	–Fran
10:30–10:40	Bud	–Bur	3:30– 3:40	Frao	–Fz
10:40–10:50	Bus	–Cam	3:40– 3:50	Ga	–Gau
10:50–11:00	Can	–Car	3:50– 4:00	Gav	–Gill
11:00–11:10	Cas	–Cha	4:00– 4:10	Gilm	–Goldl
11:10–11:20	Chb	–Ci	4:10– 4:20	Goldm	–Grah
11:20–11:30	Cj	–Cobe	4:20– 4:30	Grai	–Gri

THURSDAY, SEPTEMBER 18, 1958

A.M.			P.M.		
8:00– 8:10	Grj	–Had	1:00– 1:10	Lawrf	–Leis
8:10– 8:20	Hae	–Ham	1:10– 1:20	Leit	–Lewi
8:20– 8:30	Han	–Harrisn	1:20– 1:30	Lewj	–Lit
8:30– 8:40	Harriso	–Hd	1:30– 1:40	Liu	–Luca
8:40– 8:50	Hea	–Henl	1:40– 1:50	Lucb	–M(a)cClel
8:50– 9:00	Henm	–Hile	1:50– 2:00	M(a)cClem	–M(a)cGi
9:00– 9:10	Hilf	–Holl	2:00– 2:10	M(a)cGj	–M(a)cMa
9:10– 9:20	Holm	–How	2:10– 2:20	M(a)cMb	–Mall
9:20– 9:30	Hox	–Hur	2:20– 2:30	Malm	–Marsg
9:30– 9:40	Hus	–Jack	2:30– 2:40	Marsh	–Mat
9:40– 9:50	Jacl	–Jog	2:40– 2:50	Mau	–Mere
9:50–10:00	Joh	–Jones, J.	2:50– 3:00	Merf	–Miller, E.
10:00–10:10	Jones, K.	–Kam	3:00– 3:10	Miller, F.	–Miz
10:10–10:20	Kan	–Kea	3:10– 3:20	Mj	–Moro
10:20–10:30	Keb	–Ker	3:20– 3:30	Morp	–Munm
10:30–10:40	Kes	–Kiq	3:30– 3:40	Munn	–Nax
10:40–10:50	Kir	–Kni	3:40– 3:50	Nay	–Ne
10:50–11:00	Knj	–Koth	3:50– 4:00	Nf	–Nz
11:00–11:10	Koti	–Krug	4:00– 4:10	Oa	–Opa
11:10–11:20	Kruh	–Lami	4:10– 4:20	Opb	–Pak
11:20–11:30	Lamj	–Lawre	4:20– 4:30	Pal	–Pats

FRIDAY, SEPTEMBER 19, 1958

A.M.			P.M.		
8:00– 8:10	Patt	–Pere	1:00– 1:10	Stai	–Steu
8:10– 8:20	Perf	–Pick	1:10– 1:20	Stev	–Sto
8:20– 8:30	Picl	–Pop	1:20– 1:30	Stp	–Sup
8:30– 8:40	Poq	–Pri	1:30– 1:40	Suq	–Tas
8:40– 8:50	Prj	–Ram	1:40– 1:50	Tat	–Thomp
8:50– 9:00	Ran	–Reid, S.	1:50– 2:00	Thomq	–Toml
9:00– 9:10	Reid, T.	–Richa	2:00– 2:10	Tomm	–Tup
9:10– 9:20	Richb	–Robertsn	2:10– 2:20	Tuq	–Vandeq
9:20– 9:30	Robertso	–Rop	2:20– 2:30	Vander	–Ver
9:30– 9:40	Roq	–Rot	2:30– 2:40	Ves	–Walc
9:40– 9:50	Rou	–Rz	2:40– 2:50	Wald	–Wark
9:50–10:00	Sa	–Sarg	2:50– 3:00	Warl	–Webe
10:00–10:10	Sarh	–Schl	3:00– 3:10	Webf	–Wer
10:10–10:20	Schm	–Schwartz, R.	3:10– 3:20	Wes	–Wh
10:20–10:30	Schwartz, S.	–Send	3:20– 3:30	Wi	–Willi
10:30–10:40	Sene	–Shel	3:30– 3:40	Willj	–Wolc
10:40–10:50	Shem	–Siel	3:40– 4:00	Wold	–Wre
10:50–11:00	Siem	–Sk	4:00– 4:10	Wrf	–Yz
11:00–11:10	Sl	–Smith, L.	4:10– 4:20	Za	–Zz
11:10–11:20	Smith, M.	–Sol			
11:20–11:30	Som	–Stah			

SATURDAY, SEPTEMBER 20, 1958

Any student may register from 8:00 to 10:30 A.M. However, Saturday registration is inadvisable as many sections of course offerings will be closed. It is essential that registration and classification be completed according to schedule.

SECOND SEMESTER, 1958–1959

WEDNESDAY, FEBRUARY 4, 1959

A.M.			P.M.		
8:00– 8:10	Cohf	–Con	1:00– 1:10	Grj	–Had
8:10– 8:20	Coo	–Cou	1:10– 1:20	Hae	–Ham
8:20– 8:30	Cov	–Cro	1:20– 1:30	Han	–Harrisn
8:30– 8:40	Crp	–Dam	1:30– 1:40	Harriso	–Hd
8:40– 8:50	Dan	–Daz	1:40– 1:50	Hea	–Henl
8:50– 9:00	Db	–Deng	1:50– 2:00	Henm	–Hile
9:00– 9:10	Denh	–Din	2:00– 2:10	Hilf	–Holl
9:10– 9:20	Dio	–Dou	2:10– 2:20	Holm	–How
9:20– 9:30	Dov	–Dup	2:20– 2:30	Hox	–Hur
9:30– 9:40	Duq	–Eg	2:30– 2:40	Hus	–Jack
9:40– 9:50	Eh	–En	2:40– 2:50	Jacl	–Jog
9:50–10:00	Eo	–Fan	2:50– 3:00	Joh	–Jones, J.
10:00–10:10	Fao	–Fil	3:00– 3:10	Jones, K.	–Kam
10:10–10:20	Fim	–Foc	3:10– 3:20	Kan	–Kea
10:20–10:30	Fod	–Fran	3:20– 3:30	Keb	–Ker
10:30–10:40	Frao	–Fz	3:30– 3:40	Kes	–Kiq
10:40–10:50	Ga	–Gau	3:40– 3:50	Kir	–Kni
10:50–11:00	Gav	–Gill	3:50– 4:00	Knj	–Koth
11:00–11:10	Gilm	–Goldl	4:00– 4:10	Koti	–Krug
11:10–11:20	Goldm	–Grah	4:10– 4:20	Kruh	–Lami
11:20–11:30	Grai	–Gri	4:20– 4:30	Lamj	–Lawre

THURSDAY, FEBRUARY 5, 1959

A.M.			P.M.		
8:00– 8:10	Lawrf	–Leis	1:00– 1:10	Patt	–Pere
8:10– 8:20	Leit	–Lewi	1:10– 1:20	Perf	–Pick
8:20– 8:30	Lewj	–Lit	1:20– 1:30	Picl	–Pop
8:30– 8:40	Liu	–Luca	1:30– 1:40	Poq	–Pri
8:40– 8:50	Lucb	–M(a)cClel	1:40– 1:50	Prj	–Ram
8:50– 9:00	M(a)cClem	–M(a)cGi	1:50– 2:00	Ran	–Reid, S.
9:00– 9:10	M(a)cGj	–M(a)cMa	2:00– 2:10	Reid, T.	–Richa
9:10– 9:20	M(a)cMb	–Mall	2:10– 2:20	Richb	–Robertsn
9:20– 9:30	Malm	–Marsg	2:20– 2:30	Robertso	–Rop
9:30– 9:40	Marsh	–Mat	2:30– 2:40	Roq	–Rot
9:40– 9:50	Mau	–Mere	2:40– 2:50	Rou	–Rz
9:50–10:00	Merf	–Miller, E.	2:50– 3:00	Sa	–Saig
10:00–10:10	Miller, F.	–Miz	3:00– 3:10	Sarh	–Schl
10:10–10:20	Mj	–Moro	3:10– 3:20	Schm	–Schwartz, R.
10:20–10:30	Morp	–Munm	3:20– 3:30	Schwartz, S.	–Send
10:30–10:40	Munn	–Nax	3:30– 3:40	Sene	–Shel
10:40–10:50	Nay	–Ne	3:40– 3:50	Shem	–Siel
10:50–11:00	Nf	–Nz	3:50– 4:00	Siem	–Sk
11:00–11:10	Oa	–Opa	4:00– 4:10	Sl	–Smith, L.
11:10–11:20	Opb	–Pak	4:10– 4:20	Smith, M.	–Sol
11:20–11:30	Pal	–Pats	4:20– 4:30	Som	–Stah

FRIDAY, FEBRUARY 6, 1959

A.M.			P.M.		
8:00– 8:10	Stai	–Steu	1:00– 1:10	Andersf	–Ark
8:10– 8:20	Stev	–Sto	1:10– 1:20	Arl	–Bab
8:20– 8:30	Stp	–Sup	1:20– 1:30	Bac	–Baq
8:30– 8:40	Suq	–Tas	1:30– 1:40	Bar	–Bas
8:40– 8:50	Tat	–Thomp	1:40– 1:50	Bat	–Bec
8:50– 9:00	Thomq	–Toml	1:50– 2:00	Bed	–Benr
9:00– 9:10	Tomm	–Tup	2:00– 2:10	Bens	–Bes
9:10– 9:20	Tuq	–Vandeq	2:10– 2:20	Bet	–Blac
9:20– 9:30	Vander	–Ver	2:20– 2:30	Blad	–Boe
9:30– 9:40	Ves	–Walc	2:30– 2:40	Bof	–Bot
9:40– 9:50	Wald	–Wark	2:40– 2:50	Bou	–Bra
9:50–10:00	Warl	–Webe	2:50– 3:00	Brb	–Brown, F.
10:00–10:10	Webf	–Wer	3:00– 3:10	Brown, G.	–Buc
10:10–10:20	Wes	–Wh	3:10– 3:20	Bud	–Bur
10:20–10:30	Wi	–Willi	3:20– 3:30	Bus	–Cam
10:30–10:40	Willj	–Wolc	3:30– 3:40	Can	–Car
10:40–10:50	Wold	–Wre	3:40– 4:00	Cas	–Cha
10:50–11:00	Wrf	–Yz	4:00– 4:10	Chb	–Ci
11:00–11:10	Za	–Zz	4:10– 4:20	Cj	–Cohe
11:10–11:20	Aa	–Alc			
11:20–11:30	Ald	–Anderse			

SATURDAY, FEBRUARY 7, 1959

Any student may register from 8:00 to 10:30 A.M. However, Saturday registration is inadvisable as many sections of course offerings will be closed. It is essential that registration and classification be completed according to schedule.

INDEX

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.

Bulletin of General Information

Announcements:

- Architecture and Design, College of
- Business Administration, School of
  - Graduate
  - Undergraduate
- Dentistry, School of
- Education, School of
- Engineering, College of
- Flint College
- 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 Foundation Institute
- Public Administration, Institute of
- Public Health, School of
- Social Work, School of
- Summer Session

OTHER BULLETINS

Extension courses
Bulletins describing the work of various departments and curriculums

For general information concerning the University, address University of Michigan, Ann Arbor, Michigan.