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announcement 1961-62

College of Engineering

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University of Michigan Official Publication

College of Engineering

1961-1962

Announcement

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Summer session classes begin	June 26, Monday
Independence Day, a holiday	July 4, Tuesday
Summer session ends	August 19, Saturday

FIRST SEMESTER

Orientation period	September 11–16, Monday–Saturday
*Registration	September 13–16, Wednesday–Saturday
First semester classes begin	September 18, Monday
Thanksgiving recess begins	November 22, Wednesday (evening)
Classes resume	November 27, Monday (morning)
Christmas recess begins	December 16, Saturday (noon)

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Classes resume	January 3, Wednesday (morning)
Classes end	January 20, Saturday
Midyear Graduation	January 20, Saturday
Examination period	January 22–February 1, Monday–Thursday
First semester ends	February 3, Saturday

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Orientation period	February 5–10, Monday–Saturday
*Registration	February 7–10, Wednesday–Saturday
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Spring recess begins	April 7, Saturday (noon)
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Examination period	June 1–12, Friday–Tuesday
Commencement	June 16, Saturday

SUMMER SESSION, 1962

Registration	June 21–23, Thursday–Saturday
Summer session classes begin	June 25, Monday
Independence Day, a holiday	July 4, Wednesday
Summer session ends	August 18, Saturday

This calendar is subject to revision.

*For registration schedules, see pages 183 and 184.

COLLEGE OF ENGINEERING

HARLAN HATCHER, Ph.D., Litt.D., LL.D., *President of the University*
MARVIN L. NIEHUSS, LL.B., *Vice-President and Dean of Faculties*
STEPHEN S. ATTWOOD, M.S., *Dean of the College of Engineering*
GLENN V. EDMONSON, M.E., *Associate Dean of the College of Engineering*
JAMES C. MOUZON, Ph.D., *Associate Dean of the College of Engineering*
WALTER J. EMMONS, B.S., A.M., *Associate Dean Emeritus and Secretary Emeritus of the College of Engineering*
ARLEN R. HELLWARTH, M.S., *Assistant Dean and Secretary of the College of Engineering*
ROBERT H. HOISINGTON, M.S., *Assistant to the Dean*
IRA K. MCADAM, B.S.E. (M.E.), *Assistant to the Dean*
JOHN G. YOUNG, B.S.E. (M.E.), *Assistant to the Dean*

General Information

Engineering is the profession that applies the laws of physical science to the efficient and economic conversion of natural resources for the benefit of man.

To design and produce the structures, machines, and products of industry requires the application of scientific and mathematical knowledge, the utilization of natural resources and capital, and the management of men.

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. 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. Only through continued practice and exercise of judgment can one acquire the stature of an engineer.

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 a graduate to enter understandingly into scientific investigations and, at the same time, they provide a background that will make him immediately useful in engineering practice. Many qualified graduates will continue their formal education at the postgraduate level leading to a master's or doctor's degree. One of the opportunities for continued growth and development after college is registration as a professional engineer. In each state of the United States, after a specified length of experience, usually four years, the young engineer may pass qualifying examinations to attain this status.

The student will have the opportunity of associating with teachers who have professional experience, gained through research, consultation, and engineering employment. The University of Michigan believes that engineering experience improves the ability of teachers, both in the classroom and laboratory. Members of the faculty are encouraged to be active in professional practice in order to keep informed on new developments in their respective fields. Facilities for research at the University provide for its teachers not only an atmosphere of research but also convenient opportunities for continuing their professional development, increasing their understanding of the subjects taught, and passing on to their students the benefit of their investigations and first-hand experiences.

Teaching is often 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, at several field locations, and on a variety of engineering projects.

To profit satisfactorily by an engineering education, a student should have mental ability and alertness of a high order, good health, and perseverance. A good criterion for predicting success is superior grades in high school, particularly in mathematics, science, and English. A serious mistake is frequently made in regarding manual dexterity or an interest in mechanical things as the only standards for judging abilities important for high achievement in the profession of engineering.

The choice of a career is a most important one and should be based on sound and complete information. If at all possible, a prospective student should discuss his interests and abilities with practicing engineers. In many communities, professional engineering societies provide counseling services. The Admissions Office of the University and the officers and program advisers of the College of Engineering will gladly be of any possible service in assisting students with career planning.*

*A vocational booklet entitled *Engineering — A Creative Profession* may be obtained (25 cents per copy) from Engineers' Council for Professional Development, 29 West 39th Street, New York 18, N.Y. It answers many questions commonly experienced by high school students who are considering engineering as a career, and describes in particular five general fields of the engineering profession — civil, mining and metallurgical, mechanical, electrical, and chemical.

The fourteen undergraduate degree programs offered by the College of Engineering cover a wide spectrum. They are listed in the Contents on page 3. The time at which a student should select a particular program is covered under Freshman Program.

ACCREDITATION

The several degree programs have been examined by the Engineers' Council for Professional Development. The following have been accredited: Aeronautical, Chemical, Civil, Electrical, Engineering Mechanics, Industrial, Materials, Mechanical, Metallurgical, Naval Architecture and Marine Engineering, Physics, and Science.

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; sanitary and structural laboratories of the Civil Engineering Department; solid mechanics, fluid mechanics and dynamics laboratories of the Engineering Mechanics Department; drafting, computing, and design rooms of the Engineering Graphics Department and other departments; 360-foot naval tank with dynamometers used by the Naval Architecture and Marine Engineering Department for studies on ship models; and facilities for industrial engineering demonstrations for courses offered by the Industrial Engineering Department.

Directly across the street, the **East Engineering Building** (1923) houses well-instrumented machine-tool and machinability laboratories; gaging and measuring laboratory of the Mechanical Engineering Department; foundry and melting laboratory; metalworking, welding, heat-treating, spectrographic (mass, infrared, ultra-violet, etc.), and metallographic laboratories; an X-ray laboratory for radiography and diffraction studies; an electron microscope; chemical, high pressure, plastics, semiconductor, nuclear metallography, and measurements laboratories of the Chemical Engineering Department; and the highway and soil mechanics laboratory of the Civil Engineering Department.

The **East Engineering Addition** (1947) contains two subsonic wind tunnels, supersonic jet, structures, propulsion, and instrumentation laboratories of the Aeronautical and Astronautical Engineering Department; energy converters and power systems, communications, electronics, feedback controls, computers, space and electron physics research, radiation and propagation, and solid-state devices laboratories of the Electrical Engineering Department; and the meteorological laboratory for the program in meteorology.

The **Engineering Library,** located on the third floor of the Undergraduate Library, is one of the more than twenty divisional libraries in the University Library system. Its collection of approximately 134,000 volumes covers all fields of engineering (including naval architecture). The library subscribes to almost 900 periodicals and maintains large collections of pamphlets, technical reports, and industrial catalogues.

The Engineering Library also maintains two special collections: the **Phoenix Library,** located in the Phoenix Memorial Laboratory on the North Campus, containing an AEC depository collection of approximately 30,000 reports as well as almost 3,000 volumes on atomic energy; and the **Transportation Library,** containing more than 122,000 volumes on all phases of the subject of transportation.

Trained staffs are available to assist the student in making effective use of these libraries, as well as of the University Library system as a whole.

The **North Campus** now houses the following laboratories for instruction and research:

The memorial **Mortimer E. Cooley Building** (1953) provides space for the University's Office of Research Administration, for an auditorium and conference rooms, and for an electronic systems and circuits laboratory of the Electrical Engineering Department.

Phoenix Memorial Laboratory (1955) and the accompanying Ford Nuclear Reactor (1956) provides facilities for the Nuclear Engineering Department as well as research in the field of atomic energy.

The **Aeronautical Laboratory** (1957) provides hypersonic, supersonic, and low turbulence wind tunnels and propulsion laboratories for studies by the Aeronautical and Astronautical Engineering Department in aerodynamics and propulsion.

The **Automotive Laboratory** (1957), generously supplied with equipment by the industry of the state, provides laboratories for the Chemical, Electrical, and Mechanical Engineering departments for studies of combustion, mechanical, and electrical systems and for work on engines, chassis, and suspension systems. It also provides space for the Civil and Nuclear Engineering Departments.

The **Fluids Engineering Laboratory** (1958) provides space for all departments in the study of fluid flow problems; for the Mechanical Engineering Department on heat transfer, thermodynamics, and power generation studies; for the Chemical Engineering Department on process operation and heat transfer problems; and for the Electrical Engineering Department on plasma engineering.

The Fluids Engineering Laboratory contains a memorial plaque to the late Dean George Granger Brown, whose dreams became a reality in the development of the North Campus which will ultimately provide classroom, office, and laboratory facilities for all engineering programs as well as research.

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 first 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 the location nearly ideal for summer instruction in surveying and geology.

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.

A new radio telescope, dedicated in 1959 and situated sixteen miles from Ann Arbor, provides opportunities for electrical engineering students interested in the engineering aspects of radio astronomy.

CO-OPERATIVE PROGRAMS WITH INDUSTRY

In certain fields a desirable combination of theory and practice is available to a limited extent 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.

DEARBORN CENTER

The Dearborn Center, an integral part of The University of Michigan, provides the newest and one of the most unusual educational opportunities of the University. It offers a full-fledged co-operative program in electrical, industrial, and mechanical engineering. Students seeking admission must have completed the requirements of the first two years for the program elected either on the Ann Arbor campus, at an accredited junior college, or another accredited college or university. A student desiring further information should write: Admissions Office, Dearborn Center, 4901 Evergreen Road, Dearborn, Michigan.

PLACEMENT

The College of Engineering considers the proper placement of its graduates to be very important, since it is recognized that the first years of professional experience are of great significance in developing the full capabilities of the young engineer. For this reason the College provides an engineering placement service for both students and alumni in Room 128H, West Engineering Building. This service provides opportunities for interviewing engineering employers on campus, announcements of position openings received by mail for both graduates and experienced alumni, placement counseling service, and published information on engineering careers and employers.

Meetings for students are also conducted by the placement service at the beginning of each semester on subjects of placement interest, such as the nature and availability of engineering opportunities, techniques for effective interviewing and plant visits, and considerations of engineering practice and professional development.

Many employers of engineers provide opportunities for students, particularly after their third year in college, to work in an engineering environment during summer vacation.

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, glee clubs, sports groups, and other organizations provide excellent opportunities for self-development. They constitute an important part of the University life, and engineering students are encouraged to take an active part in them 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 upon meeting the respective requirements for membership or participation.

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 Rocket 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, honor-technical society for students in naval architecture and marine engineering
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
Tau Beta Pi, national engineering honor society
Triangles, junior honor society
Vulcans, senior honor society

Students interested in exploring other opportunities may review a complete list of campus organizations in the Office of Student Affairs, 2011 Student Activities Building.

SCHOLARSHIPS, FELLOWSHIPS, PRIZES, LOANS, AND EMPLOYMENT

Numerous scholarships, fellowships, and prizes, as well as loan funds, are available to engineering students. A list of these, with the conditions governing them, appears in the special bulletin *University Scholarships, Fellowships, and Prizes,* which is available upon request to the Office of Student Affairs, 2011 Student Activities Building. March 1 is the deadline for applying for scholarships.

The Committee on Scholarships and Loans of the College has under its jurisdiction those scholarships and aid funds which have been established for the special benefit of undergraduate students in engineering. In general, such assistance is awarded on the basis of high scholastic performance and of demonstrated need. Applications may be addressed directly to this committee at the office of the Dean.

A number of qualified seniors are employed each semester as student assistants for assigned work in the several departments. Qualified graduate students are frequently provided assistance to continue their studies toward master's or doctor's degrees either through fellowships or a variety of employment opportunities in teaching or research.

VETERANS

The University of Michigan welcomes veterans and provides information, guidance, and counseling to those eligible for educational benefits under Public Laws 550, 634, and 894.

All students who are eligible for and elect to receive education and training benefits while attending the University are required to register with the Office of Veterans Affairs, 142 Administration Building, as an integral part of the registration process.

FEES AND EXPENSES

Semester fees, subject to change without notice, are as follows:

Michigan students	**$140**
Non-Michigan students	**$375**

Semester fees are payable either at registration or in two installments within the semester. (Requirements on enrollment deposit are stated under Admission.)

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 student's contribution to the cost of class instruction, library services, 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.*

Foreign students who are not provided with health-hospitalization insurance by their sponsors are required to purchase Student Group Health Insurance. The cost of this coverage (approximately $25) *must* be paid at the time of registration. This coverage extends for a full twelve months.

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

Indebtedness to the University. Proper observance of financial obligation is deemed an essential of good conduct and students who are guilty of laxness in this regard to a degree incompatible with the general standards of conduct shall be liable to disciplinary action by proper University authorities. Students shall pay all accounts due the University in accordance with regulations set forth for such payments by the Vice-President in charge of Business and Finance.

Admission

Applicants for admission should be at least sixteen years of age and officially recommended graduates of accredited high schools. They must present acceptable evidence of good moral character and satisfy requirements as explained under Health Service Approval. General policies and requirements are stated in the bulletin *General Information.*

Applications for admission in September should be submitted by March 1 to receive equal consideration with other applicants. Since there is no application fee, no money should be sent when making application for admission.

Enrollment Deposit. In order to make best use of its facilities and staff in a period of expanding enrollment, the University must know accurately which newly admitted students are likely to enroll. New undergraduate students, both freshmen and transfers, and former students returning after an absence of one or more semesters are required to make a non-refundable enrollment deposit of fifty dollars ($50) each, in order to hold the admission granted them. The deposit may be applied only to the student's fees for the semester for which he has been admitted; it will not be an additional cost for attending the University if the student enrolls.

Instructions for making the advance payment will be sent to the student by the admissions officer who granted the admission. No student is to send money until instructed to do so by the University.

ADMISSION AS A FRESHMAN

Prospective freshmen are admitted to this College by the Director of Admissions, Student Activities Building, from whom appropriate forms and instructions may be obtained. Applications are invited from high school students who have begun the senior year. Early application will make it possible to inform students of the probability of their admission and to call attention to any requirements still unfulfilled.

The admission requirements are designed to ensure that each student who enters the College of Engineering has aptitude for the profession of engineering and intellectual capacity, as well as the necessary motivation and interest, to pursue his college work successfully. The recommendations of principals as to the applicant's character, scholarship interests and attainments, extracurricular activities, seriousness of purpose, and intellectual promise will be taken into account in determining eligibility for admission. Additional criteria are the subjects studied in high school, scholastic performance, and results of aptitude and achievement tests (covered below).

The Director of Admissions welcomes the opportunity to interview prospective students and recommends that appointments for interviews be arranged in advance. Admission, when granted to a high school student, is contingent upon satisfactory completion of his secondary school program.

Subjects Studied in High School. Admission requirements are stated in units, a unit being defined as a course covering a school year of at least 120 sixty-minute hours of classroom work. Two or three hours of laboratory, drawing, or shop work are counted as equivalent to one hour of recitation.

Applicants for admission as freshmen without entrance deficiency must present a minimum of fifteen units of acceptable high school credit in accordance with the following schedule:

English

At least three units are required. 3

Mathematics Group

At least three units are required, including algebra, one and one-half units; geometry (including some solid geometry), one unit; trigonometry, one-half unit 3

(An additional one-half unit of algebra is strongly recommended; a total of two units of algebra will be required in September 1964.)

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

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, one unit of chemistry, and one unit of physics should be presented whenever feasible since, with excellent preparation, some acceleration is possible at the University, as stated under Planning the Student's Program. In addition, these are the subjects that best give a student a good background for making a well-advised career decision.

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.

Scholastic Performance. The student's grades, particularly in English, mathematics, and science, and his standing in his class are considered important in predicting his likelihood of success in engineering. These factors reflect both his ability in the subjects on which the engineering curriculum is based and his interest and motivation in becoming an engineer.

Aptitude and Achievement Tests. As part of a two-year study of the potential value of pre-admission testing, applicants who wish to enroll as freshmen from June 1961 through February 1963 in the College of Engineering will be required to take during their senior year in high school the following College Entrance Examination Board tests before they will be permitted to enroll.

a) Scholastic Aptitude Test
b) Two achievement tests
   1. English composition
   2. One, chosen by the applicant, in any one of these subjects: chemistry, advanced mathematics, or physics

c) English writing sample

An Advanced Placement Program examination in any of the subjects listed under (*b*) is acceptable as a substitute for the College Board Achievement Test in the subject. While final admission will not be granted before test results are known, *the decision on admission will not be made on the basis of the test results.*

Advanced Placement. Many high schools throughout the country are offering work of such caliber that an incoming freshman may receive college credit for some subjects provided he has performed satisfactorily on Advanced Placement Program examinations conducted nationally by the College Entrance Examination Board. Such a student may significantly accelerate his education or he may enrich his stay in the College of Engineering by covering more material than does the normal student.

For information and time schedules on the tests referred to above, write to College Entrance Examination Board, Box 592, Princeton, New Jersey.

ADMISSION WITH ADVANCED STANDING

An applicant desiring to transfer from an approved college in the United States with advanced credit should write to the Assistant Dean, College of Engineering, for an application form and instructions. He will be required to arrange for an official transcript of both his secondary school and college work, together with evidence of honorable dismissal from his college. This applies also to students planning to transfer from another college in the University.

For admission without deficiencies, the applicant must satisfy the requirements for admission from high school as stated under Admission as a Freshman. The college transcript must list the subjects studied, the number of credit hours and grades earned in each subject, and the basis upon which grades are assigned. Results of aptitude and achievement tests taken in high school or college are helpful when available.

The history of an applicant must demonstrate that he has the ability to meet the requirements of the College of Engineering for a Bachelor of Science in Engineering degree. An over-all scholastic average satisfactory for good standing at his previous institution may not in itself be sufficient. The grades earned in subjects related to the program elected by the applicant will be taken into account in judging his ability to succeed. As a minimum requirement, his scholastic record as interpreted by the College of Engineering must be such that he would be considered in good standing if his work had been taken at this College.

Program with Basic Courses Taken in Another Institution. Basic pre-engineering courses in English, mathematics, chemistry, and physics are offered by many liberal arts colleges and community or junior colleges. Generally, such courses are offered as a complete two-year program designed to meet the requirements for study at the professional level in many engineering colleges (e.g., a mathematics sequence requiring four semesters or six quarters). While a student will be considered for admission with any amount of college credit, he should weigh the advantages of completing the required basic program before seeking a transfer.

In many institutions a student is able to satisfy the requirements of physical education, economics, and nontechnical subjects; he may also be able to complete his work in engineering graphics and engineering materials and to start engineering mechanics if his institution offers adequate instruction in these fields.

A student in another college or university who desires to transfer to the College of Engineering should examine carefully the program which he plans to elect at this College and arrange his work accordingly. Questions pertaining to choice of field or program and course elections not answered in this announcement may be addressed to the program adviser in the program he wishes to elect. Other questions of a general nature and those relating to admission requirements should be addressed to the Assistant Dean.

Combined Programs with Other Institutions. The College of Engineering has an agreement with several institutions that provides an opportunity to earn two bachelor's degrees (A.B. and B.S.E.) in approximately five years. The list includes Albion College, Alma College, Calvin College, Central Michigan University, Eastern Michigan University, Emmanuel Missionary College, and Kalamazoo College. Under the plan a student who has been enrolled 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. Under this agreement these institutions, 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 Arts degree at the end of his fourth year. Calvin College grants its degree upon completion of the requirements for the degree in engineering at the University.

In co-operation with the College of Literature, Science, and the Arts of the University, combined programs are offered in the fields of chemical and civil engineering. Each of the programs generally 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 41 and 45.

Students interested in the possibility of arranging similar programs with emphasis on other subjects should discuss their interests with the Engineering College Committee on Combined Courses with the College of Literature, Science, and the Arts.

Admitting Graduates of Other Colleges. A graduate of an approved college may be admitted as a candidate for a degree in engineering. The official transcript must certify the date of graduation. If the course completed has covered substantially the equivalent of the required work in the first two or three years of the program he desires to follow and if his record meets the scholastic standards of this College, he may be admitted as an upperclassman. Upon the satisfactory completion of the prescribed courses, covering at least two semesters' enrollment and a minimum of 30 hours of credit, the student will be recommended for the degree of Bachelor of Science in Engineering.

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 Assistant 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 equivalent low grade.

Advanced credit is adjusted in terms of semester hours completed without recording on the student's official record the grades earned. The student's scholastic average is determined solely by grades earned while he is enrolled in this College.

High school graduates desiring to be excused from taking courses in engineering graphics may be required to pass a comprehensive examination and to submit for approval appropriate drawings completed previous to entrance.

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. They pay the same fees as regular students.

Persons over twenty-one years of age who wish to pursue particular studies in engineering and who present satisfactory evidence that they are prepared to do good work in the selected courses may apply for admission as special students. The purpose 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, technician, 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, geometry, and trigonometry is required for success in engineering studies.

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

Request for admission as a special student should be addressed to the Assistant Dean. In addition to filling out an application stating age, education, experience, and course of study desired, the applicant should submit evidence of achievement such as reports and drawings, and letters of recommendation. His admission and program of study are subject to the approval of the program adviser of the program elected. To remain eligible for continued enrollment, he is required to meet the same academic standards as degree candidates.

A special student may become a candidate for a degree by fulfilling the regular requirements for admission, as described under Admission.

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

FOREIGN STUDENTS

Foreign students whose native language is other than English are required to complete basic college subjects (English, mathematics, chemistry, physics, engineering graphics) before applying to the Assistant Dean for admission to the College of Engineering; they must also meet prescribed standards of proficiency in English. For many students these requirements may be met at a minimum of expense by enrolling in a home college for a period of two years. Others may prefer to enroll in a liberal arts or engineering college in the United States for their basic college subjects before seeking transfer; this provides the advantages to the student of becoming accustomed to the educational system of this country and of improving his proficiency in English.

An applicant must submit an official copy in English of the scholastic record of his secondary and college education, showing the grade (or mark) earned in each course together with maximum and passing grades.

Since English is the language of instruction in the United States, a foreign student attends classes with students whose background and education has been in English, and he must maintain the same scholastic standards. In order that he may know that his control of the English language is adequate to carry on his studies without serious handicap, each student whose native language is not English is required to pass an English proficiency examination before he is admitted. This test is prepared by and administered abroad by the English Language Institute of the University. If the applicant is informed that his scholastic record is satisfactory, he will then be instructed to make arrangements for the test with the English Language Institute. The charge for this test taken abroad is $10.00, or its equivalent in the local currency.

For students who need to improve their control of English considerably before beginning regular college studies, the English Language Institute offers the eight-week Intensive Course in English (ELI 100). For further information, write to the English Language Institute, 3021 North University Building, Ann Arbor, Michigan.

A foreign student granted entry into the United States by virtue of admission to another college will not be considered for admission until he has successfully completed some work at that college.

It is generally desirable that a foreign student elect a rather light schedule of studies in the first semester enrolled in the College of Engineering because he is living in an unfamiliar environment and is studying under an educational system which may be new to him. If he fails in his studies and if, in the judgment of his instructors and adviser, his failure is due primarily to his lack of proficiency in the English language, his record will be disregarded and he will be required to pursue additional remedial study of English as may be deemed necessary before resuming his professional studies.

For statement on health insurance requirements for foreign students, see Fees and Expenses.

International Center. A foreign student with financial, immigration, housing, or personal adjustment problems is assured of careful and understanding counseling at the University's International Center. Students also have opportunities to plan and participate in social activities under the sponsorship of the Center.

Counseling

To plan wisely and efficiently his educational program, each student should understand his own aptitudes, abilities, and interests and their relationship with his future. A student with some question in this regard or any other personal problem on which he feels the need of counseling is urged to consult University people who are qualified to help him.

Engineering students who are uncertain regarding procedures, or who have special problems, may seek advice from the Assistant Dean's office, 259 West Engineering Building.

Orientation Period. All new students, both freshmen and those transferring from other colleges, are assigned to small groups which are guided through the various steps of the orientation period. These details include testing, a call at the Health Service, preparation of the student's identification card, the adjustment of transfer credit from other colleges, consultation with counselors, selection of courses, payment of fees, and attendance at the necessary orientation group meetings.

Freshmen entering in September are encouraged to come to the campus during the summer for a two-day appointment during which time they may be guided through the same orientation procedures that are offered during the orientation period in September. At the same time, parents are invited to attend a program particularly arranged for them.

Transfer students are instructed by the Assistant Dean's office on procedures for appraisal of their records from other colleges, necessary for determining the amount of advanced credit and schedule of courses in the program selected.

Academic Counseling for Freshmen. Freshman counselors, consisting of a group of well-qualified members of the professional teaching staff, are available in a central freshman counseling office for interviews at all times throughout the year.

Each entering freshman meets with a counselor to determine his schedule of courses for his first semester. The necessary counseling takes into account his entrance credits, level of high school achievement, test results, and other information made available to the counselor.

Developing self-reliance and ability to appraise his own performance and intellectual growth is an important part of the student's education. Nevertheless, freshmen are encouraged to consult with counselors at any time during the year concerning their career plans and academic programs and to discuss any matter of interest or concern. Particularly appropriate times to examine progress are at the time of grade reports and near the end of each semester when plans for the future must be made.

Program Adviser. At the beginning of each of the statements on the fourteen undergraduate programs (given later in this *Announcement*) is the name of a member of the faculty designated as program adviser. This person is available primarily to counsel students above the freshman level on their academic program and other matters such as changes in objectives and choices of subject electives. Program advisers will also assist each student with career planning and other decisions that are necessary to make a proper selection of a particular program. A freshman who needs help in this respect may, in addition to his freshman counselor, consult with the several program advisers. To enjoy a more leisurely discussion, the student should arrange such interviews at a time other than the busy registration week.

Counselor. The counselor with whom a student beyond freshman level meets during registration week is a delegate of the program adviser and assumes responsibility, along with the program adviser, of counseling a student on course changes after the semester is under way.

Planning the Student's Program

By offering a variety of programs, the College provides opportunities for meeting the special needs and interests of each individual student. Students are admitted with varying degrees of ability and with differences in high school or other pre-engineering preparation. These variations and the student's choice of an engineering field necessitate considerable flexibility in arranging schedules and programs.

FRESHMAN PROGRAM

The program for each freshman is planned with the objective of placing him in subjects at a level which will enable him to continue his education without repeating subject matter in which he has already demonstrated adequate proficiency. At the same time, his schedule should not include subjects or levels of work which he is unable to handle successfully. The results of English, mathematics, and chemistry tests will help the student and counselor in planning a program that meets these objectives.

Students are required to remove all admission deficiencies during their first year, unless granted an extension of time. A student who does not present three units in the mathematics group (see Admission as a Freshman) will find it to his advantage to remove the deficiency during the summer preceding the first semester of the freshman year.

Studies of the First Year. The schedules for the first year will generally include courses from among the following subjects: mathematics, English, engineering graphics, chemistry, physics, and an elective subject in a non-technical field.

Physical education (twice a week through the year without credit in hours) is required of all first-year students unless enrolled in one of the three Reserve Officers Training Corps programs.

Opportunities are offered for reserve officer training in air, military, and naval science. Enrollment in one is not required, but those who choose to enroll are excused from taking physical education (see statement concerning conditions of voluntary enrollment under Reserve Officers Training Corps).

If Reserve Officers Training Corps enrollment is elected, hours of credit and the grades earned will be recorded and included in the computation of average grades. The only hours that may be applied to degree requirements are for those advanced courses in the third and fourth years that are permitted in the schedule of requirements of the respective programs.

While many variations in freshman schedules are possible, the following will serve as a guide to each student in planning his own personal program:

FIRST SEMESTER	CREDIT HOURS	SECOND SEMESTER	CREDIT HOURS
English 111 and 121	4	English 112	2
Mathematics 233	4	Mathematics 234	4
Chemistry	4 or 5	Physics 145	5
Eng. Graphics 101	3	Chemistry 4	2 to 7*
Physical Education or	0	Eng. Graphics 2 or 3	
ROTC	1,2,or 3	Other 2 to 7	
		Physical Education or	0
		ROTC	2 or 3

Usual combinations of the subjects listed above will result in a semester schedule with 15 to 18 hours credit. The appropriate number for each student will depend on a number of factors: past scholastic record, placement tests, extracurricular activities, and need for partial self-support through outside work.

Choosing One of the Degree Programs. While the entering freshman does not need to select a specific field of engineering, there is some advantage in arriving at a decision during the first semester. He should consult with his freshman counselor, with program advisers, and others for assistance and counsel in planning his career. Near the close of the second semester, he should be ready to select the degree program in which he plans to graduate. From this point on, the degree programs differ in their requirements. The differences are not so pronounced, however, as to make difficult a transfer

*Explanations regarding the several possibilities or combinations in this group of subjects appear in the following discussions.

from one program to another in the second year should the student change his career plans.

VARIATIONS AND ACCELERATION POSSIBILITIES

The following discussions and outlines will serve as additional guides. They include a number of variations and possibilities for accelerating the progress of qualified students. A number of factors are taken into account, but other variations not covered here may be arranged in consultation with counselors and program advisers according to the needs and qualifications of each student.

English. English 111, Composition, and English 121, Speech, are generally prescribed for the first semester. A student who is considered to be unprepared for English 111 will be assigned to English 110, Preparatory Composition, but may be advanced to English 111 if the instructor finds him able to meet the requirements of that course. Generally students will take English 112 during the second semester and prior to electing courses from Group II.

If students have met the English 112 requirement during the first semester or have been excused from the course on the basis of proficiency, they may elect a course from Group II during the second semester. Courses in Group I-A are also available to freshmen to satisfy part of the requirements for nontechnical electives. See page 134.

Mathematics. Students who lack trigonometry preparation and in addition have an algebra deficiency must take Mathematics 101 (without credit) preceding Mathematics 233. When only trigonometry preparation is lacking, Mathematics 103 (without credit) must be taken, and it may either accompany or precede Mathematics 233.

Mathematics 233 and 234 shown in the freshman schedule above are followed by Mathematics 371 and 372 (each 4 hours credit). In this series of four courses, each entitled analytic geometry and calculus, calculus is introduced in the first semester and the two classical subjects are presented as an integrated basic course in college mathematics; included in the fourth semester is an introduction to probability and statistics.

Transfer students can be accommodated by Mathematics 241, 242, 363, and 364 (each 4 hours credit), when their mathematical training has begun in a sequence that presents analytic geometry first. If the transfer student has had a course in plane and solid analytic geometry which had no introduction to the calculus, as offered in Mathematics 242, he will elect Mathematics 352 for 5 hours credit instead of Mathematics 363.

Qualified students who have shown high proficiency in mathematics both in high school and in their mathematics tests may be able to accelerate their mathematics requirements by a three-semester series in analytic geometry and calculus, Mathematics 335, 336, and 337 (each 4 hours credit).

Chemistry. Chemistry is not required as a science unit for admission, although it is strongly recommended. A number of factors determine the proper elections in chemistry. These are best covered in outline form as follows:

THOSE STUDENTS WHO:	ELECT	HOURS
I. Have not had chemistry in high school (*a*) and who definitely plan to take succeeding chemistry courses for programs such as Chemical, Metallurgical, Materials, or Science Engineering;	Chemistry 103 and 106...	8
(*b*) others	Chemistry 103 and 105...	8
II. Have had chemistry in high school but do not qualify for Chemistry 107 or Physics 153 (*a*) and who definitely plan to take succeeding chemistry courses for programs such as Chemical, Metallurgical, Materials, or Science Engineering;	Chemistry 104 and 106*..	8
(*b*) others	Chemistry 104 and 105*..	8
III. Have shown proficiency in chemistry in high school and on chemistry tests†	Chemistry 107	5
IV. Qualify for Physics 153 (see Physics below) †	Chemistry 194 and 195...	8

A student planning to elect a program requiring additional chemistry should refer to the schedule of the selected program and consult with the program adviser to determine the most suitable sequence of advanced chemistry.

Engineering Graphics. The freshman schedule includes a three-hour engineering drawing course in the first semester, Engineering Graphics 101. The several programs vary with respect to additional requirements in engineering graphics. The student should refer to Group B of the departmental program in which he plans to enroll and should consult with his counselor for electing further graphics courses. Graphics 101 is usually followed by Graphics 102, 3 hours credit, or Graphics 104, 2 hours credit.

Physics. Physics is not required as a science unit for admission, although it is strongly recommended.

The freshman schedule includes Physics 145 in the second semester. This

*A student with a high record in Chemistry 104 may be invited to elect Chemistry 191, 5 hours, instead of Chemistry 105 or 106. This combination provides the student with additional background in chemistry and may permit him to take succeeding courses at a saving of credit hours.

†III and IV are acceptable to any program in the College.

course assumes knowledge of calculus and follows Mathematics 233. Transfer students placed in Mathematics 363 may elect Physics 145 concurrently. Physics 145 is followed by Physics 146, making a total of 10 hours.

Upon recommendation of a faculty committee, qualified students who have demonstrated high proficiency in physics and mathematics may be able to complete their physics requirements by two four-hour courses, Physics 153 and 154. Physics 153 should be elected during the first semester in place of chemistry and normally is accompanied by Mathematics 335. It is followed by Chemistry 194 and 195 and Physics 154 in that order, making a total of 16 hours for an integrated science sequence that provides a superior coverage of the material. An example of this sequence appears in the suggested Science Engineering schedule.

Other Possibilities for the First-Year Schedule. A student who satisfies his chemistry requirements with Chemistry 107 during his first semester has an opportunity to select two to seven hours from a number of subjects during his second semester.

For students planning to select the chemical or metallurgical engineering program, Chemical and Metallurgical Engineering 200 may be elected in the second semester.

Engineering Mechanics 218 is recommended for students planning to elect science engineering and may be elected the second semester, if preceded by Physics 153 and accompanied by Mathematics 234 or equivalent.

Acceptable nontechnical subjects may be elected as part of the requirements for nontechnical electives in Group B. For example, see English, page 134.

Rules and Procedures

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 Code, 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 code 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."

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. It is essential, however, 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.

Physical 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 a chest X ray 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 is in conformity with the rules and regulations of the Health Service.

Foreign students should see regulation regarding health insurance under Fees and Expenses.

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.

Veterans who have completed a regular tour of duty (minimum of 20 months of service) or its equivalent are excused from the regular requirements of physical education. Students who enroll in a Reserve Officers Training Corps also fulfill the requirements of physical education.

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.

ELECTION OF STUDIES

1. 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. An explanation of the number of credit hours and time requirement for graduation will be found under Undergraduate Degree Programs and Requirements.

2. The responsibility for approving the proper election of courses by the student is assigned to a counselor (see under Counseling). The coun-

selor 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 credit hours, or more than eighteen 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.

3. The counselor 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.

4. Credit is not given for a course in which the grade of E is received. Such a course must be repeated if it constitutes a requirement for graduation and unless a substitution is permitted. Courses in which D grades are earned must be, or may be, repeated in accordance with instructions in the section on Grades and Scholarship.

5. All requests for changes in classification must be made on a printed form which may be secured at the Office of the Recorder, 263 West Engineering Building. A course may be dropped without record during the first eight weeks of the semester with the consent of the counselor after conference with the instructor in the course. After the first eight weeks of the semester, except under extraordinary circumstances and with the consent of the program adviser or the head freshman counselor for freshmen, a course dropped will carry the grade of E. A student enrolled in an ROTC program must have the approval also of the professor in charge of the unit before he can drop an ROTC course or relieve himself of the obligation he assumed when he enrolled in the program.

6. 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 counselor concerning a revision of his elections. The Assistant Dean's Office may be consulted for recommendation.

7. 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 counselor 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.

8. 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 Assistant Dean's Office. 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.

9. 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)

10. Substitution of a course for one which is a requirement for graduation must be approved by the student's program adviser of his degree program, and is subject to review of the Curriculum Committee.

11. 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.

12. The faculty reserves the right to withdraw the offering of any elective course not chosen by at least six persons.

13. A student who wishes to pursue his studies in another unit of the University must apply for admission to that unit and be accepted before he will be permitted to elect a program.

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.

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.

GRADES AND SCHOLARSHIP

1. The semester average grade and the over-all 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 corre-

sponding 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 an over-all average grade below 2.0 in the courses elected in this College may be graduated. A student whose over-all average or semester average falls below 2.0 should consult with his freshman counselor or program 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 who fulfills the requirements of paragraph 10 and whose average for the following semester or summer session is 2.0 or better shall be restored to good standing, provided his over-all 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 is from 1.1 to less than 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 over-all 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 during the semester or summer session next enrolled.

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 who is placed on probation or under warning at the end of a semester or summer session must repeat as soon as possible all courses in which he received a grade of D. In exceptional cases this requirement may be waived by the student's program adviser (for freshmen, the Assistant Dean).

14. 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.

15. Except as provided above, a student may not repeat a course which he has already passed. In exceptional cases this rule may be annulled by the student's program adviser (for freshmen, the Assistant Dean) upon recommendation of the department of instruction concerned.

16. 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 considered as a D grade in the temporary average. A permanent average is recorded when a final grade is filed by the instructor.

In order that credit for a course may be given, the required work must be completed before the end of the eighth week of the first semester the student is enrolled after the semester or summer session in which the incomplete grade was recorded, unless an extension is granted by the Assistant Dean. When completed, the final grade 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.

CLASS STANDING

Primarily for statistical purposes, students are classified in terms of the number of credit hours achieved as follows:

	Underclassmen	
Class		*Credit Hours*
Freshman		0 to 29
Sophomore		30 to 61
	Upperclassmen	
Junior		62 to 99
Senior		100 or more

A transfer student is classified in this manner in terms of the tentative adjustment of credit hours applicable to his elected program. When, in the opinion of his program adviser, there is a reasonable expectancy that a transfer student will graduate within one year, he will be classified as a senior.

EXCUSES FOR ABSENCES

Underclassmen in the College of Engineering must take the initiative in securing from the Assistant Dean excuses for absences from classes, which excuses must be applied for within five days after the return to class.

Upperclassmen are not required to obtain excuses for irregularities of attendance from the Assistant Dean but should explain them to their instructors.

WITHDRAWAL FROM THE COLLEGE

A student should not withdraw from class even temporarily without obtaining permission from the Assistant Dean's office.

Withdrawal from the college requires the approval of the Assistant Dean's office.

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.

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, engineering graphics, mathematics, chemistry, and physics, which is 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 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 programs and must have completed not less than eight credit hours more than would be required for one degree.

6. All students who complete the requirements for graduation and who are entitled to receive degrees are expected to be present at the Commencement exercises.

Undergraduate Degree Programs and Requirements

The graduation requirements of the College of Engineering are expressed in terms of attainment rather than in terms of a fixed number of credit hours. The basic level of attainment required of all students in every degree program is demonstrated ability in English, mathematics, chemistry, engineering graphics, and physics equivalent, respectively, to the satisfactory completion of the following courses: English 112 and 121, Mathematics 372 or 337, Chemistry 107 or 195, Engineering Graphics 101, Physics 146 or 154. 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.

On the basis that the scholastic requirements for graduation are expressed in terms of the quality and level of attainment reached by the student, a superior student may materially decrease the time required to graduate from the University by carefully planning his high school program. Depending upon his preparation and ability, as indicated by high school standing and examinations, his program may be arranged to save credit hours in mathematics, and chemistry or physics. These savings may represent an amount equivalent to a summer session or a semester of one-half time work. In addition, a student who has attained a sufficiently high degree of proficiency in English composition and speech, in engineering graphics, and in other subjects in which attainment levels are indicated in the several degree programs, may be able to graduate with fewer hours and thereby save additional time for the completion of degree requirements.

GROUP A AND B SUBJECTS

Each degree program is composed of two groups of subjects.

Group A. Group A includes subjects in those basic areas common to all programs. These must be elected and passed or equivalent proficiencies must be demonstrated.

Subject	*Hours*
English	6
Mathematics	12 to 16
Engineering Graphics	3
Chemistry	5 to 8
Physics	8 to 10

NOTE—As explained under Physics (page 24), the number of hours elected in the integrated science sequence is 8 for chemistry and 8 for physics.

Group B. Group B is composed basically of professional subjects and varies in the 14 degree programs. Group B requirements, a total of 95 credit hours, will be found under the heading Professional Subjects and Electives for each of the programs.

For information on credit for courses taken at other recognized colleges or universities, see Admission with Advanced Standing.

CREDIT HOURS AND TIME REQUIREMENT

The total number of credit hours necessary to meet the level of attainment in Groups A and B varies around an average of 138. Usually the time requirement for such students completing their programs on schedule will be eight semesters plus a summer session, or nine semesters.

It may be necessary for students who are required to make up deficiencies or who wish to increase their electives to enroll in more than 138 credit hours. Students who are admitted with advanced preparation or with demonstrated ability to achieve at high levels may graduate with less than 138 credit hours, thereby materially accelerating their progress.

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 counselor 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.

A student's interests and objectives will normally determine his choice of subjects to meet the requirement of nontechnical electives. Definitions of acceptable courses may be found under Election of Studies. The student's counselor or program adviser is in a position to make recommendations. Anyone wishing to discuss suitable elections in the College of Literature, Science, and the Arts may consult the Junior-Senior Counseling office, 1223 Angell Hall.

AERONAUTICAL AND ASTRONAUTICAL ENGINEERING

Program Adviser: Professor Eisley, 1507 East Engineering

The design of modern aircraft, missiles, and space vehicles 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 structures courses. Studies in the field of instrumentation include principles of measurement, data transmission, automatic control, and systems 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 flight vehicles 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, aeroelasticity, mechanics of flight, or instrumentation as applied to various flight vehicle systems.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Eng. Graphics 104, Introduction to Descriptive Geometry	2
Econ. 401, Modern Economics Society	3
Math. 404, Differential Equations for Systems Analysis	3
Eng. Mech. 208, Statics	3
Eng. Mech. 210, Mechanics of Materials	4
Eng. Mech. 212, Laboratory in Strength of Materials	1
Eng. Mech. 343, Dynamics	3
Eng. Mech. 411, Structural Mechanics	3
Mech. Eng. 335, Thermodynamics I	3

	HOURS
Elec. Eng. 315, Direct and Alternating Current Apparatus and Circuits	4
Aero. Eng. 200, General Aeronautics	1
Aero. Eng. 310, Flight Structures I	3
Aero. Eng. 320, Aerodynamics I	4
Aero. Eng. 330, Propulsion I	3
Aero. Eng. 340, Mechanics of Flight I	3
Aero. Eng. 410, Flight Structures II	4
Aero. Eng. 420, Aerodynamics II	4
Aero. Eng. 430, Propulsion II	4
Aero. Eng. 440, Mechanics of Flight II	3
Aero. Eng. 470, Control Systems	3
Aero. Eng. 480, Airplane Design	3
Nontechnical electives	12
Group options and electives*	12
Total, professional subjects and electives	95

SUGGESTED SCHEDULE

FIRST SEMESTER	HOURS
Math. 233	4
Chemistry 104	4
English 111	3
English 121	1
Eng. Graphics 101	3
	15

SECOND SEMESTER	HOURS
Math. 234	4
Chemistry 106 or 105	4
Physics 145	5
English 112	2
Eng. Graphics 104	2
	17

THIRD SEMESTER	
Math. 371	4
Physics 146	5
Aero. Eng. 200	1
Eng. Mech. 208	3
Elective	3
	16

FOURTH SEMESTER	
Math. 372	4
Chem.-Met. Eng. 250	3
English, Group II	2
Eng. Mech. 210	4
Eng. Mech. 212	1
Mech. Eng. 335	3
	17

SUMMER SESSION	
Elective	3
Elec. Eng. 315	4
	7

FIFTH SEMESTER	
Math. 404	3
Aero. Eng. 320	4
Eng. Mech. 343	3
Eng. Mech. 411	3
Elective	3
	16

SIXTH SEMESTER	
Aero. Eng. 310	3
Aero. Eng. 330	3
Aero. Eng. 340	3
Aero. Eng. 420	4
Elective	3
	16

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

SEVENTH SEMESTER	HOURS
Aero. Eng. 410	4
Aero. Eng. 430	4
Aero. Eng. 440	3
Elective	3
Econ. 401	3
	17

EIGHTH SEMESTER	HOURS
Aero. Eng. 470	3
Aero. Eng. 480	3
Electives	9
English, Group III	2
	17

CHEMICAL ENGINEERING

Program Adviser: Professor Martin, 3217 East Engineering

Chemical Engineering is defined by the American Institute of Chemical Engineers as "the application of the principles of the physical sciences, together with the principles of economics and human relations, to fields that pertain to processes and process equipment in which matter is treated to effect a change in state, energy content, or composition."

The work of the chemical engineer encompasses many industries, from the manufacture of chemicals and the refining of petroleum to nuclear energy and space technology. The education of the chemical engineer is based on certain functional operations that are similar regardless of the particular industry or process in which they are employed. Examples of these operations are the flow of fluids, the transfer of heat, the diffusion and transport of matter, and the reactions of chemical compounds.

The program leading to the degree begins with a firm foundation in physics, mathematics, and chemistry, as well as the communication aids of English and engineering graphics. Work in the engineering sciences, such as mechanics, materials, thermodynamics, and electronics, follows and this forms a basis for the professional engineering subjects taken near the end of the program. Only the level of attainment in the various areas is specified, with the route to that level depending upon the preparation and ability of the individual student. Because of this and because of the large proportion of elective courses, a student may readily enter the chemical engineering program from an engineering science program or from a science curriculum taken outside the College of Engineering. Proper selection of electives permits good students to prepare for graduate work.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Chemical Engineering) are required to complete the program listed below. Since elective courses are nearly half the program, the student will be encouraged to plan the program which is best suited to his individual objectives with the advice and approval of the program adviser.

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)
(A typical sequence is shown in the first half of the representative schedule shown below.)

B. PROFESSIONAL OR ADVANCED SUBJECTS AND ELECTIVES

Basic Science

	HOURS
Advanced chemistry to include Chem. 221, 265, 266, and 346, or equivalent	17
An electronic computer course such as Math. 373	1

Chemical and Metallurgical Engineering Science

Introduction to Engineering Calculations, Chem.-Met. Eng. 200	3
Thermodynamics, Chem.-Met. Eng. 230	5
Separations Processes, Chem.-Met. Eng. 339	3
Rate Processes, Chem.-Met. Eng. 340	5
Structure of Solids, Chem.-Met. Eng. 350	3

Electives*

1. Electives in humanities, social sciences, philosophy, languages, history of art, etc. 14
   (See under English, and the *Announcement* of the College of L.S. & A. for courses in these fields.)
2. Electives in law, economics, and business administration 6
   (Typical economics electives are: Econ. 103, 104, 271, 272, 401, 411, 412, 421, 431, and 475; and business administration electives are: Bus. Ad. 480 and 481, Accounting 271 and 272, Finance 300 and 301, Ind. Relations 300, Marketing 300, and Statistics 300.)
3. Electives in engineering science and analysis, such as mechanics of solids and fluids, network analysis, electronics, systems, energy conversion, electromagnetics, and thermodynamics 14
   (Typical electives are: Eng. Mech. 343, 324, 310, 218, 219, 345, 326, 412, 422, 512, and 527; Elec. Eng. 210, 315, 442, 215, 220, 337, 310, 418, 419, and 425; Mech. Eng. 333, 335, 336, 371, 421, and 625; Chem.-Met. Eng. 450, 472, 451, 560, and 470; Instr. Eng. 570, 510, and 530; Nuc. Eng. 400 and 470.)
4. Electives in advanced science and mathematics 10
   (Typical electives are: Math. 403, 404, 447, 450, 452, and 473; Chem. 222-223 in place of 220-221, 425, 447, 466, 481, and 482; Physics 305, 347, 455, 456, 411, 463, 418, 406, 453, and 457.)
5. Electives in professional chemical engineering subjects, to include laboratory, design, and materials 14
   (Typical electives are: Chem.-Met. Eng. 479, 450, 451, 480, 460, 481, 449, 490, and 500-level courses where appropriate.)

Total hours in Group B 95

*Up to three hours of advanced courses (300 and 400 series) in the ROTC programs may be applied where appropriate.

A representative schedule is given below which shows one way in which the many elective alternatives may be chosen. Other elective possibilities may be selected from the following groups depending upon the student's desire to major in certain specialized branches of chemical engineering:

Bio-engineering: Chem.-Met. Eng. 584
Combustion: Chem.-Met. Eng. 449; Aero. Eng. 632; Mech. Eng. 493, 495
Electrochemistry: Chem.-Met. Eng. 510; Chem. 765
Electronic materials: Elec. Eng. 418, 425; Math. 403; Physics 453, 463
Graduate preparation: Math. 450 and language preparation
Instrumentation: Math. 404, 548; Instr. Eng. 510, 570
Machine computation: Math. 404, 423, 424; Instr. Eng. 510
Materials: Chem.-Met. Eng. 450, 451, 472, 560; Eng. Mech. 416
Molecular: Chem.-Met. Eng. 451, 560; Physics 425, 453
Nuclear: Nuc. Eng. 470, 560
Polymers: Chem.-Met. Eng. 451, 583; Physics 418
Petroleum: Geol. 218; Chem.-Met. Eng. 521
Propulsion and Rocketry: Chem.-Met. Eng. 449; Aero. Eng. 330, 430, 535
Systems: Chem.-Met. Eng. 481, 581; Instr. Eng. 570

Representative Schedule, showing a typical set of electives. The number in parenthesis preceding course name designates the group under Electives above.

FIRST SEMESTER	HOURS
English 111	3
Eng. Graphics 101	3
Chemistry 107	5
Math. 233	4
	15

SECOND SEMESTER	HOURS
English 112	2
Physics 145	5
Math. 234	4
Chemistry 265	4
Math. 373	1
	16

THIRD SEMESTER	
English 121	1
Physics 146	5
Math. 371	4
Chemistry 266	4
Chem.-Met. Eng. 200	3
	17

FOURTH SEMESTER	
Math. 372	4
Chemistry 346	4
Chem.-Met. Eng. 230	5
(3) Eng. Mech. 310	4
	17

FIFTH SEMESTER	
Chem.-Met. Eng. 340	5
Chemistry 221	5
(4) Chemistry 403	2
(1) English 241	2
(3) Eng. Mech. 343	3
	17

SIXTH SEMESTER	
Chem.-Met. Eng. 339	3
Chem.-Met. Eng. 350	3
(3) Elec. Eng. 315	4
(2) Bus. Ad., Acctg. 271	3
(3) Eng. Mech. 422	3
(1) English 461	2
	18

SEVENTH SEMESTER	HOURS	EIGHTH SEMESTER	HOURS
(5) Chem.-Met. Eng. 460	3	(5) Chem.-Met. Eng. 480	3
(5) Chem.-Met. Eng. 479	3	(5) Chem.-Met. Eng. 481	3
(2) Economics 401	3	(5) Chem.-Met. Eng. 490	2
(4) Chemistry 466	2	(4) Math. 473	3
(1) Russian	4	(1) Russian	4
(4) Math. 404	3	(1) English 436	2
	18		17

COMBINED PROGRAMS

CHEMICAL ENGINEERING AND METALLURGICAL ENGINEERING

Degrees in both chemical and metallurgical engineering may be earned by taking fourteen additional hours. Students in the chemical engineering program who desire to earn a degree in metallurgy as well will take fourteen hours in courses in metallurgical engineering in the field of process, physical, and mechanical metallurgy. Students in the metallurgical program will take six additional hours of chemistry and eight hours of professional chemical engineering courses, to include laboratory and engineering synthesis for a total of fourteen additional hours. These programs should be formulated in consultation with program advisers.

CHEMICAL ENGINEERING AND CHEMISTRY

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

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

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		26
English 123, 124 (L.S. & A.) and Groups II and III (Engineering)	10	
German 101, 102, 231, 232	16	
MATHEMATICS AND SCIENCE GROUP		69 to 74
Chem. 104, 106 or 191, 222, 223, 346, 421, 447, 468, 469, 481, 482, and elective 3 hours	43 or 44	
Math. 233, 234, 371, 372 (or 335, 336, 337) 373, and 403 or 404	16 to 20	
Physics 145, 146	10	
SOCIAL SCIENCES GROUP		9
Economics 103, 104	6	
Bus. Ad., Accounting 271	3	
ENGINEERING COURSES		46
Eng. Mech. 310, 343	7	
Elec. Eng. 315	4	
Eng. Graphics 101	3	
Chem.-Met. Eng. 200, 230, 330, 340, 350, 460, 479, 480, 481	33	
ELECTIVES IN HUMANITIES		6
Total	156 to 161	

CIVIL ENGINEERING

Program Adviser: Departmental Chairman

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:

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, and improvement of rivers and harbors, and other hydraulic structures. Laboratory facilities and instruction are offered for students who wish to engage in research work in hydrology and hydraulics that will lead to advanced degrees.

Railroad. 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 of Bachelor of Science in Engineering (Civil Engineering) are required to complete the following:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
Civ. Eng. 260, 261, 362, Surveying	10
English, Groups II and III	4
Eng. Graphics 102, Descriptive Geometry	3
Eng. Mech. 203, Statics	3
Eng. Mech. 210, Mechanics of Materials	4
Eng. Mech. 212, Laboratory in Strength of Materials	1
Eng. Mech. 343, Dynamics	3
Eng. Mech. 324, Fluid Mechanics	3
Advanced mathematics	3
Elec. Eng. 315, Electrical Apparatus and Circuits	4
Mech. Eng. 333, Thermodynamics and Heat Transfer	4
Civ. Eng. 312, Theory of Structures	3
Civ. Eng. 313, Elementary Design of Structures	3
Civ. Eng. 350, Concrete Mixtures	1
Civ. Eng. 370, Transportation Engineering	3
Civ. Eng. 400, Specifications and Contracts	2
Civ. Eng. 415, Reinforced Concrete	3
Civ. Eng. 420, Hydrology	3
Civ. Eng. 421, Hydraulics	2
Civ. Eng. 445, Engineering Properties of Soil	3
Civ. Eng. 480, Water Supply and Treatment	3
Civ. Eng. 481, Sewerage and Sewage Treatment	2
Geology 218	4
Economics 401	3
Humanities and social sciences (see below)	8
Technical option group* (see below)	10
Total, professional subjects and electives	95

The electives in humanities and social sciences are to be approved courses in such fields as economics, fine arts, history, law, literature, philosophy, political science, psychology, and sociology.

The technical option group will be composed of an approved sequence of subjects in some area of civil engineering practice and appropriate electives. As early as possible a student should select his particular area of interest and confer with the adviser in that field regarding the electives required for the completion of his program. Groupings of subjects which meet the technical group requirements are available in the following areas:

1. Construction—Adviser: Professor Alt
2. Geodesy and Surveying—Adviser: Professor Berry
3. Highway—Adviser: Associate Professor Cortright
4. Hydraulic—Adviser: Professor Brater
5. Railroad—Adviser: Lecturer Heimbach
6. Sanitary—Adviser: Professor Borchardt
7. Soils—Adviser: Professor Housel
8. Structures—Adviser: Professor Maugh
9. Traffic—Adviser: Professor Kohl

Other combinations of technical courses for special fields of professional interest can be formulated and approved by the program adviser to meet the needs of individual students.

*A maximum of 3 hours of advanced air, army, or naval science (300 to 400 series) may be used as electives in this group.

SUGGESTED SCHEDULE

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
Math. 233	4	Math. 234	4
Chem. 104	4	Eng. Graphics 102	3
Eng. Graphics 101	3	English 112	2
English 111	3	English, Group II	2
English 121	1	Chem. 106	4
	15		15

THIRD SEMESTER		FOURTH SEMESTER	
Math. 371	4	Math. 372	4
Physics 145	5	Physics 146	5
Eng. Mech. 208	3	Eng. Mech. 210	4
Civ. Eng. 260	3	Eng. Mech. 212	1
Civ. Eng. 350	1	Civ. Eng. 261	3
	16		17

SUMMER SESSION (at Camp Davis)	
Civ. Eng. 362	4
Geol. 218	4
	8

FIFTH SEMESTER		SIXTH SEMESTER	
Eng. Mech. 324	3	Eng. Mech. 343	3
Civ. Eng. 312	3	Civ. Eng. 415	3
Civ. Eng. 370	3	Civ. Eng. 480	3
Civ. Eng. 420	3	Civ. Eng. 421	2
Advanced mathematics	3	Civ. Eng. 445	3
*Elective	2	*Elective	3
	17		17

SEVENTH SEMESTER		EIGHTH SEMESTER	
Civ. Eng. 400	2	Mech. Eng. 333	4
Civ. Eng. 313	3	Technical electives	7
Elec. Eng. 315	4	Econ. 401	3
Civ. Eng. 481	2	*Elective	3
English, Group III	2		17
Technical elective	3		
	16		

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

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

As one of the combined programs referred to on page 17, the College of Engineering and the College of Literature, Science, and the Arts offer a

*Electives in the humanities and social sciences group.

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 123, 124, 269	9	
History of Art 101 or 102	4	
Foreign language or social sciences*	16	
Speech 211	2	
Philosophy 131 or 134, 133	6	
MATHEMATICS AND SCIENCE GROUP		37 (to 42)
Math. 233, 234, 371, 372 or 335, 336, 337	16 (or 12)	
Advanced mathematics	3	
Chem. 104, 106, or 107 and Psych. 101	8 (or 9)	
Geology 218 (at Camp Davis)	4	
Physics 145, 146	10	
SOCIAL SCIENCES GROUP		9
Bus. Ad., Accounting 271	3	
Economics 103, 104	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 hours in foreign language literature or the social sciences.

	HOURS	HOURS
ENGINEERING GROUP		79
Eng. Graphics 101, 102	6	
Chem.-Met. Eng. 250	3	
Eng. Mech. 208, 210, 212, 343, 324	14	
Elec. Eng. 315	4	
Mech. Eng. 252, 333	6	
Civ. Eng. 260, 261, 312, 313, 350, 362 (at Camp Davis), 370, 400, 415, 420, 421, 445, 480, 481, group options	46	
ELECTIVES IN COLLEGE OF L. S. & A.		5
Total	167 to	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 by careful selection of elective courses, however, a measure of specialization even within the basic undergraduate program. Extensive specialization should be reserved for graduate study.

The facilities of the Electrical Engineering Department include the following research laboratories: Digital Computer Engineering, Electron Physics, Cooley Electronics, Plasma Engineering, Radiation, Radio-Astronomy, Feedback Control Systems, Solid-State Devices, and Space Physics Research.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
Eng. Graphics 104, Introduction to Descriptive Geometry	2
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Math. 373, Elementary Computer Techniques	1
Math. 404, Differential Equations for Systems Analysis	3
English, Groups II and III	4
Econ. 103, 104,* Principles of Economics	6
Eng. Mech. 310, Statics and Stresses	4
Eng. Mech. 324, Fluid Mechanics	3
Eng. Mech. 343, Dynamics	3
Mech. Eng. 252, Engineering Materials and Manufacturing Processes	2
Mech. Eng. 333, Thermodynamics and Heat Transfer	4
Mech. Eng. 343, Machine Design	3
Elec. Eng. 210, Circuits I	4
Elec. Eng. 220, Principles of Electricity and Magnetism	3
Elec. Eng. 301, Professional and Economic Applications in Electrical Engineering	2
Elec. Eng. 310, Circuits II	4
Elec. Eng. 330, Electronics and Communications I	4
Elec. Eng. 343, Energy Conversion and Control I	3
Elec. Eng. 360, Electrical Measurements	3
Elec. Eng. 380, Physical Electronics of Electron Devices I	4
Elec. Eng. 410, Circuits III	3
Elec. Eng. 420, Electromagnetic Fields and Waves	3
Elec. Eng. 444, Energy Conversion and Control II	4
Elec. Eng. 470, Electrical Design	4
Nontechnical electives	6
Electives†	10
Total, professional subjects and electives	95

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS
Math. 371	4
Math. 373	1
Physics 146	5
Elec. Eng. 210	4
Elective (nontechnical)	3
	17

FOURTH SEMESTER	HOURS
Math. 372	4
Elec. Eng. 220	3
Chem.-Met. Eng. 250	3
Mech. Eng. 252	2
Eng. Graphics 104	2
Elective (nontechnical)	3
	17

*Econ. 401 and Bus. Ad., Accounting 271, or Econ. 401 and three additional hours of nontechnical electives also will satisfy this requirement.

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

SUMMER SESSION	HOURS		HOURS
Elec. Eng. 310	4		
Mech. Eng. 333	4		
	8		
FIFTH SEMESTER		SIXTH SEMESTER	
Elec. Eng. 360	3	Elec. Eng. 330	4
Elec. Eng. 380	4	Elec. Eng. 301	2
Eng. Mech. 310	4	Elec. Eng. 343	3
Math. 404	3	Eng. Mech. 343	3
Econ. 103	3	English, Group II	2
		Econ. 104	3
	17		17
SEVENTH SEMESTER		EIGHTH SEMESTER	
Elec. Eng. 410	3	Elec. Eng. 420	3
Elec. Eng. 444	4	Elec. Eng. 470	4
Eng. Mech. 324	3	English, Group III	2
Electives	6	Mech. Eng. 343	3
		Electives	4
	16		16

ENGINEERING MECHANICS

Program Adviser: Professor Clark, 201 West Engineering

Rapid technological developments have brought about an increasing need for engineers exceptionally well-trained in the basic sciences. The need is acute throughout industry and government as well as in institutions of research and in universities; to help fill this need is the purpose of the program in engineering mechanics. Men with training in the field of engineering mechanics are sought by companies and institutions of all kinds, particularly by those working on modern developments. Most young men in the field are engaged in highly technical work, but many, like other engineers, enter supervision and management.

A student majoring in engineering mechanics gets the same first year program as most other students. He may, in fact, choose this specialty without loss of time after one or two years of college work. The later years are filled mainly by more advanced mechanics and science courses which are designed to acquaint the student with the fundamental principles on which engineering science is based. The required mathematics exceeds that in most curriculums, but the engineering emphasis is always present.

The major areas of study in the bachelor's program are strength of materials, elasticity, plasticity, dynamics, vibrations, fluid mechanics, and thermodynamics. The department has modern laboratories and adequate computer and research facilities. The association of theory with the physical aspects of the work is very close. To help maintain the professional outlook the program contains a group option in a professional or technical area chosen by the student. In addition there are seven to nine hours of free electives.

Graduate work toward a master's degree is a natural sequence for those mechanics graduates who qualify. It is also open to graduates in other areas of engineering.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Group II and III	4
Math. 403, Differential Equations	3
Math. 447, Modern Operational Mathematics, or Math. 476, Vector Analysis	2
Math. 450, Advanced Mathematics for Engineers	4
Civ. Eng. 311, Theory of Structures	3
Elec. Eng. 315, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 335, Thermodynamics	3
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Eng. Graphics 102, Descriptive Geometry	3
Eng. Mech. 208, Statics, or Eng. Mech. 218	3
Eng. Mech. 210, Mechanics of Materials, or Eng. Mech. 402	4
Eng. Mech. 212, Strength of Materials Laboratory, or Eng. Mech. 219	1
Eng. Mech. 324, Fluid Mechanics, or Eng. Mech. 326	3
Eng. Mech. 343, Dynamics, or Eng. Mech. 345	3
Eng. Mech. 403, Experimental Mechanics	2
Eng. Mech. 412, Intermediate Mechanics of Materials	3
Eng. Mech. 422, Intermediate Mechanics of Fluids	3
Eng. Mech. 441, Intermediate Mechanics of Vibrations	3
Eng. Mech., approved advanced courses	7
Economics 401	3
Nontechnical electives	9
Group options and electives* (see below)	22
Total, professional subjects and electives	95

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, 7 to 9 hours, selected in conference with the adviser will complete this group of requirements.

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

Suggested group options are:

Aerodynamics	Mechanics of Solids
Aeromechanics	Metallurgy
Chemical Engineering	Meteorology
Dynamics	Naval Architecture
Electrical Engineering	Nuclear Engineering
Hydraulics	Physics
Instrumentation	Propulsion
Machine Design	Structural Engineering
Mechanics of Fluids	Others arranged

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

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

The meteorology program leading to a B.S.E. (Meteorology) is covered under undergraduate degree programs and courses offered under Description of Courses.

INDUSTRIAL ENGINEERING

Program Adviser: Professor Gage, 235 West Engineering

Industrial engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design; and to specify, predict, and evaluate the results to be obtained from such systems. The industrial engineer is primarily interested in problems which involve economy in the use of money, materials, time, and human effort and energy. The industrial engineer should combine the aptitudes of an engineer, an accountant, and a business executive. About one half of the program of study for the B.S.E. degree consists of basic science and engineering courses, accompanied by studies in the humanities. The rest of the work is in areas such as plant analysis work and compensation, evaluation, operations research, engineering economy, production engineering, probability and statistics, and organization and management, including the use of new mathematical techniques for solving industrial problems. As an aid to education the department has well-equipped demonstration facilities, laboratories, and digital and analogue computers.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Econ. 401	3
Eng. Mech. 310, Statics and Stresses	4
Eng. Mech. 343, Dynamics	3
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Chem.-Met. Eng. 270, Metals and Alloys	3
Eng. Graphics 102, Descriptive Geometry	3
Elec. Eng. 315, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 251, Manufacturing Processes I	3
Mech. Eng. 333, Thermodynamics and Heat Transfer	4
Mech. Eng. 334, Heat-Power Laboratory	1
Mech. Eng. 343, Machine Design	3
Mech. Eng. 381, Manufacturing Processes II	3
Mech. Eng. 460, Machine Design II	3
Ind. Eng. 400, Industrial Management	3
Ind. Eng. 447, Plant Layout and Materials Handling	3
Ind. Eng. 463, Work Measurement	3
Ind. Eng. 431, Management Control	3
Ind. Eng. 441, Production Control	2
Ind. Eng. 445, Wage Administration	2
Ind. Eng. 451, Engineering Economy	2
Ind. Eng. 472, Operations Research	3
Ind. Eng. 473, Data Processing	3
Bus. Ad., Accounting 271	3
Bus. Ad., General 454, Industrial Cost Accounting	3
Math. 461, 462, Statistical Methods of Engineers	6
Nontechnical electives	7
Technical electives*	8
Total, professional subjects and electives	95

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 371	4	Math. 372	4
Chem.-Met. Eng. 250	3	Chem.-Met. Eng. 270	3
Physics 146	5	Mech. Eng. 333	4
Bus. Ad., Accounting 271	3	Eng. Graphics 102	3
English, Group II	2	Bus. Ad., General 454	3
	17		17

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

SUMMER SESSION	HOURS		HOURS
Eng. Mech. 310	4		
Elective	3		
	7		
FIFTH SEMESTER		SIXTH SEMESTER	
Math. 461	3	Math. 462	3
Eng. Mech. 343	3	Ind. Eng. 447	3
Elec. Eng. 315	4	Ind. Eng. 463	3
Mech. Eng. 251	3	Mech. Eng. 343	3
Mech. Eng. 334	1	Mech. Eng. 381	3
Ind. Eng. 400	3	Elective	2
	17		17
SEVENTH SEMESTER		EIGHTH SEMESTER	
Ind. Eng. 445	2	English, Group III	2
Ind. Eng. 472	3	Ind. Eng. 431	3
Economics 401	3	Ind. Eng. 441	2
Mech. Eng. 460	3	Ind. Eng. 451	2
Electives	6	Ind. Eng. 473	3
		Electives	4
	17		16

MATERIALS ENGINEERING

Program Adviser: 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.

The program of studies offered by the Materials Engineering curriculum also provides a sound basis for advanced research in materials, an area that is fast becoming one of the most important fields of engineering activity. This has led to the discovery of new materials and to the improvement of properties of existing materials.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL OR ADVANCED SUBJECTS AND ELECTIVES

	HOURS
Basic Science and Mathematics	
Advanced chemistry, to include such subjects as principles of physical chemistry, organic chemistry, and quantitative analysis*	17 or 18
Computer Techniques, Math. 373	1
Electives* (see Note 1)	4 or 5
Engineering Sciences	
Thermodynamics and Rate Processes through Chem.-Met. Eng. 340 or Sci. Eng. 340 (see Note 2)	15
Engineering Materials	
Chem.-Met. Eng. 350, Structure of Solids	3
Chem.-Met. Eng. 450, Ceramic Materials	4
Chem.-Met. Eng. 451, Introduction to High Polymers	4
Chem.-Met. Eng. 470, 471, Physical Metallurgy	7
Chem.-Met. Eng. 472, X-ray Structure	3
Cognate engineering areas (must include Mechanics of Solids and Electrical Circuits) *	14
Engineering Design	
Sequence of 2 or more courses which terminate with design courses, such as one of the following: Chem.-Met. Eng. 481, Mech. Eng. 460, or Elec. Eng. 470*	6
Elections in the humanities, arts, and social sciences	
(At least one course in English; other elections must include courses in at least two of the following fields: anthropology, classical studies, economics, geography, fine arts, history, journalism, music, languages, political science, philosophy, psychology, sociology, speech) *	16
Total hours in Group B	95

*All electives must receive the advance approval of the program adviser.

Note 1: Differential equations, statistics, computer programing, and 300-level courses in Physics and Chemistry.

Note 2: Most commonly the students will take Chem.-Met. Eng. 200, 230, 340. Another possibility includes Sci. Eng. 230 and 340 and additional work in Materials Processing.

MATHEMATICS

Program Co-advisers: Professor Ullman, 270 West Engineering; Professor J. J. Martin, 3217 East Engineering

The mathematics program in the College of Engineering provides the student with an opportunity to extend his knowledge of the language of the scientist and to become more proficient in the application of mathematical reasoning to the formulation and solution of scientific problems in engineering. This program recognizes the ever-increasing demand that the changing physical and economic world imposes on the engineer. It therefore seeks to make available to him the knowledge with which he will be better able to understand and create the complex mathematical models which represent that world.

Many students who are candidates for degrees in engineering programs of other fields elect additional courses and qualify for the award of a degree in mathematics as well (see Requirements for Graduation).

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Eng. Graphics 102	3
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Mech. Eng. 252, Engineering Materials and Manufacturing Processes	2
Math. 403 or 404, Differential Equations	3
Math. 450, Advanced Calculus for Engineers	4
Electives in the humanities, social sciences, and philosophy (see the *Announcement* of the College of L.S.&A. for the basic courses in these fields of knowledge)	12
Eng. Mech. 208 or 218	3
Eng. Mech. 210 or 219	4
Eng. Mech. 324 or 326	3 or 4
Eng. Mech. 343 or 345	3
Elec. Eng. 315, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 335, Chem.-Met. Eng. 230, or Sci. Eng. 330, Thermodynamics	3
Electives in mathematics, to include work in approved advanced mathematics having applications to problems in the physical sciences, such as: operational mathematics, Fourier series, complex variables, statistics, numerical analysis and application of the computer	8
Electives in engineering analysis and design	15

	HOURS
Electives in science and engineering science	11 or 12
Electives*	9
Total, professional subjects and electives	95

The fifteen hours of electives in engineering analysis and design must constitute a sequence of courses which provide an understanding and a useful knowledge in a specific area of engineering and should include at least one course involving laboratory measurements. Suggested areas of engineering in which these electives may be chosen are:

- Aerodynamics
- Mechanics of Flight
- Aircraft Propulsion
- Automotive Engineering
- Chemical Engineering
- Computer Engineering
- Electrical Power
- Electronics
- Fluid Machinery
- Geodesy and Surveying
- Heat-Power
- Hydraulics
- Instrumentation
- Machine Design
- Marine Engineering
- Meteorology
- Metallurgy
- Naval Architecture
- Nuclear Engineering
- Solid Mechanics
- Structures

Details of these can be obtained from the program advisers and options in other areas can be arranged by conference with the Program Advisory Committee.

All electives must be approved by a program adviser.

MECHANICAL ENGINEERING

Program Adviser: Professor Pearson, 230A West Engineering

The mechanical engineer is concerned with the generation and control of power and heat transfer systems, the design and development of a wide variety of products and machinery, and the operations and methods of manufacture. As such he engages in the design, operation, and control of conventional and nuclear power plants. He designs and develops automobiles, engines, turbines, fluid machinery, production machinery, and equipment; heating, ventilating, air conditioning, refrigeration systems and equipment, appliances and other consumer goods. He is responsible for the development, operation, and control of manufacturing processes.

The mechanical engineer is employed in many industries. Automotive, machine tool, and general machinery firms are obvious examples. Less obvious, but no less important, are the aircraft, chemical, electrical, public utilities, and materials 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

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

and heat transfer, solid and fluid mechanics, electricity and electronics, and materials. These fundamentals are then applied to the design, heat 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 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 under Requirements for Graduation. 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:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Econ. 103, 104, or Econ. 401 and 3 hours nontechnical elective	6
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Chem.-Met. Eng. 270, Metals and Alloys	3
Eng. Graphics 104	2
Eng. Mech. 208, Statics	3
Eng. Mech. 210, Mechanics of Materials	4
Eng. Mech. 212, Laboratory in Strength of Materials	1
Eng. Mech. 324, Fluid Mechanics	3
Eng. Mech. 343, Dynamics	3
Math. 373, Elementary Computer Techniques	1
Math. 404, Differential Equations	3
Mech. Eng. 251, Manufacturing Processes I	3
Mech. Eng. 324, Fundamentals of Fluids Machinery	4
Mech. Eng. 335, Thermodynamics I	3
Mech. Eng. 336, Thermodynamics II	4
Mech. Eng. 340, Dynamics of Machinery	4
Mech. Eng. 362, Machine Design I	3
Mech. Eng. 371, Heat Transfer I	4
Mech. Eng. 381, Manufacturing Processes II	3
Mech. Eng. 460, Machine Design II	3
Elec. Eng. 315, D.C. and A.C. Apparatus and Circuits	4
Elec. Eng. 442, Motor Control and Electronics	4

	HOURS
Nontechnical electives	6
Technical electives*	14
	—
Total, professional subjects and electives	95

The technical 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 is encouraged to formulate his own sequence of elective courses, with the advice and subject to the approval of his adviser; example elective sequences for the fields listed above are available in the Mechanical Engineering office, 225 West Engineering Building.

SUGGESTED SCHEDULE†

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS
Physics 146	5
Eng. Mech. 208	3
Chem.-Met. Eng. 250	3
Math. 371	4
English, Group II	2
	—
	17

FOURTH SEMESTER	HOUR
Eng. Graphics 104	2
Eng. Mech. 210	4
Eng. Mech. 212	1
Chem.-Met. Eng. 270	3
Math. 372	4
Math. 373	1
	—
	15

SUMMER SESSION	
Mech. Eng. 335	3
Eng. Mech. 343	3
	—
	6

FIFTH SEMESTER	
Mech. Eng. 251	3
Eng. Mech. 324	3
Mech. Eng. 336	4
Mech. Eng. 340	4
Math. 404	3
	—
	17

SIXTH SEMESTER	
Elec. Eng. 315	4
Mech. Eng. 324	4
Mech. Eng. 362	3
Mech. Eng. 381	3
Humanities	3
	—
	17

SEVENTH SEMESTER	
Mech. Eng. 371	4
Elec. Eng. 442	4

EIGHTH SEMESTER	
Econ. 401	3
Humanities	6

*This group of electives should include at least one advanced theory course and one advanced laboratory in mechanical engineering. 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 most appropriate schedule for any student will depend upon his area of group options and electives interest. The student should develop the desired modifications to the above basic schedule with the advice and approval of his counselor.

	HOURS		HOURS
Mech. Eng. 460	3	Technical electives	9
English, Group III	2		—
Technical electives	5		18
	—		
	18		

METALLURGICAL ENGINEERING

Program Adviser: Professor Sinnott, 4020 East Engineering

Metallurgical engineering is concerned with the production, processing, and utilization of metals and alloys. It is a broad field based on the sciences of chemistry and physics and closely related to the many other engineering disciplines.

To obtain the necessary breadth the basic program consists of courses in mathematics, chemistry, physics, the humanities, basic engineering sciences, and, in the fields of process, mechanical and physical metallurgy. Considerable choice is permitted the student in electives in related fields of science, engineering, and in specialized areas within the metallurgical area.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)
A typical sequence is shown in the first half of the representative schedule below.

B. PROFESSIONAL OR ADVANCED SUBJECTS AND ELECTIVES

Basic Science

	HOURS
Advanced chemistry, to include such subjects as principles of physical chemistry, organic chemistry, and quantitative analysis	15
A course in electronic computers such as Math. 373	1

Chemical and Metallurgical Engineering Science

Introduction to engineering calculations, Chem.-Met. Eng. 200	3
Thermodynamics, Chem.-Met. Eng. 230 and 339	**8**
Rate Processes, Chem.-Met. Eng. 340	5
Structure of Solids, Chem.-Met. Eng. 350	**3**

Electives*

		HOURS
(1)	Electives in English, humanities, social sciences, philosophy, languages, etc.	14
(2)	Electives in law, business administration, and economics	6
(3)	Electives in engineering science and analysis, to include mechanics and electrical science	14
(4)	Electives in advanced science and mathematics	7
(5)	Electives in professional metallurgical engineering subjects in the fields of process, mechanical and physical metallurgy	19
	Total hours in Group B	95

Representative Schedule, showing a typical set of electives. The number in parentheses preceding course name designates the group under Electives above.

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
English 111	3	Math. 234	4
Eng. Graphics 101	3	English 112, 121	3
Chem. 107	5	Physics 145	5
Math. 233	4	Chem.-Met. Eng. 200	3
		Math. 373	1
	15		16

THIRD SEMESTER		FOURTH SEMESTER	
Physics 146	5	Math. 372	4
Math. 371	4	Chem.-Met. Eng. 230	5
Chem. 265	4	Chem. 266	4
(3) Eng. Mech. 310	4	(3) Eng. Mech. 343	3
		(1) English, Group II	2
	17		18

FIFTH SEMESTER		SIXTH SEMESTER	
Chem.-Met. Eng. 339	3	Chem.-Met. Eng. 340	5
(5) Chem.-Met. Eng. 370	2	Chem.-Met. Eng. 350	3
Chem. 220	3	Chem. 346	4
(4) Math. 104	3	(2) Bus. Ad., Acctg. 271	3
(3) Elec. Eng. 315	4	(3) Elective	3
(1) English, Group III	2		
	17		18

SEVENTH SEMESTER		EIGHTH SEMESTER	
(5) Chem.-Met. Eng. 470	4	(5) Chem.-Met. Eng. 460	3
(2) Econ. 401	3	(5) Chem.-Met. Eng. 471	3
(4) Chemistry or Physics	4	(5) Chem.-Met. Eng. 489	4
(1) Humanities	6	(5) Chem.-Met. Eng. 472	3
		(1) Humanities	4
	17		17

*Courses that satisfy the requirements of the ROTC units will also be considered for use as electives where appropriate.

METEOROLOGY

Program Adviser: Associate Professor Dingle, 5062 East Engineering

The increasing recognition of the importance of weather and climate in a wide range of engineering problems has created a demand for engineers with a knowledge of meteorology and the ability to apply it to specific problems. There is a need for qualified engineering meteorologists, both men and women, in industry, government, teaching, research, and private practice—a need which gives every evidence of continuing for years to come.

Weather forecasting has traditionally been the main occupation of meteorologists, but modern meteorology encompasses a much wider range of activities and interests. In the planning of a large industrial plant the engineering meteorologist may be called upon to evaluate the proposed location, plant processes, stack characteristics, etc., in order to avoid or minimize air pollution problems. In the design of towers or suspension bridges, the dynamic wind loadings on the structure for that region and terrain must be studied and estimated. In transportation, whether by land, water, or air, weather is often the determining factor in maintaining efficient operation. Engineering meteorology has important application in many other areas, such as vehicle design; electrical power and natural gas dispatching; air conditioning; nuclear power plant design, location, and operation; cooling tower design; evaluation and prevention of weathering of materials; design of snow clearance heating systems; hydroelectric power development; solar energy use; and analysis of planetary atmospheres.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Eng. Graphics 102, Descriptive Geometry	3
Eng. Mech. 208, Statics	3
Eng. Mech. 210, Mechanics of Materials	4
Eng. Mech. 324, Fluid Mechanics	3
Eng. Mech. 343, Dynamics	3
Sci. Eng. 330, Thermodynamics	3
Sci. Eng. 340, Rate Processes	3
Elec. Eng. 215, Network Analysis	3
Elec. Eng. 320, Electromagnetics and Energy Conversion	4

	HOURS
Ind. Eng. 472, Operations Research	3
Math. 403 or 404, Differential Equations	3
Meteor. 412, Physical Climatology	3
Meteor. 432, Atmospheric Thermodynamics and Radiation	3
Meteor. 440, Principles of Weather Analysis	3
Meteor. 441, Laboratory in Weather Analysis I	3
Meteor. 445, Dynamic Meteorology	3
Meteor. 452, Physical Meteorology	3
Meteor. 462, Meteorological Instrumentation	3
Meteor. 472, Hydrology and Hydrometeorological Design	4
Meteor. 475, Meteorological Analysis and Design Criteria	4
Electives in mathematics, engineering science, physical science, and biological science*	11
Electives in humanities and social sciences	13
Total, professional subjects and electives	95

With the assistance of his adviser, each student is expected to draw up his own program of studies which may include not only the required courses in meteorology but also one or more sequences of related courses in the humanities and social sciences and in such areas as instrumentation, electronics, statistics, high-speed computation, geophysics, operations analysis, upper atmosphere analysis, water resources, air sanitation, or some other appropriate area.

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 371	4	Math. 372	4
Physics 146	5	Eng. Graphics 102	3
Eng. Mech. 208	4	Elec. Eng. 215	3
English, Group II	2	Eng. Mech. 210	4
Chem.-Met. Eng. 250 or elective	3	Electives	4
	18		18

FIFTH SEMESTER		SIXTH SEMESTER	
Sci. Eng. 330	3	Math. 403 or 404	3
Eng. Mech. 324	3	Eng. Mech. 343	3
Meteor. 432	3	Sci. Eng. 340	3
Meteor. 440	3	Meteor. 445	3
Meteor. 441	3	Meteor. 452	3
Elective	3	English, Group III	2
	18		17

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

SEVENTH SEMESTER	HOURS
Elec. Eng. 320	4
Meteor. 412	3
Meteor. 462	3
Meteor. 472	4
Elective	3
	17

EIGHTH SEMESTER	HOURS
Ind. Eng. 472	3
Meteor. 475	4
Electives	11
	18

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Program Adviser: Professor Benford, 448C 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 1 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 2 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 engine; boilers of different types; auxiliaries; propellers; and the general problem of heat transfer.

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 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:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Eng. Graphics 104, Descriptive Geometry	2
English, Groups II and III	4
Math. 373, Elementary Computer Techniques	1
Math. 404, Differential Equations	3
Econ. 401	3
Eng. Mech. 208, Statics	3
Eng. Mech. 210, Mechanics of Materials	4
Eng. Mech. 212, Laboratory in Strength of Materials	1
Eng. Mech. 324, Fluid Mechanics	3
Eng. Mech. 343, Dynamics	3
Eng. Mech. 411, Structural Mechanics	3
Eng. Mech. 446, Theory of Vibrations	3
Mech. Eng. 252, Engineering Materials & Manufacturing Process	2
Mech. Eng. 335, Thermodynamics I	3
Mech. Eng. 362, Machine Design I	3
Elec. Eng. 315, D.C. and A.C. Apparatus and Circuits	4
Nav. Arch. 200, Introduction to Practice	2
Nav. Arch. 201, Form Calculations I	3
Nav. Arch. 310, Structural Design I	3
Nav. Arch. 331, Marine Auxiliary Machinery	3
Nav. Arch. 420, Resistance, Propulsion, and Propellers	5
Free electives	2
Nontechnical electives	9
Group options and electives	20
Total, professional subjects and electives	95

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

1. NAVAL ARCHITECTURE. *Adviser:* Professor Benford

Mech. Eng. 337, Heat Power Laboratory	2
Nav. Arch. 300, Form Calculations II	2
Nav. Arch. 330, Marine Propulsion Machinery	3
Nav. Arch. 400, Specifications and Contracts	2
Nav. Arch. 410, Stress Analysis in Ship Structures	2
Nav. Arch. 440, Ship Dynamics	2
Nav. Arch. 470, Ship Design I	3
Nav. Arch. 471, Ship Design II	2
Nav. Arch. 472, Structural Design II	2
	20

2. MARINE ENGINEERING. *Adviser:* Associate Professor West

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

Elec. Eng. 442, Motor Control and Electronics	4
Mech. Eng. 336, Thermodynamics II	4
Mech. Eng. 371, Heat Transfer	4
Nuc. Eng. 400, Elements of Nuclear Engineering	3
Nav. Arch. 430, Design of Marine Power Plants I	2
Nav. Arch. 473, Design of Marine Power Plants II	3
	20

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 371	4	Math. 372	4
Physics 146	5	Eng. Mech. 210	4
Eng. Mech. 208	3	Eng. Mech. 212	1
Nav. Arch. 200	2	Nav. Arch. 201	3
Eng. Graphics 104	2	Chem.-Met. Eng. 250	3
Math. 373	1	Mech. Eng. 252	2
	17		17

SUMMER SESSION	
Mech. Eng. 335	3
Math. 404	3
English, Group II	2
	8

FIFTH SEMESTER	Option 1	Option 2
Nav. Arch. 310	3	3
Eng. Mech. 324	3	3
Eng. Mech. 343	3	3
Elec. Eng. 315	4	4
Nav. Arch. 300	2	–
Nav. Arch. 330	3	–
Mech. Eng. 336	–	4
	18	17

SIXTH SEMESTER	Option 1	Option 2
Mech. Eng. 362	3	3
Eng. Mech. 411	3	3
Nav. Arch. 331	3	3
Nav. Arch. 440	2	–
Nontechnical elective	3	–
Elec. Eng. 442	–	4
Mech. Eng. 371	–	4
Elective	2	–
	16	17

SEVENTH SEMESTER	Option 1	Option 2
Eng. Mech. 446	3	3
Mech. Eng. 337	2	–
Econ. 401	3	3
Nav. Arch. 400	2	–
Nav. Arch. 410	2	–
Nav. Arch. 470	3	–
Nontechnical elective	3	3
Nav. Arch. 420	–	5
Nav. Arch. 430	–	2
Elective	–	2
	18	18

EIGHTH SEMESTER	Option 1	Option 2
English, Group III	2	2
Nav. Arch. 420	5	–
Nav. Arch. 471	2	–
Nav. Arch. 472	2	–
Nuc. Eng. 400	–	3
Nav. Arch. 473	–	3
Nontechnical electives	3	6
	14	14

PHYSICS

Program Co-advisers: Professor Wolfe, 4063 Randall; Professor Kerr, 3028 Phoenix Memorial Laboratory

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.

REQUIREMENTS

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

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
English, Groups II and III	4
Modern language	8
Chem.-Met. Eng. 250, Principles of Engineering Materials	3
Chemistry 265	4
Math. 373	1
Math. 403 or 404, Differential Equations	3
Eng. Mech. 208, Statics	3
Eng. Mech. 210, Mechanics of Materials	4
Eng. Mech. 343, Dynamics, or Physics 401, Intermediate Mechanics	3
Eng. Mech. 324, Fluid Mechanics, or Physics 411, Mechanics of Fluids	3
Elec. Eng. 210, Circuits I	4
Elec. Eng. 310, Circuits II	4
Mech. Eng. 252, Engineering Materials and Manufacturing Processes	2
Physics 405, Intermediate Electricity and Magnetism	3
Physics 406, Heat and Thermodynamics, or a course in engineering thermodynamics	3
Physics 453, Atomic and Molecular Structure	3
Physics 455, Electron Tubes	4
Group options and electives	36
Total, professional subjects and electives	95

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 including analysis, design, and systems in some particular field of engineering.

	HOURS
Physics	7
Mathematics	4
Engineering electives	12
From economics, geography, history, philosophy, political science, psychology, or sociology	6
Electives*	7
	36

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

SCIENCE ENGINEERING

Program Adviser: Associate Professor Bigelow, 3036 East Engineering

Recent trends in engineering have been characterized by an increasing emphasis on science, with many revolutionary advances in the scientific bases of the older fields of engineering as well as a spectacular expansion of engineering into many new fields such as nuclear energy, instrumentation, operations and systems analysis, and space technology.

The Science Engineering program is designed to develop engineers having the versatility and flexibility required to meet the needs of our expanding and changing technology by providing a broad basis of training in the fundamental principles with a sound knowledge of the application of the scientific method to engineering design and analysis.

Students completing the Science Engineering program have a scientific background equivalent to that obtained in many programs leading to the master's degree, but they are not required to complete all of the specialized courses required for the bachelor's degree in most traditional engineering programs. In recognition of the increasing contributions of scientists and engineers to the political, social, cultural, and philosophical aspects of modern civilization, the Science Engineering program also affords an opportunity for electing a number of courses in humanities, social sciences, and foreign languages.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Science Engineering) are required to complete the program outlined below. Among the Group A subjects, the accelerated and integrated sequences of preparatory courses beginning with Mathematics 335, Physics 153, and Chemistry 194 are strongly recommended for those students who are qualified; the suggested schedule below is expressed in terms of these accelerated sequences. The many alternative sequences of preparatory courses with the same terminal level of accomplishment are acceptable, of course, but they add hours to the preparatory portion of the illustrated schedule. The mathematics sequence beginning with Mathematics 233 adds 4 hours; the physics sequence beginning with Physics 145 adds 2 hours; the chemistry sequence beginning with Chemistry 107 adds 1 hour; and the chemistry sequence beginning with Chemistry 103 adds 4 hours.

For the engineering science courses of the Group B subjects, the special sequences of courses beginning with Engineering Mechanics 218, Electrical Engineering 215, and Science Engineering 330 are normally recommended; however, certain equivalent courses may be substituted for these, with the approval of the program adviser, when it is advantageous in developing a program to meet the special interests of individual students.

A unique feature of the science engineering program is the unusual amount of freedom allowed in the selection of advanced engineering courses. The engineering electives, together with the unspecified electives and the electives in advanced mathematics, chemistry, physics, and thermodynamics, may be selected so as to provide a high degree of competence in one of the traditional fields of engineering; or they may be used to combine courses from several fields to obtain training in some special phase of engineering that is common to several of the traditional fields of engineering. This elective freedom frequently makes it possible for a student to obtain two bachelor's degrees in engineering with only a little extra course work or to prepare for graduate work in almost any of the professional engineering fields. Science Engineering counselors work closely with the students and with counselors in other engineering programs to select courses best suited for such special purposes.

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 34)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
Engineering science, including engineering materials, statics, strength of materials, dynamics, fluid mechanics, thermodynamics, electromagnetics and energy conversion, network analysis, electronics and systems, rate processes	36
Electives in engineering, including at least one elective in design or analysis and at least one elective involving engineering laboratory	17
Electives in mathematics, physics, chemistry, or thermodynamics, including Chemistry 15 or equivalent and at least 3 hours of advanced mathematics	16
Electives in English, literature, fine arts, or philosophy	6–10
Electives in anthropology, economics, geography, history, journalism, political science, psychology, or sociology	6–14
Electives in foreign language	0–8
Electives*	6
Total, professional subjects and electives	95

SUGGESTED SCHEDULE

(In terms of accelerated sequences)

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
Math. 335	4	Math. 336	4
Physics 153	4	Chemistry 194	4
Eng. Graphics 101	3	Eng. Mech. 218	3
English 111	3	English 112	2
English 121	1	Elective (humanities, soc. sci.)	3
	15		16

*Advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

THIRD SEMESTER	HOURS
Math. 337	4
Chemistry 195	4
Eng. Mech. 219	4
Electives (humanities, soc. sci.)	6
	18

FOURTH SEMESTER	HOURS
Elective (math.)	3
Physics 154	4
Eng. Mech. 345	3
Elec. Eng. 215	3
Electives (humanities, soc. sci.)	5
	18

FIFTH SEMESTER	
Sci. Eng. 330	4
Elec. Eng. 320	4
Eng. Mech. 326	4
Elective (math., chem., physics)	3
Elective (humanities, soc. sci.)	3
	18

SIXTH SEMESTER	
Sci. Eng. 340	4
Elec. Eng. 337	4
Chem.-Met. Eng. 350	3
Elective (math., chem., physics)	3
Elective (engineering)	4
	18

SEVENTH SEMESTER	
Electives (engineering)	6
Elective (math., chem., physics)	3
Elective (humanities, soc. sci.)	3
Electives	6
	18

EIGHTH SEMESTER	
Electives (engineering)	7
	7

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.

COMMUNICATION SCIENCES

The program of communication sciences is concerned with the communication and processing of information by natural and artificial systems. Two general areas of study are particularly important in the communication sciences: (1) the technical study of natural and artificial languages as modes of communication; (2) the investigation of systems found in nature and of mathematical automata as information processing systems. The investigation of information processing systems is directed toward the analysis, synthesis, and coding of information in such devices as digital computers, speech recognizers, and automata.

A bachelor's degree is required before the student may specialize in communication sciences. Areas of concentration which are valuable as a background for graduate work in communication sciences are: mathematics, electrical engineering, physics, biology, and psychology. Students who are preparing for graduate study in the communication sciences should consult with the chairman of the Advisory Committee, Professor Gordon E. Peterson, 2515 East Engineering or 180 Frieze Building.

Undergraduate students may begin specialization in the communication sciences by electing one or more of the following courses: Com. Sci. 400 and 401, Introduction to the Communication Sciences; Com. Sci. 510, Descriptive Models of Natural Languages; Philosophy 414, Mathematical Logic; Mathematics 429, Mathematical Theory of Probability.

INSTRUMENTATION ENGINEERING

Instrumentation engineering is a program covering the dynamical aspects of systems engineering. This involves the principles and application of areas including measurement, information theory, data transmission, computers, feedback control, and random processes as they relate and are basic to systems in all fields of technology and science.

The best preparation can be achieved 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 under M.S.E. degree programs and course listings.

Undergraduate students may start these special studies by electing one or more of the following courses: Instr. Eng. 570, Principles of Automatic Control *(3)*; Instr. Eng. 571, Automatic Control Laboratory *(1)*; Instr. Eng. 530, Probability in Instrumentation *(2)*; Elec. Eng. 418, Networks and Electron Tube Circuits *(4)* or 438, Electronics and Radio Communication *(4)*; Math. 548, Operational Methods for Systems Analysis *(4)*.

MANAGEMENT SCIENCES

The last decade has developed new and complex tools for management in the form of high-speed computational, display, and communication techniques as well as of powerful analytical methods such as information theory, linear programing, and queueing theory. These tools are being applied to continuing industrial problems, such as production and labor force scheduling, inventory control, sales forecast, and data processing (flow of information), as well as to special problems arising in connection with planning, market analysis, and organization. There is a rapidly growing demand for those well trained in the management sciences. Special graduate training in this field may be based on undergraduate study leading to a bachelor's degree in such fields as business administration, engineering, mathematics or the physical sciences, economics, and psychology. Undergraduate training should stress mathematics, regardless of field of origin, at least through a course beyond differential equations.

Undergraduate students may start the special studies by electing one or more of the following courses: Math. 517, Introduction to Linear Algebra and its Application *(3)*; Math. 561, Theory of Statistics I *(4)*; Math. 473, Methods of High-Speed Computation I *(3)*; Math. 447, Modern Operational Mathematics *(2)*.

NUCLEAR ENGINEERING

Nuclear engineering is concerned with the release, control, and utilization of energy from nuclear sources. This energy has new and unusual properties and it presents special problems to the engineer. If sound and economic use of nuclear energy is to be developed, men with the necessary specialized training must enter this field. The engineers choosing this field should have maturity, creative talent, and an understanding of the economic criteria used to judge engineering development in general. The degree programs, therefore, are now offered only at the graduate level (see under Graduate Studies).

Students desiring only a one-semester course in nuclear engineering should elect Nuc. Eng. 400. Students planning to enter the nuclear engineering program should take courses in atomic and nuclear physics (Nuc. Eng. 470 or equivalent), advanced calculus (Math. 450 or 551 or equivalent), and electronics (Elec. Eng. 337 or Physics 455 or equivalent) during their senior year. Students who do not meet these prerequisites will be requested to make up the deficiencies in addition to the thirty hours required for the master's degree. Mech. Eng. 371 and Elec. Eng. 420 are also recommended as desirable preparation.

RESERVE OFFICERS TRAINING CORPS

The objective of the ROTC is to train well-qualified officers for the armed forces. Each male student attending The University of Michigan has the opportunity to enroll in the Army ROTC, the Navy ROTC, or the Air Force ROTC if he meets the specific requirements of the respective unit. Enrollment is voluntary but the University and the Armed Forces expect each student who enrolls in ROTC to meet the full obligations assumed by that enrollment unless excused by the regulations of the Army, Navy, or Air Force:

1. The student agrees to add to his own degree requirements the completion of the ROTC program in which he is enrolled as follows:

Unit	ROTC Program in which student is enrolled	Student agrees to add to his degree requirements for graduation	Credit allowed toward degree requirement as electives
Army or Air Force	2 year basic	Completion of 2 years (Fr.-Soph.)	None
	2 year advanced (upon application and selection)	Completion of 2 years (Jr.-Sr.)	See degree requirements of professional program elected
Navy	NROTC Contract and Regular	Completion of 4 years	See degree requirements of professional program elected (300 and 400 series courses only)

2. The student completing four years of ROTC agrees to accept his commission as a condition of receiving his diploma.

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.

On permission to drop, see paragraph 5 under Election of Studies.

AIR SCIENCE

Professor White; Assistant Professors Archibald, Finley, and O'Neill; Instructors Buist, Keene, and Larsen. Department office, North Hall.

General Information. The Department of Air Science offers four years of generalized Air Science studies in combination with non-ROTC courses all designed to prepare selected male officer candidates for commissioning in the United States Air Force. The sequence of courses provides understanding of national and international defense requirements; of the global mission and organization of the USAF; and of officer leadership and management responsibilities and skills. To comply with federal law concerning total hours of contact time, freshman and sophomore cadets in the basic program spend three class periods per academic week in Air Science or approved non-ROTC courses; juniors and seniors in the advanced program spend five hours per week in Air Science or approved non-ROTC courses; advanced cadets attend a twenty-eight-day summer training period at an active Air Force base, normally following the junior year. Enrollment in basic program courses is the same as for all University courses, with no commitment made to seek a commission; however, the student must be interviewed by the chairman of the Department of Air Science before registering for his first Air Science course. In the spring of the sophomore year a cadet may apply for the advanced program to earn a commission. Upperclass cadets may seek a commission in one of the following categories: pilot or navigator training (regardless of college academic major), engineering and science specialties, and other specialties. Graduates who apply and are selected for pilot or navigator training will serve three and one-half to four years on active duty following completion of flying training. Graduates entering nonflying positions serve on active duty for four years. Active service may be delayed in order to study for an advanced degree.

Flying Activities. Senior year cadets qualified and desiring active service pilot training receive in a Flight Instruction Program approximately thirty-six hours of dual/solo light plane instruction under a licensed civilian instructor, having opportunity also to earn a private pilot's license. They receive thirty-five hours of "ground school" work (see A.S. 401 listing below). When possible, local area orientation flights and overnight flights to active Air Force bases are made to familiarize cadets with Air Force life.

Requirements For Enrollment. A male student enrolled in the University who is a physically qualified citizen of the United States (or will become a citizen during his fourth semester) who can complete eight semesters of air science work prior to receiving his degree and who will meet all requirements for commissioning prior to his twenty-eighth birthday may enroll in the basic program. Students with prior military service may enroll above the entry level based upon evaluation of such military service by the Professor of Air Science. Women students may apply for enrollment in a noncommission-seeking status.

Transfer Students. Students who have completed one or more years of ROTC studies (Air Force, Army, or Navy) at any college-level institution or who have sufficient prior military service may enter the AFROTC program as late as the first semester of the junior year. They should contact the Professor of Air Science prior to registration week, if possible, in order that a tentative determination of eligibility may be made and to allow time for the Department of Air Science to procure records from the ROTC department with which previously enrolled.

Alternates for ROTC Courses. University courses have been substituted for approximately 45 per cent of the basic and advanced programs. In the fall of the freshman year and in the spring of the sophomore year students may designate from their own degree program courses one course (in mathematics, physical or natural or social sciences, foreign language, or humanities) as alternate for the *academic* portion of the Air Science course. Advanced cadets take non-ROTC courses in speech, political geography, and international relations along with reduced time in Air Science classes. See listings below.

Monetary Allowances are paid to advanced cadets (3rd and 4th Air Science years) totaling approximately $275 per year plus approximately $75 and a travel allowance for the summer training period.

Uniforms and Books are furnished to all Air Science cadets. Each advanced program cadet is measured for a fitted uniform which becomes a gift from the University on the date of his commissioning. A uniform deposit of $20 is required; it is refunded when Air Science studies are terminated.

Commissions in the Regular Air Force. Any AFROTC cadet designated a Distinguished AFROTC Cadet and who maintains his standing and becomes a Distinguished AFROTC Graduate may be commissioned in the Regular Air Force upon entering active service.

Selective Service Deferment. Basic program cadets are entitled to deferment after the first semester, based on enrollment in ROTC. Deferment of a cadet may be continued as late as one year beyond the completion of the fourth year of Air Science studies provided the cadet is still working to earn his degree and commission.

Extracurricular Activities. The Department of Air Science sponsors a rifle team, drill team, and cadet work in Air Explorer training; it also co-sponsors a triservice ROTC band. Selected cadets may become members of the local chapter of the national Arnold Air Society. Qualified cadets may participate in triservice honorary organizations.

COURSES OFFERED IN AIR SCIENCE

101. Foundations of Leadership. (*1*).
To be accompanied by approved non-ROTC course. Laboratory and seminar, 1 hour a week.

102. Foundations of Air Power I. (*2*).
Elements and potentials of air power; air vehicles and principles of flight; military instruments of national security; professional opportunities in the USAF. Seminar, 2 hours a week; laboratory, 1 hour a week.

201. Fundamentals of Aerospace Weapons.
Evolution of aerial warfare; elements of aerial warfare; employment of air forces; space operations. Seminar, 2 hours a week; laboratory, 1 hour a week.

202. Foundations of Leadership.
To be accompanied by approved non-ROTC course. Laboratory and seminar, 1 hour a week.

301. Air Force Officer Development.
Introduction to Advanced AFROTC; AF command and staff; air base functions;

communicating and instructing; problem-solving techniques. Seminar, 2 hours a week; laboratory, 1 hour a week; accompanied by English 241.

302. Air Force Officer Development.
Leadership principles and techniques; military justice system; preparation for summer training. Seminar, 4 hours a week; laboratory, 1 hour a week.

401. Global Relations.
Weather; navigation. This academic work constitutes 30 of the 35 hours of "ground school" for seniors in the Flight Instruction Program seeking pilot training. Seminar, 2 hours a week; laboratory, 1 hour a week; accompanied by Geography 435.

402. Global Relations.
The AF Officer, preparation for active service. Seminar, 1 hour a week; laboratory, 1 hour a week; accompanied by Political Science 160.

MILITARY SCIENCE

Professor Woodman, Chairman; Assistant Professors E. Hicks, R. Hicks, Pulver, and Trost. Department office, 212 Temporary Classroom Building.

General Information. The objective of the Army ROTC program is 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, after attaining a baccalaureate degree, are commissioned as second lieutenants in the Army Reserve. Outstanding ROTC cadets who are designated as Distinguished Military Students may apply for a direct commission in the Regular Army (the same commission as given West Point Military Academy graduates).

Regularly enrolled University of Michigan male students who meet the established physical, citizenship, age, and moral standards prescribed may enroll in the Army ROTC program. Enrollment in the ROTC is voluntary, and ROTC cadets are excused from the University requirement of two semesters of physical education. A cadet may drop ROTC, if he so desires, only during the first few weeks of the first semester. A cadet that remains in the ROTC after the dropout period authorized by his own college is required to complete four semesters of ROTC as a University degree requirement. This requirement can be waived only in exceptionally grave circumstances such as when a student is placed on academic probation.

In order for a cadet to continue into the advanced ROTC program (junior and senior years), he must have exhibited marked leadership potential. Thus, entrance into the advanced program is on an invitational basis, the cadet having the option to accept or decline. A cadet, having accepted the advanced program, is required to sign a contract to: (1) continue the ROTC program for the remaining four semesters; (2) accept a commission, if tendered; and (3) serve his military obligation of active duty and reserve duty as required by law.

The current military obligation is either (1) two years of active duty and four years in the Reserve, or (2) six months of active duty for training and seven and one-half years in the Reserve. ROTC graduates indicate their personal preference, but determination of length of tour of active duty is based upon the current needs of the Department of the Army. In the past, almost everyone received his preference.

Each cadet is required to attend a six-week ROTC Summer Camp, normally at the end of his junior year. Emphasis of training at summer camp is on leadership and field application of studies at the University.

ROTC graduates who desire to defer their tour of active duty in order to do graduate work at any accredited university may apply for an academic delay. Academic delays are given for one year and may be renewed for a number of years. To date, no University of Michigan ROTC graduate has been denied his request for delay or extension of delay.

Branch Assignments. During their senior year, cadets will be classified for branch assignment upon commissioning to one of the following branches in accordance with their leadership, aptitude, curriculum, interest, physical condition, and the nationwide needs of the Army:

Arms. Armor, Artillery, Infantry, Corps of Engineers, Signal Corps. (Physical qualifications for all of above are the same, somewhat more demanding than for the services listed below. Engineers and Signal are *both* an Arm and a Service.)

Technical and Administrative Services. Adjutant General's Corps, Army Security, Chemical Corps, Corps of Engineers, Finance Corps, Medical Service Corps, Military Intelligence, Military Police Corps, Ordnance Corps, Quartermaster Corps, Signal Corps, Transportation Corps. Though completion of the ROTC program does *not* lead directly to commissions in Medical Corps, Dental Corps, Chaplain's Corps, Judge Advocate General's Corps, or Veterinary Corps, students interested in these fields are encouraged to contact the Military Science Department personally as there are many cogent reasons for enrolling in the ROTC program.

Advanced Standing. Students with prior military service or prior ROTC training (high school or college) may receive advanced standing in the ROTC program. The many variables preclude a blanket statement of eligibility; thus, students should contact the Military Science Department personally for advanced standing determination.

Pay and Allowances. Pay and allowances begin with enrollment in the third year of military science and amount to approximately $265 for each of the last two years. In addition, the cadet receives approximately $117, plus travel expenses to and from summer camp, for the six-week summer camp.

Uniforms, Texts, and Equipment. All ROTC cadets are furnished a uniform and all texts and equipment without charge; however, a security deposit of $20 is required. The uniform furnished at the beginning of the third year is custom tailored and may be retained by the individual for active duty wear as an officer.

Extracurricular Activities. Cadets are free to elect as few or as many of the following activities as desired:

Army Rifle Team—Range, rifle and ammunition available without charge.

ROTC Marching Band—Spring semester only, instruments furnished, attendance not required at Leadership Laboratory.

Pershing Rifles—A national honorary to promote leadership and comradeship through impeccable close order drill and fancy drill.

Scabbard and Blade—A national honorary

Course of Instruction. The complete course of instruction comprising eight semesters plus summer camp is divided into four major blocks of instruction: (1) American Military History; (2) Operations, Tactics, and Techniques; (3) Logistics and Material; (4) School of the Soldier and Exercise of Command (Leadership Laboratory). The instructional objective of the Department of Military Science 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.

The Department of the Army has revised the course of instruction for the four-year period to include "academic substitution." The effect of the substitution program is that it is far less demanding on the cadet's time, a reduction of 24 per cent of the classroom hours over the four-year period. For each hour that the cadet is "excused" from ROTC classes, he is required to attend one hour of class in one of the following broad fields: General psychology; science comprehension; effective communication; and political development and political institutions. The "substitute course" may be a degree requirement of the cadet's own college according to currently available information.

COURSES OFFERED IN MILITARY SCIENCE

101. Organization of the Army. *Prerequisite: None.*

Five hours of instruction on Organization of the Army and ROTC plus eight two-hour periods of Leadership Laboratory. Academic substitution of 25 hours (2 credit hours) required. Leadership Laboratory designed to teach the fundamentals of drill, drill being the vehicle used by the ROTC for progressive leadership development and evaluation.

102. United States Army and National Security. *Prerequisite: M.S. 101. (2).*

Ten hours of instruction on the M-1 Rifle and Rifle Marksmanship; fifteen hours on U. S. Army and National Security; seven two-hour periods of Leadership Laboratory. Leadership Laboratory designed to perfect individual performance and prepare cadets to serve as Noncommissioned Cadet Officers during sophomore year.

201. Land Navigation. *Prerequisite: M.S. 102. (2).*

Twenty hours of instruction in Map Reading and Aerial Photography; ten hours on U.S. Army and National Security; eight two-hour periods of Leadership Laboratory (U.S. Army and National Security now transferred to freshman year, M.S. 102). Leadership Laboratory designed for sophomores, acting as Cadet Noncommissioned Officers, to develop their leadership potential teaching the freshmen.

202. Operations and Tactics. *Prerequisite: M.S. 201. (2).*

Thirty hours of instruction in Operations and Basic Tactics; seven two-hour periods of Leadership Laboratory. Leadership Laboratory designed to give sophomores continued opportunity to develop their leadership potential as Cadet Noncommissioned Officers with view toward selection by Army Staff into Advanced Course.

301. The Army Team. *Prerequisite: M.S. 202 and selection. (1).*
Fifteen hours of instruction on Branches of the Army; 45 hours (3 credit hours) of academic substitution; eight two-hour periods of Leadership Laboratory. Leadership Laboratory designed to prepare each cadet for Summer Camp by rotating positions of leadership (company commander, platoon lieutenant, and NCO positions) weekly within the junior class.

302. Tactics and Communications. *Prerequisite: M.S. 301. (3).*
Ten hours of instruction on Leadership; twenty hours of Military Teaching Principles; thirty hours of Small Unit Tactics and Communications; five hours of Pre-camp Orientation; seven two-hour periods of Leadership Laboratory. Leadership Laboratory continuation of M.S. 301.

401. Operations, Administration and Logistics. *Prerequisite: M.S. 302. (3).*
Fifteen hours of instruction in Operations; fifteen hours of Logistics; fifteen hours of Army Administration; fifteen hours of Military Law; eight two-hour periods of Leadership Laboratory. Leadership Laboratory designed for seniors to act as Cadet Officers by organizing, running, and evaluating the Leadership Laboratory for all undergraduates.

402. Role of the United States in World Affairs. *Prerequisite: M.S. 401. (1).*
Ten hours of instruction in the Role of the United States in World Affairs; ten hours of Service Orientation; forty-five hours (3 credit hours) of academic substitution; seven two-hour periods of Leadership Laboratory. Leadership Laboratory designed as the final chance in the ROTC program for continued leadership development prior to functioning as commissioned officers on active duty in the Army.

NAVAL SCIENCE

Professor Steen; Associate Professor O'Day; Assistant Professors Arkland, DeMartini, Dunn, Graves, Henry, and Spetz; Instructors Girten, Hagar, Lofquist, McMurray, Schneider, and Sweeney. 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 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).

Officer 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 released sooner 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 active duty for a period of obligated service. 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 not less than 20/40 uncorrected by glasses and in all cases must be correctible to 20/20.

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. A psychology course taught by the civilian faculty of the University is required during one semester of the sophomore year.

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.

Contract students must have satisfactorily completed a sequence of mathematics through trigonometry in high school or one semester of mathematics in college by the end of their second year in the program. Regular students must satisfactorily complete one year of college mathematics and one year of college physics by the end of their sophomore 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 and Sea Power. I. (*3*).
Study of various components of the United States Navy; shipboard organization and duties. Develops the psychology and techniques of leadership by means of practical problems and the study of the history of sea power.

102. Naval History and Sea Power. II. (*3*).
A study of history of sea power and its influence in shaping world affairs socially, economically, and politically.

200. Naval Weapons. I or II. (*3*).
A basic familiarity in modern naval weapons and the purpose of each, stressing the following specifics: ballistics and ordnance, automatic control equipment, fire control problem, and fleet air defense. Instruction in the general nature of naval weapons systems stressing guided missiles, nuclear weapons, antisubmarine warfare, and space technology. A course in psychology, as selected by the Professor of Naval Science, is required during the semester the student is not enrolled in N.S. 200.

301. Naval Machinery. 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.

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.

303 **(301S). Navy Supply.** I. (*3*).
For Navy Supply Corps candidates only. Naval finance, organization, logistics, and naval accounting methods.

304 **(302S). Navy Supply.** II. (*3*).
For Navy Supply Corps candidates only. Supply organization and administration afloat.

305 **(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.

306 **(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.

402 **(402, 402S). Principles and Problems of Leadership.** II. (*3*).
Introduces the basic principles of human relations, leadership, and management with emphasis on Naval shipboard administration and an introduction to the Uniform Code of Military Justice. (Required for supply option students.)

403 **(401S). Naval Administration.** I. (*3*).
For Navy Supply Corps candidates only. Supply problems with emphasis on ship's store, clothing, and basic commissary management and operation.

405 (401M). Amphibious Warfare. I. *(3)*.
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare.

406 (402M). Amphibious Warfare. II. *(3)*.
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare (15 sessions only; remaining 30 sessions deal 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 preparation for their first employment. The University of 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 scholastic requirements of study at an advanced level, may apply for admission to the Horace H. Rackham School of Graduate Studies. In general, an applicant must have earned a B average in his undergraduate work to be accepted into a master's degree program. If the preparation of an otherwise acceptable candidate is not adequate, he will be required to take the necessary preparatory courses without graduate credit.

The requirements for the degree of Master of Science in Engineering include the completion of at least thirty credit hours of graduate work approved by the program adviser or advisory committee for the program elected with an average grade of at least B covering all courses elected as a graduate student. Courses numbered 400 and above are acceptable for graduate credit. A grade below B will not be accepted unless, after review of the circumstances, the acceptance of the credit is recommended by the program adviser or the advisory committee.

A superior student who is well prepared may complete the requirements for a master's degree in two semesters.

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

The degree earned for each of the programs offered in engineering will read: Master of Science in Engineering in (*name of program completed*).

AERONAUTICAL AND ASTRONAUTICAL ENGINEERING

Advisory Committee: Professors Isakson, Morrison, Uberoi; Associate Professor E. O. Gilbert

A candidate for this degree will normally include in his program three to five advanced courses in aeronautical and astronautical engineering, two to three courses in mathematics beyond advanced calculus, and one or two selected courses in other cognate fields. Up to four credit hours of non-technical studies and up to five credit hours of directed study may be selected. The courses in aeronautical and astronautical engineering may be selected to emphasize one or more of the following technical areas: aerodynamics, aeroelasticity, flight mechanics, guidance and control, propulsion, and structures.

CHEMICAL ENGINEERING

Advisory Committee: Professors Van Vlack, York, and Young; Associate Professors Gordon and Ragone

The requirements for this degree include Chem.-Met. Eng. 530, 540, 580, 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: Departmental Chairman

A candidate for this degree 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 following special fields: construction, geodesy and surveying, highway and traffic, hydraulics, municipal, railway, sanitary, structures, and soil mechanics.

COMMUNICATION SCIENCES

Advisory Committee: Professor Peterson, Chairman; Professors Burks, Hok, Lawrence, Rapoport, Thrall, Walker; Associate Professor Paper.

Candidates may be admitted to advanced study in Communication Sciences after a bachelor's degree in an appropriate area of concentration. See Special Fields.

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

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 Civ. Eng. 501, 531, 532, and 545; 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, Macnee, and Scott

A candidate for this degree must have satisfactorily completed the undergraduate electrical engineering program of the University or its equivalent. Normally, a minimum of thirty credit hours of advanced graduate work is required for this degree and must include Elec. Eng. 620 and two courses in advanced mathematics. At least fifteen credit hours must be in electrical engineering. By suitable selection of his remaining courses he may specialize in any of the following fields; communications engineering, computer engineering, engineering systems and design, electrical measurements and instrumentation, electric power engineering, electromagnetic field theory, feed-back control systems, illumination engineering, energy conversion machinery, microwave engineering, physical electronics, solid-state engineering.

ENGINEERING MATERIALS

Advisory Committee: Professors Van Vlack, York, and Young; Associate Professors Gordon and Ragone

A candidate for this degree is required to have a basic science background essentially equivalent to that represented by the program leading to the degree of Bachelor of Science in Engineering (Materials Engineering) at the University. This includes chemistry, through organic and physical, structure of materials, mechanics of materials, and thermodynamics. Thirty credit hours of graduate work are required, which are to be selected with the approval of the advisory committee of the program and which will include Chem.-Met. Eng. 570, 636, or 650.

ENGINEERING MECHANICS

Advisory Committee: Professors Clark, Dodge, Haythornthwaite, Masur, Ormondroyd, and Yih; Associate Professors Enns and Smith

Candidates may be admitted to this degree program from any of the undergraduate engineering curriculums. A student whose undergraduate training is inadequate will be permitted to make up the deficiency in a manner prescribed by the advisory committee. The transition is simplified for those who have had some advanced mathematics.

A total of thirty credit hours of graduate study is required for the master's degree, seventeen from the graduate courses offered in the Department of Engineering Mechanics and thirteen from cognate fields. The program must include Eng. Mech. 412, 422, and 441 and Math. 452 and 455 or their equivalents. Students who have had any of the required courses, or their equivalents, may substitute cognate subjects as part of the seventeen required hours if permitted to do so by the adviser. For those who expect to pursue the doctorate, Math. 557 is recommended. A master's thesis, subject to departmental approval, may be substituted for part of the course work. The student's program of study is to be approved by the departmental graduate adviser.

GEODESY AND SURVEYING

Program Adviser: Professor Berry

This program is available to students who have satisfactorily completed an undergraduate engineering program of the University, or its equivalent, including mathematics through differential equations and at least nine semester hours in surveying, geodesy, or astronomy. A minimum of thirty credit hours of graduate work, approved by the Department of Civil Engineering, is required for this degree, including Civ. Eng. 560 and 561; and other courses in engineering, mathematics, astronomy, city planning, or other closely allied fields related to the professional practice of geodesy and surveying in government or in private practice.

INDUSTRIAL ENGINEERING

Program Adviser: Professor Allen

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

Program Adviser: Professor Rauch

Candidates may be admitted to this degree program from any of the undergraduate engineering curriculums. The requirements for the degree include Math. 548; Elec. Eng. 418 or 438; Instr. Eng. 530, 570, 571, and a 600-level Instrumentation Engineering course; and other courses approved by the committee on instrumentation. The systems-engineering concept is emphasized throughout the program. See under Special Fields and course listings.

MANAGEMENT SCIENCES

Advisory Committee: Professors Dwyer, Fitts, Flood, and Rauch; Associate Professor Gardner

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

MECHANICAL ENGINEERING

Program Adviser: Professor Alvord

Candidates for this degree 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 and fields of specialization 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 Van Vlack, York, and Young; Associate Professors Gordon and Ragone

The requirements for this degree include Chem.-Met. Eng. 535, 570, and 690 (4 hours) ; and a minimum of one course from each of the following groups of courses: Chem.-Met. Eng. 573, 574, 587, 589; Chem.-Met. Eng. 536, 561, 577, 636; and Chem.-Met. Eng. 571, 572, 575, 870.

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

MUNICIPAL ENGINEERING ADMINISTRATION

Program Adviser: Assistant Professor Glysson

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: Assistant Professor Michelsen

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 usually include Math. 450, Nav. Arch. 590 or

591, Eng. Mech. 422, and electives in mathematics, engineering mechanics, and naval architecture.

It is also possible to obtain a combined degree Master of Science in Engineering in marine and nuclear engineering. 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

Program Advisers: Professor Kerr; Assistant Professor Gyorey

Students entering the program in nuclear engineering must have a bachelor's degree from an accredited engineering program. The nuclear science program is available to those with bachelor's degrees from recognized programs in physics, chemistry, or mathematics and who wish to work on nuclear energy development. The undergraduate preparation required for these programs is listed under Special Fields.

The credit requirements for the master's degree are thirty hours of completed course work including twenty hours from nuclear engineering. The following core courses must be included in the twenty hours: Nuclear Eng. 560, 570, 660, 670, and 680. A B average must be maintained in the core courses. All students are required to complete a one-semester research or design problem under Nuclear Eng. 690 for at least two credit hours. When desired, facilities for and supervision of work leading to a master's thesis will be made available. Additional courses are selected with the help of the program adviser from courses in nuclear engineering, cognate fields of engineering, mathematics, physics, chemistry, and others. Where the entering student presents evidence of satisfactory completion of work equivalent to any of the core courses, substitution of other courses will be arranged by the program adviser.

SANITARY ENGINEERING

Program Adviser: Professor Borchardt

The program leading to this degree 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

Programs are offered which lead to the following professional degrees:

AERONAUTICAL AND ASTRONAUTICAL ENGINEER—Ae. & Astrn.E.
APPLIED MECHANICS ENGINEER—App.M.E.
CHEMICAL ENGINEER—Ch.E.
CIVIL ENGINEER—C.E.
ELECTRICAL ENGINEER—E.E.
INDUSTRIAL ENGINEER—Ind.E.
INSTRUMENTATION ENGINEER—Instm.E.
MARINE ENGINEER—Mar.E.
MECHANICAL ENGINEER—M.E.
METALLURGICAL ENGINEER—Met.E.
NAVAL ARCHITECT—Nav.Arch.
NUCLEAR ENGINEER—Nuc.E.

The professional degree programs require a minimum of thirty credit hours of work beyond the Master of Science in Engineering level or its equivalent, taken at this University with a grade average of B or better. Successful completion of a qualifying examination for admission to candidacy is required.

The total graduate program shall include:

1. At least twenty-four hours in the area of the department or program cited in the degree. The department or program advisers may specify these hours in greater detail.
2. At least six hours devoted to a research, design, or development problem, including a written report covering the work. A committee of faculty members will supervise the work, approve the report, and conduct a final oral examination on this work.
3. At least three courses in cognate fields other than mathematics.
4. At least nine hours in mathematics beyond the Bachelor of Science in Engineering mathematics requirements of the department cited in the degree.

DOCTOR'S DEGREE

DOCTOR OF PHILOSOPHY—Ph.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.

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, Dr. Leta Lewis, 3028 Rackham Building, at his earliest convenience after becoming an applicant. A student who completes French 112, German 112, Spanish 112, or Russian 112 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 University year is composed of two semesters, and the credits are granted in semester hours. The present *Announcement* covers the first and second semesters. A special announcement is issued for the summer session. Just *prior* to the beginning of each semester and summer session a time schedule is issued giving hours and room assignments for classes.

As a general rule, courses numbered from 100 to 199 are introductory or beginning courses, 200 to 299 are intermediate, and 300 to 599 are advanced level courses. Those numbered 400 and above are acceptable for graduate credit. After each course number will be found in parentheses the number formerly used. Prerequisites appear in italics immediately after course titles.

Roman numerals in lightface type indicate the semester in which the course is given: I, first semester; II, second semester. S.S. indicates summer session. The italic number enclosed in parentheses indicates the hours of credit for the course, e.g. *(3)* denotes three credit hours, or *(To be arranged)* denotes credit to be arranged.

AERONAUTICAL AND ASTRONAUTICAL ENGINEERING

200(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.

310(130). Flight Structures I. *Prerequisite: Eng. Mech. 411. (3).*

Application of the basic equations of strength of materials and elasticity to elements of light-weight structures. Among the topics included are thin-walled beams, rings and frames, plates in bending, and an introduction to thermal stress.

320(110). Aerodynamics I. *Prerequisite: preceded or accompanied by Eng. Mech. 343 and Math. 404.* 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.

330(163). Propulsion I. *Prerequisite: Mech. Eng. 335, Aero. Eng. 320, or Mech. Eng. 336. (3)*.

Introduction to aerothermodynamics and applications to problems in flight propulsion. Discussion of the momentum theorem, one-dimensional flow systems, with heat addition, shock waves, diffusers, compressors, and turbines.

340(141). **Mechanics of Flight I.** *Prerequisite: preceded by Aero. Eng. 320. (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.

410(131). **Flight Structures II.** *Prerequisite: preceded or accompanied by Aero. Eng. 310 and 440. (4).*
Stability of structural elements in compression and shear; beam columns; deflection analysis, influence coefficients and functions, matrix algebra; introduction to structural dynamics. Lectures and laboratory.

415(135). **Principles of Flight Structures.** *Prerequisite: Eng. Mech. 210. (3).*
An accelerated coverage of the material in Aero. Eng. 310 and 410 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 310 or 410.

420(114). **Aerodynamics II.** *Prerequisite: Aero. Eng. 320, and preceded or accompanied by Aero. Eng. 330.* 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.

422(117). **Theory of Propellers and Fans.** *Prerequisite: Aero. Eng. 320 and Mech. Eng. 335. (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.

425(116). **Principles of Aerodynamics.** *Prerequisite: Eng. Mech. 324. (3).*
An accelerated coverage of the material in Aero. Eng. 320 and 420 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 320 or 420.

430(164). **Propulsion II.** *Prerequisite: Aero. Eng. 330 or equivalent. (4).*
Performance and analysis of flight propulsion systems including the reciprocating engine-propeller, turboprop, ramjet, pulsejet, and rocket. Lectures and laboratory.

435(165). **Principles of Propulsion.** *Prerequisite: Mech. Eng. 335 or equivalent. (3).*
An accelerated coverage of the material in Aero. Eng. 330 and 430 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 330 or 430.

439(166). **Aircraft Propulsion Laboratory.** *Prerequisite: preceded by Aero. Eng. 330. (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 pulsejet, turbojet, ramjet, and rocket motors.

440(142). **Mechanics of Flight II.** *Prerequisite: preceded by Math. 404 and preceded or accompanied by Aero. Eng. 340. (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.

442(146). **Performance of High-Speed Vehicles.** *Prerequisite: Aero. 445 and 435 or equivalent. (3).*
Properties of the atmosphere, regimes of flow, analysis and optimization of

thrust programing, performance of high-speed vehicles, including coasting and glide trajectories, optimum flight paths, orbital vehicles and re-entry problems.

445(145). Principles of Mechanics of Flight. *Prerequisite: a course in differential equations. (3)*.

An accelerated coverage of the material in Aero. Eng. 340 and 440 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 340 or 440.

447(176). Flight Testing. *Prerequisite: Aero. Eng. 340 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.

449(150). Principles of Vertical Take-off and Landing Aircraft. *Prerequisite: Aero. Eng. 340. (3)*.

Lifting rotor and propeller analysis in vertical and forward flight; ducted fan analysis; helicopter performance analysis; transitional flight problems of VTOL aircraft; stability and control problems of helicopters and VTOL aircraft.

460(173). Wind Tunnel Instrumentation. *Prerequisite: permission of instructor.* (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. Lectures and laboratory.

464(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.

470(143). Aircraft Control Systems. *Prerequisite: preceded by Aero. Eng. 440. (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 powerplane control systems; use of the analog computer in the laboratory for simulation. Two lectures and one laboratory.

480(101). Airplane Design I. *Prerequisite: preceded by Aero. Eng. 310 and 340.* 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.

482(103). Airplane Design II. *Prerequisite: Aero. Eng. 480.* (2).

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

500(181). Directed Study. (*To be arranged*).

Individual study of specialized aspects of aeronautical engineering.

510(133). Flight Structures III. *Prerequisite: Aero. Eng. 410. (3)*.

Strength and deformation analysis of light-weight structures, with emphasis on secondary stress, stress concentration and fatigue, inelastic deformation, and other selected topics.

515(134). Structures at Elevated Temperatures. *Prerequisite: Aero. Eng. 410 or 415. (3)*.

Aerodynamic heating of high-speed aircraft and space vehicles. Thermal radiation. Heat transmission within the structure. Thermal stress; thermal deflection and buckling. Brief discussion of material properties at elevated temperature, creep, thermal stress effects on structural stiffness.

520(119). Intermediate Aerodynamics. *Prerequisite: Aero. Eng. 420 or 425 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. Physical aspects of subject are stressed.

521(118). Experimental Aerodynamics. *Prerequisite: Aero. Eng. 520. (2).*

Covers the work presented in the experiments in Aero. Eng. 420 but with more attention to detail and more elaborate discussion of the advanced theories and methods used in this field. Lectures and laboratory.

523(121). Turbulence and Diffusion. *Prerequisite: a course in advanced calculus and Aero. Eng. 420 or Eng. Mech. 324. (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.

525(123). Aerodynamics of High Speed Flight. *Prerequisite: Aero. Eng. 420 or 425 or permission of instructor. (3).*

Treatment of problems in the aerodynamics of flight at supersonic and hypersonic velocities; linearized theory of wings with arbitrary planform and bodies of revolution; wing body interference; hypersonic aerodynamics, aerodynamic heating, real gas effects.

530(167). Propulsion III. *Prerequisite: Aero. Eng. 430 or equivalent. (3).*

Continuation of Aero. Eng. 430. Further treatment of aircraft engine performance, including off-design operation, and study of selected problems in the field of propulsion.

532(168). Topics in Gas Dynamics. *Prerequisite: Aero. Eng. 420 or permission of instructor. (3).*

The role of transport phenomena in gas dynamics problems is stressed. The subjects covered include simplified gas kinetics, definition of transport properties, general conversation equations, laminar boundary layer and mixing problems with heat transfer and diffusion.

535(169). Rocket Propulsion. *Prerequisite: Aero. Eng. 430 or 435 or equivalent. (3).*

Analysis and performance of liquid and solid propellant rocket powerplants; propellant thermochemistry, heat transfer, system considerations, advanced rocket propulsion techniques.

540(179). Flight Mechanics of Space Vehicles I. *Prerequisite: a course in differential equations. (3).*

Kinematics of motion, particle dynamics, orbital motion and calculation of orbital parameters, Lagrange's equations. Rigid body dynamics including Euler's equations, the Poinsot construction, spin stabilization, the rotation matrix. Vibrations of coupled systems, orthogonality relationships, generalized co-ordinates and system parameters.

544(144). Aeroelasticity I. *Prerequisite: Aero. Eng. 410. (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.

610(230). Advanced Structural Analysis. *Prerequisite: Aero. Eng. 410 or equivalent, Math. 450. (3).*

Application of the theorems of minimum potential and complementary energy, Galerkin's method, finite difference approximations, and relaxation procedures to the deformation and stress analysis of light-weight structures.

620(201). Dynamics of Viscous Fluids. *Prerequisite: Aero. Eng. 520 or permission of instructor. (3).*

Effect of viscosity in fluid flows. Flow in laminar and turbulent, compressible and incompressible boundary layers, boundary layer stability, real gas effects at low densities.

621(202). Dynamics of Compressible Fluids. *Prerequisite: Aero. Eng. 520. (3).*

Emphasis on transonic and hypersonic flow, and on real gas effects at high temperature. Heat transfer near the stagnation point.

622(222). Theory of Supersonic Wings and Bodies. *Prerequisite: preceded or accompanied by Aero. Eng. 520. (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. 520 that is directed toward aerodynamic aspects of the design of supersonic aircraft and missiles.

624(220). Theory of Thin Airfoils. *Prerequisite: Aero. Eng. 320 or equivalent and preceded or accompanied by Math. 455. (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.

626(205). Introduction of Magnetohydrodynamics. *Prerequisite: permission of instructor. (3).*

Review of electrodynamics. The basic equations of magnetohydrodynamics and magnetogasdynamics, simple solutions of these equations, stability theory in laminar flow, magnetohydrodynamic shock waves, theory of characteristics, applications to aerodynamics.

628(208). Molecular Theory of Flow. *Prerequisite: Aero. Eng. 532 or permission of instructor. (3).*

Molecular approach to the subject of gas dynamics and the discussion of transition in outlook from the continuum to the molecular viewpoint. Emphasis is on dynamics of rarefied gases from the standpoint of Maxwell-Boltzmann equation and its applications to problems concerning high altitude missile and satellite aerodynamics.

632(262). Combustion and Flame Propagation. *Prerequisite: permission of instructor. (3).*

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.

640(245). Flight Mechanics of Space Vehicles II. *Prerequisite: Aero. Eng. 540 and preceded or accompanied by Aero. Eng. 520 or 525. (3).*

Dynamic performance of hypervelocity vehicles within the atmosphere. Problems associated with departure from and re-entry to the atmosphere.

641(246). Flight Mechanics of Space Vehicles III. *Prerequisite: Math. 450, Physics 401, or equivalent. (3).*

Motion of a point mass in a gravitation field. Restricted three-body problems; perturbations from reference trajectories. Analysis of orbital transfers; capture and hyperbolic encounters, including error analysis. Trajectories of powered space vehicles.

644(244). Aeroelasticity II. *Prerequisite: Aero. Eng. 544. (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.

670(212). Control and Guidance of Missiles. *Prerequisite: Instr. Eng. 670 or Elec. Eng. 646, Math. 548. (2).*

Analysis and synthesis of missile autopilot systems. Navigational homing systems; inertial and celestial navigation systems. Trajectories of ballistic missiles.

671(212a). Missile Guidance and Control Laboratory. *Prerequisite: preceded or accompanied by Aero. Eng. 670. (1).*

Simulation of missile control and guidance systems on the electronic differential analyzer.

674(274). Control of Space Vehicles. *Prerequisite: Instr. Eng. 570 or equivalent; Aero. Eng. 540 or equivalent. (3).*

Analysis and synthesis of nonlinear control systems. Design of autopilots using thrust vector control; transfer functions of elastic structures as part of closed-loop systems. Mechanization of space vehicle guidance. Attitude control of satellites and space vehicles using jet reaction and inertia wheel control systems.

810(330). Seminar in Structures. *(To be arranged).*

820(310). Seminar in Aerodynamics. *(To be arranged).*

830(360). Seminar in Propulsion. *(To be arranged).*

840(340). Seminar in Mechanics of Flight. *(To be arranged).*

870(370). Seminar in Instrumentation. *(To be arranged).*

880(341). Seminar in Space Technology. *Prerequisite: permission of instructor. (2).*

882(371). Seminar in Guided Missiles. *Prerequisite: permission of instructor. (To be arranged).*

Primarily for military officers.

895(395). Seminar in Space Research. *Prerequisite: permission of instructor. (2).*

Detailed analyses of objectives, procedures, and results of research being carried out at The University of Michigan. Topics will include the following: structure of the upper atmosphere; measurement of temperature, pressure, density, composition, and winds. The ionosphere; measurement of ion and electron density and temperature. Investigation of radio waves incident on the earth at frequencies absorbed by the ionosphere by means of instrumented satellites. Interpretation of infrared data from meteorological satellites. Research in attitude control of multistage sounding rockets.

900(182). Research. *(To be arranged).*

Specialized individual or group problems of research or design nature supervised by a member of the staff.

BUSINESS ADMINISTRATION*

Professors Brummet, Dixon, Dykstra, Hayes, Moore, and Rewoldt; Associate Professors Jones and Leabo.

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 Accounting 271 and 272 which are listed as sophomore-level courses in the economics department.

2. Juniors may elect courses numbered 300 to 399 inclusive, and seniors may

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elect any course numbered 300 to 499 inclusive, provided they have satisfied particular course prerequisites.

3. Courses numbered above 500 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:

BUSINESS ADMINISTRATION—GENERAL
454(154). Industrial Cost Accounting. (*3*).
480(180). Business Law. (*3*).
481(181). Business Law. (*3*).

ACCOUNTING
271(100). Principles of Accounting. (*3*).
272(101). Principles of Accounting. (*4*).

FINANCE
300(100). Money and Banking. (*3*).
301(101). Financial Principles. (*3*).

INDUSTRIAL RELATIONS
300(100). Management of Personnel. (*3*).

MANAGEMENT
311(111). Production Management. (*3*).

MARKETING
300(100). Marketing Principles and Policies. (*3*).

STATISTICS
300(100). Statistical Method. (*3*).

CHEMICAL AND METALLURGICAL ENGINEERING

200(3). Introduction to Engineering Calculations. *Prerequisite: a university course in chemistry or physics.* I and II. (*3*).

Material and energy balances, the equilibrium concept. Properties of fluids and solids. Engineering systems.

230(110). Thermodynamics. *Prerequisite: Chem.-Met. Eng. 200, Physics 146, and Math. 371.* I and II. (*5*).

Introduction to laws of thermodynamics with emphasis on property relations, energy balances, and entropy balances. Utilizes enthalpy and entropy charts, PVT data, and generalized fluid and solid properties. One laboratory per week.

250(18). Principles of Engineering Materials. *Prerequisite: Chem. 105 or equivalent; preceded or accompanied by Physics 146. (Physics 153 and Chem. 194 are equivalent to this prerequisite.)* I and II. (*3*).

An introductory course in the science of engineering materials. Engineering properties are correlated with (1) internal structures (atomic, crystal, micro-, and macro-); and (2) service environments (mechanical, thermal, chemical, electrical, magnetic, and radiation). Two lectures and two recitations.

270(107). Metals and Alloys. *Prerequisite: Chem.-Met. Eng. 250.* (*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. Lecture, recitation, and laboratory.

339. Separation Processes. *Prerequisite: Chem.-Met. Eng. 340.* I and II. (*3*).
Separation processes involving physical and chemical equilibria; use of the equilibrium stage concept.

340(112). Rate Processes. *Prerequisite: Chem.-Met. Eng. 230.* I and II. (*5*).
A unified study of heat, mass, and momentum transfer and chemical kinetics. Emphasis on the measurement, interpretation, and correlation of rate data and the use of rate data in process design. Lecture, recitation, and laboratory.

350(118). Structure of Solids. *Prerequisite: Chem. 266.* I and II. (*3*).
Atomic structure, crystallography, equilibria, rate processes, solid types, bonding, structure, imperfections. Mechanical, thermal, electrical, magnetic, optical, and surface properties of solids. Electron and zone theories of solids.

360(16). Measurements Laboratory. *Prerequisite: preceded or accompanied by Chem. 266.* I and II. (*3*).
Electrical and physicochemical measurements and determination of properties. Lecture, laboratory, computation, and reports.

370(13). Processing of Cast Metals. *Prerequisite: preceded or accompanied by Math. 364.* (*2*).
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. One lecture and one three-hour laboratory.

448(123). Unit Operations. *Prerequisite: calculus, senior or graduate standing.* I. (*4*).
Equipment and theory of unit operations, including separations, heat and mass transfer with particular reference to basic operations in sanitary engineering, pharmaceutical manufacturing and the chemical industry.

449(105). Fuels and Chemical Equilibrium in Combustion. *Prerequisite: Mech. Eng. 335 or Chem.-Met. Eng. 200.* (*3*).
Chemical properties of jet fuels, rocket fuels, and oxidizers, computation of propulsive performance under equilibrium conditions, kinetics of reactions.

450(122). Physical Ceramics. *Prerequisite: preceded or accompanied by Chem. 266 and Chem.-Met. Eng. 350.* II. (*4*).
The nature, properties, processing, and application of ceramic materials. Lectures, recitation, and laboratory.

451(125). Introduction to High Polymers. *Prerequisite: organic chemistry, physical chemistry, or permission of instructor.* I. (*4*).
Preparation, properties, and utilization of polymeric materials. Lectures, recitations, and laboratory.

460(129). Engineering Operations Laboratory. *Prerequisite: Chem.-Met. Eng. 330 and 489.* I and II. (*3*).
Laboratory determination of factual operating data of equipment for chemical and metallurgical operations. Laboratory, conferences, and reports.

470(127). Physical Metallurgy I. *Prerequisite: Chem.-Met. Eng. 350.* I and II. (*4*).
Structure and properties of nonferrous metals as related to their composition, thermal and mechanical treatments. Metallurgical laboratory techniques. Lectures, recitation, and laboratories.

471(128). Physical Metallurgy II. *Prerequisite: Chem.-Met. Eng. 470.* I and II. (*3*).
Surface hardening, hardenability, hardening, tempering, isothermal transformation, related properties of iron and steel. Lecture, recitation, and laboratory.

472(124). X-ray Studies of Engineering Materials. *Prerequisite: Chem.-Met. Eng. 360 and 350.* I. (*3*).
Radiography, investigation of welds and castings; diffraction studies of metals and alloys. Lectures, recitations, and laboratory.

477(148). Metallurgy of Joining. *Prerequisite: Chem.-Met. Eng. 470 or 479 or 576.* II. (*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.

479(117). Metals and Alloys. *Prerequisite: Chem.-Met. Eng. 350.* I and II. (*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.

480(121). Design of Process Equipment. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 340.* I and II. (*3*).
Applications of fluid flow, heat transfer, mass transfer, stress analysis, and behavior of materials to the design of chemical and petrochemical process equipment for vacuum, low-pressure, high-pressure, and high-temperature services.

481(130). Chemical Process Design. *Prerequisite: Chem.-Met. Eng. 340 and 479.* I and II. (*3*).
Application of mathematics, chemistry, physical, natural and engineering sciences to the design of chemical processes and engineering systems.

489(119). Metallurgical Process Design. *Prerequisite: Chem.-Met. Eng. 340.* II. (*4*).
Unit process treatment of extractive metallurgical operations. Applications of principles involved in the extraction of metals from ores and scrap, the production of alloys, and their commercial shapes or forms.

490. Research and Special Problems. I and II. (*To be arranged*).
Laboratory and/or conferences. Provides an opportunity for undergraduate students to work in research or areas of special interest such as design problems and economic studies. Where the subject covers some aspect of plant work as in summer employment in industry, arrangements should be made in advance.

500(202). Advanced Chemical Engineering Calculations. *Prerequisite: Chem.-Met. Eng. 340 and courses in differential equations and operational mathematics with concurrent registration in latter permitted.* I and II. (*3*).
Calculations on steady and unsteady-state heat and mass transfer, stagewise operations, fluid mechanics, thermodynamics, chemical reactions, and automatic control systems. Emphasizes formulation and solution of mathematical models that are often similar for different processes.

510(258). Electrochemical Operations. *Prerequisite: Chem.-Met. Eng. 230 and 330 and course in physical chemistry.* I or II. (*4*).
Theory and applications of electrochemistry with first half of time devoted to basic principles and last half to research problems and industrial processes. One laboratory per week included.

520(212). Equilibrium Stage Operations. *Prerequisite: Chem.-Met. Eng. 340.* II. (*3*).
Design of multicomponent separation systems including absorption, distillation, extraction, and ion exchange. Emphasis is on the equilibrium stage concept with rates and efficiencies examined.

521(235). Petroleum Engineering. *Prerequisite: Chem.-Met. Eng. 340.* I. (*3*).
Properties of petroleum gases and liquids under pressure, process design in the production and refining of natural gas, crude oil and other important fossil fuels.

522(256). Mechanics of Multiphase Flow. *Prerequisite: Chem.-Met. Eng. 340 or permission of instructor.* (*3*).

The fluid mechanics of multiphase flow systems, such as suspensions, fluidized solids, and gas-liquid systems, with emphasis on engineering principles and relation with equipment and surroundings.

530(211). Engineering Thermodynamics. *Prerequisite: Chem.-Met. Eng. 230 and 330.* I and II. (*3*).

Thermodynamic property relations, energy balances, and entropy balances applied to chemical and metallurgical processes. Statistical mechanical approach to properties of matter and irreversible thermodynamics.

535(209). Metallurgical Thermodynamics. *Prerequisite: a course in physical chemistry and an undergraduate course in thermodynamics, Chem.-Met. Eng. 230 and Chem.-Met. Eng. 330.* I. (*3*).

Laws of thermodynamics applied to metallurgical systems. Introduction to statistical mechanics.

536(240). Metal Reactions in Melting and Refining. *Prerequisite: Chem. 469, Chem.-Met. Eng. 489.* I. (*4*).

Applied thermodynamics and kinetics of high temperature melting and refining reactions employed in extractive metallurgical processes. Experiments concerning these reactions. Lecture and laboratory.

540(113). Rate Operations. *Prerequisite: Chem.-Met. Eng. 340.* I. (*4*).

A unified study of heat, mass, and momentum transfer and chemical kinetics. The interpretation of rate data and theories and their use in process design.

550(222). Solid State Kinetics. *Prerequisite: physical chemistry or a course in solid state.* II. (*3*).

Kinetics and mechanism of reactions involving solids. Solid state defects and thermodynamics and kinetics of solid state transformations. Nonstoichiometric compounds, spinels, ceramics. Oxidation, carburization, nitridization of metals and compounds. Lectures and recitations.

551(223). Solid State Chemical Principles of Semiconductors. *Prerequisite: Chem.-Met. Eng. 500 or permission of instructor.* II. (*3*).

Structures and properties of semiconductor materials. Quantum concepts, band theory of solids. Mass action, ionization, and kinetics in semiconductors. Diffusion and field equations; p-n junction theory, Zone refining, p-n junction fabrication processes. Surface properties: adsorption and heterogeneous catalysis. Theory and materials for thermoelectric converters.

560(126). Electron Microscopy. *Prerequisite: senior or graduate standing in engineering or science.* I. (*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.

561(216). Engineering Experiments and Their Design. *Prerequisite: senior or graduate standing in engineering or science.* II. (*3*).

The use of statistical methods in analyzing and interpreting experimental data and in planning complex experimental programs. Subjects covered include: probability, distribution functions, theory of sampling techniques and process control, use of the "Chi-Squared" and "t" tests in analyzing and comparing data from simple experiments. An introduction to the analysis of variance and the design of complex experiments. Lecture, recitation, and computation.

563(257). Chemical Process Control and Dynamics. *Prerequisite: a course in Laplace transforms, or permission of instructor.* I. (*3*).

The concepts of automatic control and process dynamics are presented and applied to typical processes encountered in chemical engineering practice, such as the control of temperature, fluid flow, mass transfer processes, and chemical reaction system.

570(218). **Theoretical Metallurgy.** *Prerequisite: a course in physical metallurgy.* II. (*3*).

Electron and zone theories of metals. Theories of alloying, nucleation and growth; theories of imperfections, transformations; topology of metallurgical structures; diffusion.

571(228). **Nonferrous Metallurgy.** *Prerequisite: Chem.-Met. Eng. 471.* II. (*3*).

Ternary systems, phase transformations, plastic deformation and fracture. Lecture, recitations, and laboratory.

572(224). **X-ray Studies of Engineering Materials.** *Prerequisite: Chem.-Met. Eng. 472.* II. (*3*).

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

573(217). **Corrosion and High Temperature Resistance of Metals.** *Prerequisite: Chem.-Met. Eng. 270 or 479.* I. (*3*).

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

574(207). **Metals at High Temperatures.** *Prerequisite: Chem.-Met. Eng. 270, 479, or 470.* II. (*3*).

Fundamental principles determining the behavior of metals at high temperatures and the selection and performance of alloys in such applications as jet-propulsion engines, gas turbines, chemical industries, and steam power plants.

575(242). **Steels.** *Prerequisite: Chem.-Met. Eng. 471 or equivalent.* II. (*3*).

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

576(147). **Metals for Process Design.** *Prerequisite: a course in physical chemistry.* II. (*3*).

The structures and properties of solids. Influence of composition, mechanical and thermal treatments on the properties of metals, and their subsequent behavior in service in industry.

577(219). **Metallurgical Operations.** *Prerequisite: Chem.-Met. Eng. 489.* II. (*3*).

The plastic deformation of metals and alloys. Rolling, forging, extrusion, piercing, and deep drawing.

579(227). **Nuclear Metallurgy.** *Prerequisite: a course in physical metallurgy.* II. (*3*).

The process, mechanical and physical metallurgy of metals used in nuclear reactors: uranium, plutonium and thorium. Radiation damage to solids. Container materials, fuel element design and fabrication, moderator and control elements, liquid metals.

580(215). **Rate Operations Design.** *Prerequisite: Chem.-Met. Eng. 540.* (*3*).

Simultaneous rate operations and process design.

581(220). **Chemical Plant Process Design.** *Prerequisite: Chem.-Met. Eng. 481.* (*3*).

Selection and design of processes, equipment, and control systems for chemical plants. Utilization and extension of minimum available information to produce workable systems. Economic studies and comparisons in optimization of systems.

582(221). **Process Equipment Design for Advanced Chemical Engineering Students.** *Prerequisite: Chem.-Met. Eng. 340 or equivalent.* I. (*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.

583(232). Process Engineering of Polymer Plants. *Prerequisite: Chem.-Met. Eng. 340 and 479, or permission of instructor.* II. (*3*).
Processing methods for production of polymers from raw materials. Design of plants for the manufacture of materials such as polyhydrocarbons, cellulose plastics, nylon, and rubbers.

584(238). Fermentation Processes. *Prerequisite: organic chemistry and Chem.-Met. Eng. 340 or permission of instructor.* I and II. (*3*).
Detailed study of the processes, operations, and equipment involved in selected industrial fermentation processes directed towards the production of pharmaceuticals and industrial chemicals and industrial waste disposal. Lecture, calculation periods.

585(255). Petrochemical and Refining Studies. II. (*4*).
Designs and economic studies of selected petrochemical and refining processes.

586(267). Nuclear Fuels and Fuel Processing. II. (*3*).
The processing of ores containing fissionable and fertile materials; the reprocessing of spent fuel systems; aqueous techniques including solvent extraction and ion exchange; pyrometallurgical methods for component separations. Problems arising when handling fissionable and radioactive materials will be treated in connection with student design problems.

587(241). Cast Iron and Steel. *Prerequisite: Chem.-Met. Eng. 270, 470, or 479.* II. (*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.

589(244). Cast Metals in Engineering Design. *Prerequisite: Chem.-Met. Eng. 479, 470 or permission of instructor.* II. (*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. One lecture and one three-hour laboratory.

636. Metallic-Ceramic Reactions. *Prerequisite: physical chemistry and graduate standing.* I. (*3*).
Ceramic solids; metallic and nonmetallic liquid structures; polycomponent equilibria; polycomponent microstructures; high temperature kinetics. Metallurgical and ceramic applications: melting and refining slags, high temperature oxidation-reduction reactions, refractories, nonmetallic inclusions, cermets.

645. Process Analysis *Prerequisite: Chem.-Met. Eng. 500 or equivalent.* II. (*3*).
Problems in the analysis, design, stability and sensitivity, optimization, and transient response of staged, continuous, and batch operations are considered with emphasis on their common mathematical and physical foundations.

650(204). High Polymer Process and Materials. *Prerequisite: course in physical and organic chemistry or permission of instructor.* I. (*3*).
Nature and types of polymers and copolymers. Condensation, free radical and ionic polymerization. Stereospecific polymerization. Amorphous and crystalline polymers. Structure and properties of polymeric materials, plastics, fibers, elastometers. Lectures and recitations.

661. The Design of Complex Experiments. *Prerequisite: Chem.-Met. Eng. 561 or equivalent.* I. (*3*).
Consideration of statistical methods which are useful in designing and analyzing experiments involving several variables.

690(210). Research and Design. I and II. (*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.

691. Engineering Problems. *Prerequisite: permission of instructor.* I and II. (*To be arranged*).

A study of contemporary engineering problems and of new areas of engineering exploitation of recent mathematical or scientific advances or breakthroughs.

730(311). Advanced Thermodynamics. *Prerequisite: Chem.-Met. Eng. 530.* II.

Special topics in the thermodynamics of chemical engineering processes. Review of latest developments and current research in thermodynamics. Students select individual problems for intensive study.

780(315). Advanced Separations. *Prerequisite: Chem.-Met. Eng. 520 and 580.* I. (*3*).

Advanced study and design of multicomponent and non-ideal separations with emphasis on distillation, absorption, and extraction. Equilibrium, rate and stage.

835. Seminar in Metallurgical Thermodynamics. *Prerequisite: a graduate course in thermodynamics.* II. (*3*).

Selected subjects in thermodynamics. Irreversible thermodynamics, and statistical mechanics applied to metallurgical systems.

840(363). Heat Transfer Seminar. *Prerequisite: Chem.-Met. Eng. 580.* I. (*2*).

Theoretical aspects of heat transfer. Classical and current developments presented by students, staff, and guest lecturers. Term paper on original work.

841(365). Mass Transfer Seminar. *Prerequisite: Chem.-Met. Eng. 580.* I. (*2*).

870(328). Physical Metallurgy Seminar. *Prerequisite: open to persons engaged in doctoral level research.* I. (*2*).

Selected topics in the more advanced fields of physical metallurgy.

885(355). Petroleum Seminar. *Prerequisite: Chem.-Met. Eng. 521 or 585.* (*2*).

Individual study of advanced topics in production, commercial natural gas, refining and petrochemical processes. Seminar and reports.

CHEMISTRY*

Professor Anderson; Professors Bernstein, Brockway, Elderfield, Elving, Halford, Parry, Smith, Vaughan, and Westrum; Associate Professors Case, Meinke, Rulfs, Tamres and Taylor; Assistant Professors De Rocco, Eisch, Gordus, Ireland, Jaselskis, Liu, Nordman, Schilt, and Stiles; Instructors Cooke, Longone, and Martin.

103(1). General and Inorganic Chemistry. I. (*4*).

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

104(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 .

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105(6). General Chemistry. *Prerequisite: Chem. 103 or 104.* II. (*4*).

Continuation of Chem. 103 or 104 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. 106. *Chem. 105 will not be accepted as a prerequisite for more advanced courses in chemistry.* Two lectures, two recitations, and four hours of laboratory.

106(4). General and Inorganic Chemistry. *Prerequisite: Chem. 103 or 104.* I and II. (*4*).

Continuation of Chem. 103 or 104 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. 105 rather than Chem. 106. In Chem. 103 or 104 and Chem. 106 the fundamental principles of chemistry are studied, accompanied by the descriptive chemistry of most of the nonmetallic elements (Chem. 103 or 104) and of the important metallic elements (Chem. 106). Two lectures, two recitations, and four hours of laboratory.

107(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. 103 or 104 followed by Chem. 105 or 106.* 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.

191(8). Inorganic Chemistry and Qualitative Analysis. *Prerequisite: Chem. 104 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.

194(14). Unified Chemistry. *Prerequisite: Physics 153.* II. (*4*).

The properties of matter discussed from the viewpoint of dynamics: discussions of thermodynamic functions, kinetic theory, and chemical kinetics. Lectures, recitations, and laboratory.

195(15). Unified Chemistry. *Prerequisite: Chem. 194 and Physics 153.* I. (*4*).

Properties of matter from the viewpoint of atomic structure, including periodic relationships; organic and inorganic chemistry. Lectures, recitations, and laboratory.

220. Organic Chemistry. *Prerequisite: Chem. 106, 107, 191, or 195.* II. (*3*).

A survey of the field of organic chemistry. Will not meet premedical or predental requirements and is not accepted as a prerequisite for any other course in the Chemistry Department except Chem. 419 or 465. Students wishing more organic chemistry will be required to take Chem. 222 and 223.

221. Organic Chemistry. *Prerequisite: same as for Chem. 220.* II. (*5*).

This course is the same as Chem. 220 with the additional requirement of seven hours of laboratory for experiments which illustrate typical reactions of important types of organic compounds and standard laboratory techniques.

222-223. Organic Chemistry. *Prerequisite: Chem. 106, 107, 191 or 195.* I and II. (*5 each*).

These two courses constitute a year course in organic chemistry. The first part (222) covers aliphatic compounds, carbohydrates, and other selected topics; the second part (223) covers aromatic compounds, proteins, and other topics. Students should plan programs which permit following 222 with 223 in the next semester and at the same time. Three lectures, one recitation, and two afternoons of laboratory work each week.

265. Principles of Physical Chemistry. *Prerequisite: Chem. 106 or 107 and preceded or accompanied by Math. 234 or 336 and Physics 145 or 153. (4).*

An introduction to topics such as: kinetic theory of gases and liquids, the first and second laws of thermodynamics, free energy and spontaneity of chemical reactions, and phase equilibrium. Lecture and recitation.

266. Principles of Physical Chemistry. *Prerequisite: Chem. 265 and preceded or accompanied by Math. 337 or 371 and Physics 146 or 154. (4).*

A continuation of Chemistry 265 covering topics such as: chemical kinetics, electrochemistry, elementary quantum theory, and atomic and molecular structure. Lecture, recitation, and laboratory.

346(41). Quantitative Analysis. *Prerequisite: Chem. 191, 195, or 266.* 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.

425(163). Qualitative Organic Analysis. *Prerequisite: Chem. 223, 295, or 421.* I and II. *(3).*

Laboratory fee. Fundamental organic reactions are studied as a basis for systematic analysis and identification of organic compounds.

445(141R). Physicochemical Methods in Analytical Chemistry. *Prerequisite: Chem. 346 and 468. (2).*

Chemistry of some of the important rare elements. Discussion of techniques and physicochemical methods not covered in Chem. 346. Lecture and recitation.

446(141L). Physicochemical Methods in Analytical Chemistry. *Prerequisite: preceded or accompanied by Chem. 445. (2).*

Laboratory fee. Laboratory work involving techniques and physicochemical methods not covered in Chem. 346.

447(141). Systematic Analytical Chemistry. *Prerequisite: Chem. 346 and Physics 126.* I and II. *(4).*

Laboratory fee. Analysis of natural and synthetic materials. Chemistry of the more important rarer elements. Discussion of techniques and physiochemical methods not covered in Chem. 346. Lecture, recitations, and laboratory.

466(171). Electrochemistry. *Prerequisite: Chem. 469.* I. *(2).*

Elementary treatment of the fundamentals of the subject. Two lectures.

468(182). Physical Chemistry. *Prerequisite: Chem. 346, Physics 126, and Math. 364 or 372.* I and II. *(3).*

Nature of the gaseous and liquid states, solution theory, homogeneous and heterogeneous equilibria, thermochemistry and thermodynamics.

469(183). Physical Chemistry. *Prerequisite: Chem. 468.* I and II. *(3).*

Electrochemistry, atomic concepts of matter and energy, molecular and crystal structures, chemical kinetics.

471(188). Physical Chemistry. *Prerequisite: permission of instructor.* I and II. *(4).*

Fundamentals of physical chemistry, particularly for students enrolled in the curriculum in physics; others by special permission. Four lectures.

481(185). Physiochemical Measurements. *Prerequisite: Chem. 346, and preceded or accompanied by Chem. 465 or 468.* I and II. *(2).*

Laboratory fee. Laboratory work, including determinations of molecular weights, measurements of properties of pure liquids and solutions, and thermochemical measurements. One discussion period dealing with treatment of errors and related topics to be arranged.

482(186). **Physiochemical Measurements.** *Prerequisite: Chem. 481.* I and II. (*2*).
Laboratory fee. A continuation of Chem. 481. Homogenous and heterogeneous equilibria, kinetics, atomic and molecular properties, and electrochemistry. One discussion period to be arranged.

538(256). **Organic Chemistry of Synthetic Polymers.** *Prerequisite: Chem. 223 or 421.* 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

260(1). **Basic Surveying.** *Prerequisite: Math. 233.* I and II. (*3*).
Use, care, and adjustment of basic surveying instruments; horizontal angle measurement, leveling, taping; circular curves, grades and vertical parabolic curves, profiles, earthwork; computations, significant figures, errors, desk calculators, U. S. Public Land System.

261(2). **Surveying Computations.** *Prerequisite: Civ. Eng. 260 or equivalent, preceded or accompanied by Math. 234.*
Principles of horizontal control, unified system of geometric computations based on rectangular co-ordinates and the "Intersection Solution"; logical synthesis of computations for complicated geometrical engineering applications; introduction, applications, and use of electronic computers; principles of surveying astronomy, use of ephemeris and star catalog; elements of photogrammetry.

310(20). **Structural Drafting.** *Prerequisite: Eng. Graphics 102.* I and II. (*2*).
Standard civil engineering drafting-room practice, including conventional signs and symbols, detailing of structural elements of steel and concrete, and the use of standard structural handbooks.

311(21). **Theory of Structures.** *Prerequisite: Eng. Mech. 210.* I and II. (*3*).
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. Not open to civil engineering students.

312(22). **Theory of Structures.** *Prerequisite: Eng. Mech. 210.* I and II. (*3*).
Calculations of reactions, shears, and bending moments in simple, restrained, and continuous beams due to fixed and moving loads; simple trusses with fixed and moving loads; determinate frames; columns; tension members; girders; introduction to design.

313(23). **Elementary Design of Structures.** *Prerequisite: Civ. Eng. 312.* I and II. (*3*).
Design and details of simple beams, girders, columns, and trusses. Computations, drawing work, and laboratory experiments.

350(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, and laboratory.

362(3). **Advanced Surveying Measurements.** *Prerequisite: Civ. Eng. 260, 261, and Math. 371. Camp Davis.* S.S. (*4*).
Precise observational methods for triangulation and control levels; use of theodolite and geodetic level, base-line measurements; electronic distance meas-

urements; field assessment of errors and adjustments; astronomical observations for precise azimuth determinations; application of precise control to layout of engineering projects.

363(4). **Basic Surveying.** *Prerequisite: Math. 233 or equivalent.* 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; computation, use of calculating machines.

364(12). **Surveying.** *Prerequisite: Math. 241.* II. (*3*).

Designed for forestry students.

370(65). **Transportation Engineering.** *Prerequisite: Civ. Eng. 261.* I and II. (*3*).

Planning, location, design, construction, and maintenance of inland transportation facilities. Introduction to transportation economics.

400(180). **Contracts, Specifications, Professional Conduct, and Engineering-Legal Relationships.** I and II. (*2*).

Legal principles of contracts, torts, and agency; ethics, professional registration and professional conduct; technical specifications; engineering-legal relationships and problems. Lectures, reading, problems, and discussion.

415(121). **Reinforced Concrete.** *Prerequisite: Civ. Eng. 312.* 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, and laboratory.

420(140). **Hydrology.** *Prerequisite: preceded or accompanied by Eng. Mech. 324.* 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.

421(141). **Hydraulics.** *Prerequisite: Eng. Mech. 324.* 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.

445(135). **Engineering Properties of Soil.** *Prerequisite: Eng. Mech. 210 and 324.* 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.

480(52). **Water Supply and Treatment.** *Prerequisite: Eng. Mech. 324.* I and II. (*3*).

Sources of water supply, quality and quantity requirements, design fundamentals of works for development, collection, purification, and distribution of water.

481(53). **Sewerage and Sewage Treatment.** *Prerequisite: Civ. Eng. 480.* I and II. (*2*).

Requirements of residential and municipal sewerage systems, procedures for the design and construction of sewerage and sewage treatment works.

500(120). **Fundamentals of Experimental Research.** I. (*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, and laboratory.

501(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, and discussion.

505(115). Boundary Surveys. *Prerequisite: Civ. Eng. 260 or equivalent.* I. *(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.

511(127). Timber Construction. *Prerequisite: Civ. Eng. 313.* I. *(1)*.
Physical characteristics of structural woods; grading rules; design of timber structures.

512(122). Advanced Theory of Structures. *Prerequisite: Civ. Eng. 312.* I and II. (3).
Stresses in subdivided panel trusses; principle of virtual displacements and virtual work; energy theorems; graphical methods; analysis of statically indeterminate trusses and frames.

513(123). Design of Structures. *Prerequisite: Civ. Eng. 313, 415.* I and II. *(3)*.
Design of reinforced concrete and steel structures. Computations and drawing.

514(124). Rigid Frame Structures. *Prerequisite: preceded or accompanied by Civ. Eng. 415.* I and II. *(3)*.
Analysis of rigid frames by methods of successive approximations and slope deflections; special problems in the design of continuous frames.

515(125). Prestressed Reinforced Concrete. *Prerequisite: Civ. Eng. 313 and 415.* I and 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.

516(223). Advanced Design of Structures. *Prerequisite: Civ. Eng. 513.* I. *(3)*.
Functional design of buildings; selection and analysis of structural elements; reinforced concrete flat slab design; digital computer applications. Lectures and computation laboratory.

517(227). Bridge Engineering and Design. *Prerequisite: Civ. Eng. 513 or 573.* II. *(3)*.
History of bridges; selection and design of reinforced concrete and steel highway and railway bridge structures based upon the requirements of economics, underclearance, site, foundations, erection, maintenance, aesthetics, safety, and financing. Lectures and computation laboratory.

522(142). Hydraulic Transients. *Prerequisite: Eng. Mech. 324.* II. *(2)*.
Introduction to water power development, including selection of type of turbine; storage and pondage; surge in pipe lines; water hammer analysis; digital programing of unsteady flow situations.

523(143). Flow in Open Channels. *Prerequisite: Civ. Eng. 421 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.

524(144). Advanced Hydraulics. *Prerequisite: Civ. Eng. 421.* I. *(3)*.
Two-dimensional potential flow; the flow net; percolation and hydrostatic uplift; side-channel spillways; boundary-layer; hydraulic similitude; hydraulic models; stilling pools.

526(146). Hydraulic Engineering Design. *Prerequisite: Civ. Eng. 415 and 420; preceded or accompanied by Civ. Eng. 523.* 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.

531(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.

532(132). Construction Methods and Equipment. *Open to seniors and graduates.* II. *(3)*.

Contractors' organizations; plant selection and layout; equipment studies; methods of construction.

533(133). Estimating Practice. *Prerequisite: preceded or accompanied by Civ. Eng. 531.* I. *(1)*.

Laboratory practice in the estimating and pricing of construction work. Quantity surveys, unit costs of labor and material, indirect costs.

543(163). Soils in Highway Engineering. *Prerequisite: Civ. Eng. 445 and 546.* II. *(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.

544(174). Airport Design and Construction. *Prerequisite: Civ. Eng. 445 and 546.* I. *(3)*.

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 and surface and subsurface drainage; airport pavement design. Airphoto analysis; typical land forms, drainage patterns, and mapping.

545(235). Foundation and Underground Construction. *Prerequisite: Civ. Eng. 445; preceded or accompanied by Civ. Eng. 546.* 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.

546(136). Soils Mechanics Laboratory. *Prerequisite: preceded or accompanied by Civ. Eng. 445. 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.

550(161). Highway Materials. *Prerequisite: preceded or accompanied by Civ. Eng. 370.* I. *(3)*.

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

551(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, and laboratory.

552(162). Bituminous Materials and Pavements. *Prerequisite: Civ. Eng. 370.* II. *(2)*.

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

560(113). Photogrammetry. *Prerequisite: preparation in trigonometry and physics.* II. (*2*).

Basic theory of photogrammetry, geometry of photogrammetric systems, analytical solutions; application to mapping from aerial photographs.

561(101). Geodesy. *Prerequisite: Civ. Eng. 362.* I. (*3*).

Introduction to geodesy; history, theory, figure of the earth, geographic position, map projections, state plane co-ordinate systems, application to the several branches of surveying. Each student will prepare a term paper on a subject approved by the instructor. Lectures, reference work, and recitation.

562(102). Geodetic Field Methods. *Prerequisite: Civ. Eng. 561 or permission of instructor. II.* (*2*). *Camp Davis. S.S.* (*4*).

Reconnaissance for geodetic triangulation; special observing methods for first-order horizontal and vertical control; Laplace stations and deflection of the vertical; actual observations, reduction, and adjustment of results in an actual field situation. Term paper or project report required of each student.

563(105). Adjustment of Geodetic Measurements. *Prerequisite: Math. 372 and Civ. Eng. 261 or permission of instructor.* (*2*).

Theory of least squares, applications to the adjustment of geodetic observations; arrangement for solution of complex adjustments on electronic computers; actual solution of selected problems.

564(106). Special Problems in Advanced Surveying. I and II. (*To be arranged*).

Special advanced work can be provided for those who have received credit in Civ. Eng. 362.

565(107). Municipal Surveying. *Prerequisite: Civ. Eng. 362.* (*2*).

Control surveys, methods and adjustments for use in municipal mapping and administration, surveys for streets, utilities, property lines, tax maps, subdivision control and development.

570(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.

571(166). Traffic Engineering. *Prerequisite: Civ. Eng. 370 or permission of instructor.* II. (*3*).

Principles of highway traffic flow, traffic surveys and planning, analysis and presentation of data, traffic design.

572(167). Highway Economics. *Prerequisite: Civ. Eng. 370.* II. (*2*).

Principles of engineering economics applied to highway planning, location, and design; highway finance, taxation, and administration.

573(169). Highway Design. *Prerequisite: Civ. Eng. 370.* I and II. (*3*).

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

574(172). Railroad Engineering. *Prerequisite: Civ. Eng. 370.* II. (*3*).

Theory and practice of railroad engineering principles. 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.

575(173). Terminal Design. *Prerequisite: Civ. Eng. 370.* (*3*).

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

576(176.) Economics of Railroad Construction and Operation. *Prerequisite: Civ. Eng. 370.* II. (*2*).

Statistical and 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.

580(151). Microbiology I. *(3).*

Lectures and laboratory. Principles and techniques of microbiology with an introduction to their application in the several fields of engineering.

581(156). Sanitary Chemistry. *Prerequisite: Chem. 104 and 106 or equivalent.* I. *(2-3).*

Procedures required in the analysis of water, sewage, and industrial wastes.

582(154). Sanitary Engineering Design. *Prerequisite: Civ. Eng. 480, 481, and 415.* II. *(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.

583(152). Water Purification and Treatment. *Prerequisite: Civ. Eng. 480 and 581 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.

584(153). Sewerage and Sewage Disposal. *Prerequisite: Civ. Eng. 481 and 581 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.

585(155). Municipal and Industrial Sanitation. *(3).*

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

586(157). Industrial Waste Treatment. *Prerequisite: Civ. Eng. 581 and 584 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.

587. Industrial Bacteriology II. *Prerequisite: Civ. Eng. 580 or equivalent.* *(3).*

Lectures and demonstrations to illustrate the application of microbiological principles and techniques to industrial processes.

602(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. Texts, cases, and discussion.

603(183). Public Utility Problems. II. *(2).*

Nature of public service corporations; organization; ownership; valuation; depreciation; accounting; regulations; taxation; rates.

611(231). Structural Dynamics. *Prerequisite: Math. 404 or equivalent.* *(3).*

Structural vibrations. Transient and steady state response to dynamic forces. Response beyond the elastic range. Response to nuclear explosions. Earthquake forces. Structural response to earthquake. The response spectrum. Seismic building codes and their relation to structural dynamics.

612(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.

613(233). **Structural Plate Analysis.** *Prerequisite: Math. 403 or equivalent.* II. (*2*).
Stress analysis of flat plates loaded either in their plane or in bending. Numerical analysis. Applications to special problems in flat slab construction.

614(224). **Advanced Problems in Statically Indeterminate Structures.** *Prerequisite: Civ. Eng. 514.* II. (*3*).
Continuous truss bents; hinged and fixed arches; rings; frames with curved members; flexible members including suspension bridges; frames with semirigid connections.

615(221). **Analysis and Design of Folded Plates, Domes, and Shells.** *Prerequisite: Civ. Eng. 512 and 514 or equivalent.* I. (*3*).
Stresses and special design problem in folded plate construction; membrane stresses in domes and double curved shells; flexural action near boundaries; cylindrical concrete shell roofs; cylindrical tanks.

616(226). **Plastic Analysis and Design of Frames.** I. (*2*).
Yield, fracture, and fatigue failure of metals. Plate buckling design criteria. Rules of practice for the plastic design of structures. Plastic analysis and design of continuous beams and frames.

617(229). **Mechanical Methods of Stress Analysis.** *Prerequisite: preceded or accompanied by Civ. Eng. 514.* 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.

618. **Computer Analysis of Structures.** *Prerequisite: Civ. Eng. 512 and 514.* II. (*3*).
The analysis of beams, frames, trusses, and arches by high-speed digital computer. The general method of influence coefficients; matrix methods, Algorithm development, flow charts, programing. Students will solve a sequence of problems on the high speed computer in the University Computing Center.

623(243). **Applied Hydromechanics.** *Prerequisite: Civ. Eng. 523 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.

652(262). **Advanced Bituminous Materials and Flexible Pavement Design.** *Prerequisite: Civ. Eng. 552.* (*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, and reports.

670(265). **Transportation Planning.** *Prerequisite: Civ. Eng. 570 and 672, 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.

671(160). **Advanced Highway Engineering.** *Prerequisite: Civ. Eng. 370.* I. (*2*).
Seminar course dealing with special phases of highway design and construction. Assigned reading and reports.

672(178). **Transportation.** *Prerequisite: principles of economics.* I. (*3*).
Transportation facilities, services, and policies, with emphasis on comparative performance of the various agencies of transport.

673(164). **Highway Transport.** II. (*2*).
Fundamentals of transportation of passengers and commodities over highways; regulation of motor carriers, management of transportation companies.

674(264). Industrial Transport Management. *Prerequisite: Civ. Eng. 672 or Econ. 433, 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.

680. Microbiology II. *Prerequisite: Civ. Eng. 580 or equivalent. (2).*

Lectures and laboratory dealing with inter-relationships between organisms of sanitary significance such as fungi, algae, protozoa, and higher forms of invertebrates.

681. Advanced Sanitary Chemistry. *Prerequisite: Civ. Eng. 581.* II. (*3*).

Specialized techniques in sanitary engineering laboratory studies designed to acquaint the graduate student with modern applications of the latest analytical equipment and the fundamental principles of its operation.

682(254). Advanced Sanitary Engineering Design. *Prerequisite: Civ. Eng. 584 and preceded or accompanied by Civ. Eng. 583.* II. (*3*).

Functional design of sanitary engineering structures and typical plant layouts; drafting room and field studies; preparation of design reports.

685. Special Problems in Sanitary Engineering I. (*To be arranged*).

Special problems in sanitary engineering offered the first semester only. Designed to broaden the graduate student's perspective in one or more special fields.

686. Special Problems in Sanitary Engineering II. (*To be arranged*).

Further special problems in sanitary engineering offered the second semester only for additonal special work in a limited field.

780(251). Public Water Supply II. (*3*).

Conservation and protection of sources of water supply; laws governing appropriation and use of water resources as affecting both 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.

810(225). Structural Engineering Seminar. I and II. (*1*).

Preparation and presentation of reports covering assigned subjects.

825(145). Seminar in Hydraulic Engineering. *Prerequisite: Civ. Eng. 420 and 523.* (*To be arranged*).

Lectures, assigned reading, and student reports on problems selected from the field of hydraulic engineering.

880(255). Sanitary Engineering Seminar. I and II. (*1*).

Preparation and presentation of reports covering assigned topics.

910(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.

920(240). Hydrological Research. *Prerequisite: Civ. Eng. 420.* (*To be arranged*).

Assigned work on some special problem in the field of hydrology; an enormous amount of data is available for such studies.

921(241). Hydraulic Engineering Research. *Prerequisite: Civ. Eng. 523.* (*To be arranged*).

Assigned work in hydraulic research; a wide range of matter and method permissible.

946(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.

960(210). Geodesy and Surveying Research. *Prerequisite: Civ. Eng. 561. (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.

970(260). Highway Engineering Research. *Prerequisite: permission of instructor.* I and II. *(To be arranged).*

Individually assigned work in the field of highway engineering.

971(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.

980(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, experimental in the laboratory, searches in the library and among public records, and drafting room designing.

990(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.

COMMUNICATION SCIENCES

The following courses have been developed through co-operation of the College of Engineering and the College of Literature, Science, and the Arts, including departments of Mathematics, Psychology, and Philosophy. These courses are offered by the graduate degree Program in Communication Sciences.

400. Introduction to the Communication Sciences I. *Prerequisite: Math. 364 or 372 and Physics 126 or 146, or permission of instructor.* I. *(3).*

Introduction to the concepts of communication and processing of information by natural and artificial systems. Not open to students who have had Com. Sci. 510.

401. Introduction to the Communication Sciences II. *Prerequisite: Com. Sci. 400.* II. *(3).*

Continuation of Com. Sci. 400. Not open to students who have had Com. Sci. 510.

510. Descriptive Models of Natural Languages. *Prerequisite: Philos. 414 or Math. 429, 497 or 561.* I or II. *(3).*

Introduction to the physical, structural, and mathematical methods of analyzing and describing natural languages. Not open to students who have had Com. Sci. 401.

522. Theory of Automata. *Prerequisite: Philos. 414 or Math. 497 and Math. 473, or permission of instructor.* II. *(3).*

The application of logic to finite computers, Turing machines, probabilistic automata, and self-reproducing automata.

524. Theory of Adaptive Systems. *Prerequisite: Com. Sci. 401 or Math. 473, or permission of instructor.* II. *(3).*

Theory of the design and programing of automata which change their structure and behavior in order to adapt to environments containing them.

540. Acoustical Analysis in Speech Communication. *Prerequisite: Com. Sci. 401 or 510 or permission of the instructor.* II. (*3*).

The application of instrumental and experimental techniques to the study of the linguistic structure of speech. Lecture and laboratory.

542. Mathematical Linguistics. *Prerequisite: Com. Sci. 401 or 510.* II. (*3*).

The statistical properties of linguistic units; lexicostatistics. Finite-state and nonfinite-state languages. Algebraic models of natural languages.

640. Acoustical Theory of Speech Communication. *Prerequisite: Com. Sci. 540.* (*3*).

An analysis of the research literature on the acoustical theory of speech. It includes the study of advanced instrumental and experimental techniques in speech analysis. Lecture and laboratory.

648. Automation of Natural Languages. *Prerequisite: Com. Sci. 540.* (*3*).

Automatic speech recognition, speech synthesis, and the machine translation of languages. The basic theoretical problems involved, the current research literature, and current instrumental techniques in the field are studied.

802. Interdisciplinary Seminar in Communication Sciences I. *Prerequisite: permission of instructor.* I. (*3*).

The integration of information essential to the communication sciences, and the study of theoretical formulations and experimental research in the communication sciences.

803. Interdisciplinary Seminar in Communication Sciences II. *Prerequisite: Com. Sci. 802.* II. (*3*).

Continuation of Com. Sci. 802.

900. Advanced Studies in the Communication Sciences. *Prerequisite: permission of instructor.* I and II. (*To be arranged*).

Individual study and research.

ECONOMICS*

Professor Ackley; Professors Boulding, Brazer, Ford, Haber, Hayes, Katona, Levinson, Morgan, Palmer, Peterson, Smith, Stolper, and Suits; Associate Professors G. Anderson, Fusfeld, Lansing, and Mueller; Assistant Professors L. Anderson, Ayal, Bornstein, and Shearer; Lecturers Milstein, Obelsky, and Spivey. Department office, 106 Economics Building.

Economics 103 and 104 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 271, 473 and 475 without having had Economics 103 and 104. 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.

103, 104(53, 54). General Economics. *Prerequisite: Econ. 103 is prerequisite to Econ. 104.* 103, I and II; 104, 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

*College of Literature, Science, and the Arts

of economic principles and problems, with primary emphasis on the latter during the second semester.

271, 272(71, 72). Accounting. *Prerequisite: Econ. 271 is prerequisite to Econ. 272. Not open to freshmen.* 271, I and II. (*3*); 272, I and II. (*4*).

Concepts and procedure of accounting from the standpoint of investors and business management.

350(91). Economic and Financial Problems of the Family. *Open to juniors and seniors.* I and II. (*2*).

An introduction to problems and methods in budgeting and spending the consumer's money and effort. Among other topics are consumer co-operation, insurance, and other security measures.

401(153). Modern Economic Society. I and II. (*3*).

For juniors, 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.

411, 412(101, 102). Money and Banking. *Prerequisite: Econ. 103 and 104. Econ. 411 is prerequisite to Econ. 412.* 411, I and II; 412, I and II. (*3 each*).

Nature and function of money and banking and contemporary monetary problems.

421, 422(121, 122). Labor. *Prerequisite: Econ. 103 and 104. Econ. 421 is prerequisite to Econ. 422.* 421, I and II; 422, I and II. (*3 each*).

Econ. 421 considers the labor force, its employment and unemployment, wages, hours, social security, and an introduction to trade unions. Econ. 422 deals with union history, union structure and organization, the development of collective bargaining, labor disputes, labor law, and the significant issues in labor relations.

423(123). Social Security. *Prerequisite: Econ. 421 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.

431(131). Corporations. *Prerequisite: Econ. 103 and 104.* 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.

433(133). Transportation. *Prerequisite: Econ. 103 and 104.* II. (*3*).

An economic analysis of the transportation industries and the application of this analysis to public policy problems.

434(134). Public Utilities. *Prerequisite: Econ. 103 and 104.* II. (*3*).

Nature and problems of the public utility industries from the standpoint of government regulation.

457(197). Comparative Economic Systems. *Prerequisite: Econ. 103 and 104.* I. (*3*).

Theories of capitalism and socialism and of market and planned economies, and their application in selected countries, including the United States, the Soviet Union, and others.

475(175). Elementary Economics Statistics. *Prerequisite: Econ. 103 or 104. Juniors and seniors may elect this course concurrently with Econ. 103 or 104.* I and II. (*3*).

Introduction to the principal methods of statistical analysis as applied to economic problems.

481(181). Public Finance. *Prerequisite: Econ. 103 and 104.* I. (*3*).

Principles and problems of government finance—federal, state, and local.

ELECTRICAL ENGINEERING

210(3). Circuits I. *Prerequisite: preceded or accompanied by Math. 363 or preceded by Math. 364. (4).*

Direct current and alternating current circuits. Kirchoff'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 three-hour computing period, and one three-hour laboratory.

215(9). Network Analysis. *Prerequisite: preceded or accompanied by Math. 372. (3).*

Analysis of resistive, inductive, and capacitive circuits, direct current, transient and sinusiodal 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.

220(10). Principles of Electricity and Magnetism. *Prerequisite: preceded or accompanied by Physics 145 and either preceded by Math. 234 or preceded or accompanied by Math. 364. (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.

301(141). Professional and Economic Applications in Electrical Engineering. *Prerequisite: preceded or accompanied by Elec. Eng. 330 or permission of instructor. (2).*

Economic, financial, and intangible analysis, corporate finance, time element of values, comparison of alternatives, economic decay, replacement, effect of income taxes. Kelvin's Rule, Game theory, linear programing, and economics of large systems.

310(100). Circuits II. *Prerequisite: Elec. Eng. 210. (4).*

Writing circuit equations; node and loop methods; transient and steady-state response; Fourier series analysis; Fourier integral; transients by Laplace methods; complex frequency; poles and zeros; admittance and impedance; network theorems; graphical analysis methods; energy and power effects; polyphase circuits; electromechanical systems.

315(5). Direct and Alternating Current Apparatus and Circuits and Electronics. *Prerequisite: Math. 364 or 372 and Physics 146. (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.

320(11). Electromagnetics and Energy Conversion. *Prerequisite: preceded by Elec. Eng. 215 and Physics 146. (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.

330(120). Electronics and Communications I. *Prerequisite: Elec. Eng. 310 and 380 or Physics 455. (4).*

Circuit models of electronic devices; linear and nonlinear analysis of basic electronic circuits; rectification, amplification, modulation, and oscillation; circuit and device noise analysis. Lectures and laboratory.

337(87). **Electronic Circuits and Systems.** *Prerequisite: Elec. Eng. 320. (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 close-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.

343(153). **Energy Conversion and Control I.** *Prerequisite: Elec. Eng. 220, 310, and Math. 404. (3).*

A unified and integrated treatment of the basic principles governing the dynamic behavior of physical components and systems utilizing field, torque, current, voltage, force, and energy relations. Application to transformers, d-c and a-c machines; hydraulic, pneumatic, photo-electrical, and thermal electric elements.

360(130). **Electrical Measurements.** *Prerequisite: Elec. Eng. 310. (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.

361(131). **Technical Electrical Measurements.** *Prerequisite: Elec. Eng. 360 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.

376(172). **Electric Lighting and Distribution.** *Prerequisite: Math. 103. (2).*

For students of architecture particularly; students of electrical engineering cannot receive credit for this course.

380(180). **Physical Electronics of Electron Devices I.** *Prerequisite: Elec. Eng. 210 or 315; preceded by Elec. Eng. 220. (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; transistors physics. Lectures and laboratory.

407(187). **Seminar in Professional and Industrial Practices in Electrical Engineering.** *Prerequisite: open to seniors and graduate students. (1).*

The nature of typical engineering decisions in electronic and other research, development, and production; organizational pattern 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.

410(101). **Circuits III.** *Prerequisite: Elec. Eng. 310. (3).*

Analysis of distributed parameter systems; transmission of electromagnetic waves in lines and waveguides; reflections; measurements; equivalent circuits; image wave filter analysis.

412(102). **Circuit Analysis by Symmetrical Components.** *Prerequisite: Elec. Eng. 310. (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.

415(105). **Network Analysis and Synthesis.** *Prerequisite: Elec. Eng. 310. (2).*

Matrix analysis of multiterminal networks; network function properties; two-port networks; synthesis of driving-point and transfer functions; cascaded networks; image filter synthesis.

418(108). Networks and Electronic and Transistor Circuits. *Prerequisite: Elec. Eng. 315 or equivalent.*

Network analysis; vacuum tube and transistor circuits; amplifiers, mixers, modulators, and detectors. Not open to electrical engineering students. Lectures and laboratory.

419(109). Transistor Circuits. *Prerequisite: Elec. Eng. 315 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.

420(110). Electromagnetic Fields and Waves. *Prerequisite: Elec. Eng. 220 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.

425(112). Electric and Magnetic Properties of Solids I. *Prerequisite: Elec. Eng. 380 or permission of instructor. (3).*

The roles of solids in determining electric and magnetic parameters of circuit elements and in wave propagation. The origin, frequency, and field dependence of the permittivity and the permeability. The thermodynamics of electric and magnetic processes. Metallic conduction, superconductivity and superconducting devices. Semiconductors, the relationships between the physical phenomena and the circuit representations, phosphors, light amplifiers.

430(121). Electronics and Communications II. *Prerequisite: Elec. Eng. 330 and preceded or accompanied by Elec. Eng. 410. (4).*

Wide band amplifiers; radio-frequency amplification; modulation and detection; transmitting and receiving circuits; radio-frequency transmission lines. Lectures and laboratory.

431(181). Industrial Electronics. *Prerequisite: Elec. Eng. 310 and 380. (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.

433(103). Electroacoustics and Ultrasonics. *Prerequisite: Math. 404 and Elec. Eng. 310, 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.

434(104). Architectural Acoustics. *Prerequisite: Math. 234 or permission of instructor. (1).*

The application of acoustics to architectural problems. Acoustical terminology and the properties of sound waves. Sound absorptive materials, noise control in relation to architecture, and the acoustics of rooms and buildings.

435(225). Television. *Prerequisite: preceded or accompanied by Elec. Eng. 430. (2).*

Basic principles, cathode-ray scanning devices and television receivers and transmitters.

438(128). Electronics and Radio Communications. *Prerequisite: Elec. Eng. 310. (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.

441(151). **Induction Machinery.** *Prerequisite: Elec. Eng. 444. (3).*

Theory and operating characteristics of polyphase and single-phase induction motors, performance tests, speed control, time and space harmonics, unbalanced operation, transient operation, design considerations including the use of the computer.

442(7). **Motor Control and Electronics.** *Prerequisite: Elec. Eng. 315. (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.

444(154). **Energy Conversion and Control II.** *Prerequisite: Elec. Eng. 343 or permission of instructor. (4).*

Generalization of the basic principles of the dynamic behavior and energy conversion of physical elements, including an introduction of Lagrange's equations, Hamiltonian functions, and Legrendre transformations. Introduction to feedback control system principles and transfer functions. Laboratory experiments demonstrating and corroborating the theory developed in class. Lectures and laboratory.

445(155). **Feedback Control Systems I.** *Prerequisite: Elec. Eng. 444. (4).*

Analysis and synthesis of linear feedback control systems utilizing the Laplace transform, frequency response and root locus as methods of analysis. Laboratory experiments involve the study of several control systems and their simulation on the differential analyzer. Lectures and laboratory.

447(157). **Introduction to Servomechanisms.** *Prerequisite: Math. 404 and Elec. Eng. 310 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.

448(158). **Principles of Electric Traction.** *Prerequisite: Elec. Eng. 210 or 315. (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.

450(140). **Power Plants and Transmission Systems.** *Prerequisite: Elec. Eng. 444, 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.

460(135). **Methods of Instrumentation—A.** *Prerequisite: Elec. Eng. 310 and 380. (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.

461(136). **Methods of Instrumentation—B.** *Prerequisite: Elec. Eng. 315. (3).*

Similar to Elec. Eng. 460 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.

462(137). **Instrumentation Laboratory.** *Prerequisite: to accompany Elec. Eng. 460 or 461. (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.

465(132). Electronic Computers I. *Prerequisite: Math. 404; preceded or accompanied by Math. 373. (4).*

Introduction to the design and engineering application of digital computers, differential analyzers, and digital differential analyzers. Treats computer organization and languages; system modeling and simulation; elementary numerical analysis; and application of computers to engineering problems. Lectures and laboratory.

466(233). Digital Computer Engineering Laboratory. *Prerequisite: Elec. Eng. 465 or permission of instructor.* (2).

Study of logic circuits and electronic circuits of digital computer systems. Laboratory projects are carried out on the MIC (Michigan Instructional Computer) to investigate circuits for arithmetic, control, and storage. Lecture and laboratory.

467(134). Switching Circuits and Logical Design. *Prerequisite: junior standing in engineering. (3).*

Introduction to methods of designing and minimizing networks of switching elements, such as relays, magnetic cores, transistors, or other computer elements. Use of switching algebra and graphical techniques for the logical design of combinational and sequential switching circuits.

470(160). Fundamentals of Electrical Design. *Prerequisite: Elec. Eng. 210 and 220. (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.

475(170). Incoherent Electromagnetic Radiation. *Prerequisite: Elec. Eng. 220 and Math. 372. (3).*

Sources of incoherent electromagnetic radiation; black body radiation, electronic transitions, molecular transitions. The incoherent radiant field; luminous emittance, illumination, luminance, light vector, luminous intensity. Geometric optics. Receptors of radiant energy; the human eye, energy conversion from ultra violet and infrared to optical, photoelectric cells, photoconductive cells.

476(174). Electric Distribution, Wiring, and Control for Lighting. *Prerequisite: Elec. Eng. 210.* (2).

Selection and application of equipment, design of circuits, study of methods of installation for electric-power supply lamps.

477(176). Residence Lighting. *Prerequisite: preceded by Elec. Eng. 475 or 376.* (2).

For students of architecture and engineering. Co-ordination of architecture with illumination as applied to residence lighting.

499(79). Directed Research Problems. *Prerequisite: Elec. Eng. 210. (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. 699 in that the instructor is in close touch with the work of the student. Elec. Eng. 699 is for graduates.

510(201). Transients. *Prerequisite: Elec. Eng. 310.* (2).

Advanced theory of electrical circuits; Laplace transform method of solution for transients in circuits with lumped constants; introduction to the complex frequency domain.

515(205). Network Synthesis I. *Prerequisite: Elec. Eng. 415, or 510, or permission of instructor.* (3).

Energy relations in passive networks; complex variable theory; realizability and synthesis of driving point impedance and transfer functions.

525(212). **Electric and Magnetic Properties of Solids II.** *Prerequisite: Elec. Eng. 420 or 425 or permission of instructor. (3).*

Stationary energy states in resonant cavities; equivalent stationary states in the hydrogen atom; extension to higher atomic numbers; molecular binding, exchange integral; binding in solids; the effect of wave function symmetry upon distribution function; electronic properties within a periodic potential field; the different forms of electronic conduction; paramagnetism, ferrimagnetism.

530(220). **Microwaves I.** *Prerequisite: Elec. Eng. 410 and 420. (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.

531(221). Radiation, Propagation, and Antennas. *Prerequisite: Elec. Eng. 330, 410, and 420. (3).*

Fundamental theory; general propagation phenomena; short and long linear antennas and arrays; ground and atmospheric reflection and refraction; transmission loss; ground wave propagation; ionosphere; sky-wave propagation; tropospheric propagation; forward scatter.

533(123). **Pulse Circuits.** *Prerequisite: Elec. Eng. 330. (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.

534(284). **Noise in Electronic Circuits and Devices.** *Prerequisite: Elec. Eng. 310, Math. 404, and preceded or accompanied by Math. 452, 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.

536(226). **Cosmic Radio-Frequency Radiation.** *Prerequisite: Elec. Eng. 420 and 330 or permission of instructor. (2).*

A description is given of the results of planetary, solar, and cosmic radio observations. The propagation characteristics for radio waves through space is treated. The generation of radio-frequency energy by the synchrotron process, by Cerenkov radiation, by gyroradiation, and by thermal processes in plasmas and in planetary atmospheres will be discussed and related to the above astronomical observations.

538(228). **Microwaves, Radiation, and Propagation.** *Prerequisite: Elec. Eng. 438. (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.

541(251). **Alternating Current Apparatus.** *Prerequisite: Elec. Eng. 444. (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.

542(252). **Synchronous Machinery.** *Prerequisite: Elec. Eng. 444. (2).*

M.m.f. and flux distribution in the air gap and voltage wave shapes of nonsalient and salient pole machines. Direct and quadrature reactances under steady-state and transient conditions.

550(240). **Generating Stations.** *Prerequisite: Elec. Eng. 444. (2).*

Integrated performance of electrical equipment used in the generation of electrical energy. Electrical and mechanical transients of synchronous machines.

551(241). Electric Transmission and Distribution Systems. *Prerequisite: Elec. Eng. 310. (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.

552(242). Electric Rates and Cost Analysis. *Prerequisite: Elec. Eng. 450. (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.

555(245). Power System Stability. *Prerequisite: Elec. Eng. 450. (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.

556(246). Analysis of Electric Power Systems. *Prerequisite: Elec. Eng. 412. (3).*

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 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.

557(247). Power System Protection. *Prerequisite: Elec. Eng. 450. (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.

558(248). Power System Transients. *Prerequisite: Elec. Eng. 450. (2).*

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.

565(232). Analog and Digital Computer Technology. *Prerequisite: Elec. Eng. 465 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.

568(238). Digital Computer Applications. *Prerequisite: Elec. Eng. 438 and Math. 548. (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 computing facilities.

570(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.

571(261). Design of D.C. and Synchronous A.C. Motors and Generators. *Prerequisite: Elec. Eng. 444 and 470. (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.

577(271). Interior Illumination, Study of Design. *Prerequisite: Elec. Eng. 475 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.

580(189). Physical Electronics of Electron Devices II. *Prerequisite: Elec. Eng. 380, or permission of instructor. (4).*
Conformal analysis of fields in space-charge control tubes; multigrid-tube interelectrode capacities; electron transit time principles; electron optics of cathode ray focusing; solid state physics of thermionic, secondary, and photo-electric emission; mobilities, mean free times, and conductivities in semiconductors and in gaseous conducting plasmas; television pickup and camera tubes; initiation of current in thyratrons, ignitrons, and circuit breakers; Paschen's Law, radiation counter tubes. Lectures and laboratory.

588(288). Theory of Solid-State Electronic Devices. *Prerequisite: Elec. Eng. 380 and Math. 404. (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.

591(281). High-Voltage Experimental Techniques. *Prerequisite: Elec. Eng. 310 and 380. (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.

592(282). Electron Tube and Vacuum Techniques. *Prerequisite: Elec. Eng. 380 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.

615(206). Network Synthesis II. *Prerequisite: Elec. Eng. 515. (3).*
Synthesis for prescribed transfer functions; the approximation problem; synthesis for a prescribed time response; application to engineering problems.

617(208). Network Analysis. *Prerequisite: Elec. Eng. 510, or 515, or permission of instructor. (3).*
Stability theory and feedback amplifier design, and selected topics from the following: Hilbert transforms, band pass analysis, Z-transforms, correlation and spectral analysis, and radar and communication systems analysis by circuit theory concepts.

620(210). Electromagnetic Field Theory I. *Prerequisite: Elec. Eng. 420 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.

630(224). Microwaves II. *Prerequisite: Elec. Eng. 530 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.

634(285). **Information Theory in Electrical Communication.** *Prerequisite: Elec. Eng. 534 or equivalent preparation in probability and statistics. (3).*

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.

645(255). **Feedback Control Systems II.** *Prerequisite: Elec. Eng. 445 or Instr. Eng. 570 and 571 or permission of instructor. (3).*

Linear feedback control systems using circuit synthesis techniques; approximation to the frequency and time domain; sampled-data systems using z and w transforms; correlation functions; design of linear systems with random inputs; design for the minimization of the mean-square-error.

646(256). **Feedback Control Systems III.** *Prerequisite: Elec. Eng. 445 or Instr. Eng. 570 and 571 or permission of instructor. (3).*

Linear time-varying systems; nonlinear systems using describing function and phase space analysis; analysis of piece-wise linear systems of the optimum control type using phase-space techniques. Laboratory demonstrations of typical systems.

647(257). **Introduction to Navigation Systems.** *Prerequisite: Elec. Eng. 445 or Instr. Eng. 570. (2).*

A theoretical study of the basic concepts which underlie celestial, Doppler, and inertial navigation systems. Emphasis is placed on the following topics: Doppler spectrum, matrix co-ordinate transformation, Shuler tuning, and other selected topics. Theory and application of gyroscopes, accelerometers, and astrocompasses as applied to navigation systems.

665(235). **Digital Computer Design Principles.** *Prerequisite: Elec. Eng. 565. (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 system.

667(234). **Theory of Networks of Switching Elements.** *Prerequisite: Elec. Eng. 467, Philos. 414 or permission of instructor. (3).*

The use of Boolean algebra and propositional calculus in the study of two-terminal and multiterminal relay contact networks; analysis and synthesis of sequential networks and functional automata; use of predicate calculi in the theory of logical design; other current topics. The point of view is that of abstract algebra.

673(265). **Large-Scale Systems Design I.** *Prerequisite: Math. 450 and permission of instructor. (2).*

A treatment of the functional organization of large-scale systems touching on those areas of mathematics and scientific endeavor relevant to this organization. Particular attention will be directed towards the applications of probability theory, theory of testing statistical hypotheses, observation theory, and communication theory. Optimization problems will be considered, with particular attention to the time range over which the outcomes are optimized.

674(266). **Large-Scale Systems Design II.** *Prerequisite: Elec. Eng. 673. (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.

686(286). **Microwave Electron-Beam Tubes I.** *Prerequisite: Elec. Eng. 620 or per-*

mission 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 low-density and high-density beams, conservation of momentum, Busch's theorem, confined flow, Brillouin flow, Harris flow, electrolytic tanks; space-charge wave analysis; velocity modulation, klystrons, small-signal traveling-wave tubes, magnetron amplifiers, backward-wave oscillators, double-beam tubes. Lectures and laboratory.

687(287). Microwave Electron-Beam Tubes II. *Prerequisite: Elec. Eng. 686 or permission of instructor. (3).*

Electric and magnetic lenses, periodic magnetic focusing, effect of magnetic field on space-charge wave propagation; nonlinear theory of O-type amplifiers and oscillators; nonlinear theory of M-type amplifiers and oscillators; space-charge models; omega-beta diagram, periodically loaded waveguides.

689(289). Noise in Electron-Stream Devices. *Prerequisite: Elec. Eng. 620, 534 and 686, or permission of instructor. (2).*

Statistical mechanics of multi-electron systems; medium-like models of an electron gas, applied to electron beams, gas discharges and solids; single-velocity and Maxwellian streams; generation and propagation of noise; general discussion in three dimensions of the noise output of an electron gun; the one dimensional model, its justification and limitations; the transmission-line analogy; noise in the retarding-field diode and in the space-charge-limited equivalent diode of the electron gun of a traveling-wave amplifier; the conditions for minimum noise factor; modulation noise in a semiconductor and the transistor noise factor. (To be offered first semester, alternate years.)

699(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.

720(211). Electromagnetic Field Theory II. *Prerequisite: Elec. Eng. 620. (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.

725(215). Methods of Solving Radiation and Scattering Problems. *Prerequisite: Elec. Eng. 620 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.

735(222). Microwave Antenna Theory. *Prerequisite: Elec. Eng. 620 and 531 or permission of instructor. (3).*

Methods of solution of microwave antenna design problems, reciprocity theorem, circuit relationships, impedance concept, reaction concept, slots, mutual coupling.

802(403). Interdisciplinary Seminar in Communication Sciences I. *Prerequisite: permission of instructor. (3).*

General aspects of human communication. Selected topics related to the application of information theory to psychology, speech, linguistics, logical nets, and communication engineering.

803(404). Interdisciplinary Seminar in Communication Sciences II. *Prerequisite: Elec. Eng. 802. (3).*

A continuation of Elec. Eng. 802.

820(310). Topics in Electromagnetic Field Theory. *Prerequisite: Elec. Eng. 620. (3).*

Differential, integral, and variational formulation of field problem; classical solutions. Method of linear operators; discontinuous solutions and theory of distributions; propagations in random medium, coherent and incoherent discrete processes; approximate solutions; theory of multiple scattering and problem of radiative transfer.

845(355). Seminar on the Theory of Adaptive and Optimalizing Control Systems. *Prerequisite: Elec. Eng. 445 and 565. (2).*

The analytical design of feedback control systems by perturbation theory and variational principles; study of adaptive control systems of the input-signal and extremum type; laboratory demonstrations using computers as control system elements. (To be offered first semester, alternate years.)

846. Seminar on Lyapunov's Second Method and Its Applications to Control System Design. *Prerequisite: Elec. Eng. 646 or the permission of instructor. (2).*

Stability concepts; Lyapunov functions and Lyapunov's Second Method; selection of Lyapunov functions; application of Lyapunov's Second Method to the design of nonlinear control systems.

865(335). Seminar on Research Topics in Computer Organization. *Prerequisite: Elec. Eng. 565 or permission of instructor. (1).*

Study and discussion of current research in computer organization, language, structure, and logic, with particular reference to recent periodical literature.

883(383). Topics in Physical Electronics. *Prerequisite: Elec. Eng. 380 or 580, and Math. 450. (2) without a laboratory; (3) with a laboratory. (2 or 3).*

Suggested topics for analysis: high pressure and high temperature plasmas, including magnetohydrodynamic effects; interactions producing extreme electron temperatures; mean free paths and ion mobilities and ionization rates; ambipolar diffusions; probe measurements in gas discharges; initiation of microwave gas discharges; high density electron beam formation, focusing, hysteresis, and instability; the quantum-mechanics of electron emission; initial electron velocity effects; space charge suppression of slot noise. Lectures and optional laboratory.

886(386). Special Topics in Microwave Circuits and Tubes. *Prerequisite: Elec. Eng. 687 or permission of instructor. (2).*

Energy theorems for electron streams; beam-type parametric amplifiers; modulation and nonlinear bunching of beams; linear accelerators; relativistic beams, electronic waveguides. Lectures.

895(395). Seminar in Space Research. *Prerequisite: permission of instructor. (2).*

Detailed analyses of objectives, procedures, and results of research being carried out at The University of Michigan. Topics will include the following: structure of the upper atmosphere; measurement of temperature, pressure, density, composition and winds. The ionosphere; measurement of ion and electron density and temperature. Investigation of radio waves incident on the earth at frequencies absorbed by the ionosphere by means of instrumented satellites. Interpretation of infrared data from meteorological satellites. Research in attitude control of multistage sounding rockets.

ENGINEERING GRAPHICS

101(1). Engineering Drawing. I, II, and S.S. (*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.

102(2). Descriptive Geometry. *Prerequisite: Eng. Graphics 101.* I, II, and S.S. (*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.

104(4). Introduction to Descriptive Geometry. *Prerequisite: Eng. Graphics 101.* I, II, and S.S. (*2*).
Elementary principles of orthographic projection in representing relations of lines and planes, and in the graphical measurement of distances, angles, and areas. Constructions employing auxiliary views as utilized in engineering practice. Credit cannot be allowed for both this course and Engineering Graphics 102.

141(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.

232(32). Graphical Presentation and Computation. *Prerequisite: permission of instructor.* II. (*2*).
Special geometrical constructions, graphical solutions of equations, theory of graphical scales and nomography, empirical equations, graphical calculus and vector graphics. Theory and execution of methods followed by construction of working charts and computing aids.

233(33). Advanced Engineering Drawing. *Prerequisite: Eng. Graphics 102 or 104.* 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.

235(35). Production Illustration. *Prerequisite: Eng. Graphics 101, or equivalent.* II. (*2*).
Various methods of making 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.

ENGINEERING MECHANICS

208(1). Statics. *Prerequisite: preceded by Math. 234 or 363 and Physics 145, or written permission.* I and II. (*3*).
Fundamental principles of mechanics and their application to the simpler problems of engineering; forces, vector algebra, moments, couples, friction, hydrostatics, virtual work, and centroids.

210(2). Mechanics of Material. *Prerequisite: Eng. Mech. 208 and preceded or accompanied by Math. 364 or 371.* I and II. (*4*).
Application of mechanics to problems in stress and strain on engineering materials; resistance to direct force, bending, torque, shear, eccentric load, deflection of beams, buckling of columns, and compounding of simple stresses.

212(2a). Laboratory in Mechanics of Material. *Prerequisite: preceded or preferably accompanied by Eng. Mech. 210.* I and II. (*1*).
Behavior of engineering materials under load in both the elastic and the plastic ranges; use of testing machines; use of mechanical, optical, and electrical strain measuring instruments; tension, compression, torsion, bending, and hardness tests; column experiments; demonstrations in photoelasticity and stress coat.

218(11). Statics. *Prerequisite: Physics 153, preceded or accompanied by Math. 234.* I and II. (*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.

219(12). Strength of Materials. *Prerequisite: Eng. Mech. 218, preceded or accompanied by Math. 371.* I and II. (*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.

310(5). Statics and Stresses. *Prerequisite: Physics 145 and Math. 364 or 372.* I and II. (*3*).
Fundamental principles of statics and their application to engineering problems; forces, moments, couples, friction, centroids, moment of inertia; application of statics to problems in stress and strain on engineering materials, including resistance to direct loads, bending, torque, shear, eccentric loads.

324(4). Fluid Mechanics. *Prerequisite: Eng. Mech. 208 or 310 and Math. 364 or 372.* I and II. (*3*).
Principles of mechanics applied to liquids and gases. Dynamic similitude; special topics; manometers, Venturi and orifice meters, equilibrium of floating bodies, laminar and turbulent flow; resistance to flow, circulation, lift, boundary layers, free-surface flow, adiabatic flow of ideal gases in conduits.

326(14). Fluid Mechanics. *Prerequisite: Eng. Mech. 345, accompanied by Math. 372.* I and II. (*4*).
An introduction to the statics, dynamics, and thermodynamics of real and ideal fluids; laminar, turbulent, compressible and incompressible flows; the Euler,

Bernoulli and continuity equations; construction of flow nets; dimensional analysis and similitude applied to such subjects as flow in channels and conduits and lift and drag of bodies.

328(4a). **Fluid Mechanics Laboratory.** *Prerequisite: preceded or accompanied by Eng. Mech. 324 or 326.* I and II. (*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.

343(3). **Dynamics.** *Prerequisite: Eng. Mech. 208 or 310 and preceded by Math. 364 or 372.* I and II. (*3*).

Vectorial kinematics of moving bodies in both fixed and moving reference frames. Kinetics of particles, assemblies of particles and of rigid bodies with emphasis on the concept of momentum. Keplerian motion, moment of inertia tensor and its transformations, elementary vibrations and conservative dynamic systems are treated as special topics.

345(13). **Dynamics.** *Prerequisite: Eng. Mech. 218, accompanied by Math. 372.* I and II. (*3*).

Kinematics, rectilinear and curvilinear motion, Coriolis' acceleration, kinetics of particles and bodies, d'Alembert's principle, momentum, conservative and nonconservative systems, impact, dynamic stresses, propulsion; vibrations of rigid bodies, vibrating mass systems, electrical and acoustical analogies, gyroscopes, balancing.

402(102). **Experimental Stress Analysis.** *Prerequisite: Eng. Mech. 210 or 219.* I. (*2*).

Review of plane stress-strain relationships, with mechanical, optical and electrical resistance strain-measuring techniques; applications including strain rosettes; dynamic and transient strain and displacement measurements; brittle coatings and brittle models; fundamentals of photoelasticity. Laboratory sessions with assigned experiments. Recommended as a substitute for Eng. Mech. 210.

403(103). **Experimental Mechanics.** *Prerequisite: Eng. Mech. 210, 343, and Elec. Eng. 315.* II. (*2*).

Theory and practice in the design and execution of experiments in engineering. Modeling theory. Probability and elementary statistics applied to data treatment; analysis, design and use of instruments for static or dynamic conditions, including measurement of strain, pressure, temperature, and viscosity. Laboratory sessions with assigned experiments.

411(123). **Structural Mechanics.** *Prerequisite: Eng. Mech. 210 or 219.* I and II. (*3*).

Review of plane states of stress and strain. Basic equations of plane elasticity and selected problems. Failure criteria and applications. Energy principles of structural theory. Introduction to plate theory.

412(112). **Intermediate Mechanics of Material.** *Prerequisite: Eng. Mech. 210 or equivalent and Math. 403 or 404.* I and II. (*3*).

Classification of materials: elasticity, viscosity, plasticity. Analysis of simple combinations. Limit theory of plasticity. Introduction to general linear elasticity; plane solutions and torsion problem. Energy principles and application to approximate systems.

413(122). **Photoelasticity.** *Prerequisite: Eng. Mech. 210 and Math. 403.* I and II. (*2*).

Lectures and laboratory experiments covering the fundamentals of the photoelastic method of stress determination including the use of double refraction and interference of light, determination of the maximum shear stress, methods of separating the principal stresses, and three-dimensional photoelasticity. Models to suit interest of students.

416(126). **Stress Analysis.** *Prerequisite: Eng. Mech. 210.* (*2*).

Basic concepts of stress and strain in two dimensions; curved beams and beams on elastic foundations; fundamentals of photoelasticity.

422(114). Intermediate Mechanics of Fluids. *Prerequisite: Eng. Mech. 324 or equivalent and Math. 403 or 404.* I and II. *(3)*.

Continuity, stream functions, vorticity; Euler and Bernoulli equations; irrotational flows, Laplace equation, conformal mapping, relaxation method; hydrodynamic forces and moments; compressible flows, method of characteristics; Navier-Stokes equations, elements of hydrodynamic stability, and turbulence; boundary layers, jets, wakes, drag.

441(113). Intermediate Mechanics of Vibrations. *Prerequisite: Eng. Mech. 343 or equivalent and Math. 403 or 404.* I and II. *(3)*.

Free and forced vibration for lumped and continuous mechanical systems; vibration of multimass systems, strings, bars and plates; normal modes, mechanical impedence, vibration control; Rayleigh's Method and introducton to Lagrange's Equations.

446(136). Theory of Vibrations for Naval Architects. *Prerequisite: Eng. Mech. 343 and Math. 364 or 372. (3)*.

General outline of vibration theory; vibration of masts, longitudinal and torsional vibration of propulsion machinery; hull vibrations, vertical, lateral, longitudinal, and torsional; other selected problems.

514(124). Theory of Elasticity I. *Prerequisite: Eng. Mech. 412 or equivalent.* I. *(3)*.

Basic equations of three-dimensional elasticity. Variational principles, the plane problem, and torsion and bending of prismatic beams, with application of complex function theory.

515(125). Theory of Plates. *Prerequisite: Eng. Mech. 412 or equivalent.* II. *(3)*.

Classical linear plate theory, with application to various shapes, boundary conditions, and loading systems; refinements to account for anisotropy, shear deformations, large deflections; plastic collapse and elastic instability.

518(128). Theory of Elastic Stability I. *Prerequisite: Eng. Mech. 412 or equivalent.* I. *(3)*.

Elastic and inelastic buckling of bars and frameworks: variational principles and numerical solutions; lateral buckling of beams. Instability of rings.

519(129). Theory of Plasticity I. *Prerequisite: Eng. Mech. 412 or equivalent.* II. *(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.

522(141). Mechanics of Inviscid Fluids I. *Prerequisite: Eng. Mech. 422 and Math. 450.* II. *(3)*.

Solution of Laplace's equation by various methods; added masses, Taylor theorem; forces and moments, Blasius and Lagally theorems; free-streamline flows, wave motion, vortex motion, and shear flows; theory of thin airfoils or projectiles; high speed flow.

523(143). Mechanics of Viscous Fluids I. *Prerequisite: Eng. Mech. 422 or equivalent and Math. 450.* I. *(3)*.

Stress and rates-of-deformation tensors, dissipation function, exact solutions of the Navier-Stokes equations, very slow motion, boundary layers, jets and wakes, energy equation, forced and free convections, hydrodynamic stability, statistical theories of turbulence.

525(145). Mechanics of Control of Fluid Systems. *Prerequisite: Math. 450.* II. (2).

Analysis of the dynamics of closed-loop feedback systems, pressure-controlled hydraulic systems, and velocity-control systems.

527(142). Thermodynamics. *Prerequisite: Math. 403 or 404.* I. (2).
Fundamental concepts; first and second laws of thermodynamics, equilibrium of homogeneous systems; applications to elastic and plastic deformations and fluid dynamics.

529(149). Advanced Laboratory in Mechanics of Fluids. *Prerequisite: Eng. Mech. 422 or permission of instructor.* II. (2).
Laboratory experiments designed to give the student an insight into the physical behavior of fluids and the role of experimentation in research. Experimental results are compared with existing theory whenever possible. Experiments include fundamental studies of free streamline flows, drag forces and moments, pressure distributions, thermal instability, slow motion flows, and Prandtl-Meyer flows.

542(132). Advanced Dynamics. *Prerequisite: Eng. Mech. 441, or equivalent and Math. 450.* II. (*3*).
Vector mechanics for particle and rigid body motions. Lagrange's equations. Introduction to Hamilton's development of mechanics.

543(133). History of Dynamics. *Prerequisite: Eng. Mech. 343 and Math. 403.* (2).
A review of the important publications in which the fundamental principles of dynamics were developed from Aristotle to Lagrange. The influence of astronomical theories on the development of dynamics.

544(134). Dynamics and Stability of Rotors. *Prerequisite: Eng. Mech. 441.* II. (*3*).
Problems of balance and vibration in turbine rotors and reciprocating engine moving parts, blade and disc vibrations, harmonic analysis, vibration dampers and absorbers, vibration stress analysis.

545(135). Vibrations of Continuous Media. *Prerequisite: Eng. Mech. 412 and 441, or permission of instructor.* I. (*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.

547(137). Theory of Gyroscopes. *Prerequisite: Eng. Mech. 441, or permission of instructor.* I. (*2*).
General theory of rigid body rotational dynamics applied to gyroscopes of one and two degrees of freedom. Various applications of gyroscopes to measurement and control problems.

***572(112a). Intermediate Mechanics of Material I.** (2).

***573(112b). Intermediate Mechanics of Material II.** (2).

***574(114a). Intermediate Mechanics of Fluids I.** (2).

***575(114b). Intermediate Mechanics of Fluids II.** (2).

707(200). Theory of a Continuous Medium. *Prerequisite: Eng. Mech. 412, 422 and permission of instructor.* (*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.

714(224). Theory of Elasticity II. *Prerequisite: Eng. Mech. 514.* II. (*3*).
Three-dimensional elasticity problems. Derivation of approximate systems (plates, shells, etc.) from variational principles; introduction to nonlinear elasticity.

715(225). Theory of Shells. *Prerequisite: Eng. Mech. 514.* I. (*3*).
The general theory for deformation of thin shells with small deflections; various approximate theories, including the membrane theory. Application to various

*Offered in Detroit only. For description, see Eng. Mech. 412 and 422.

configurations with special reference to shells of revolution; stability of shells. Shells of revolution with large deflections.

718(228). Theory of Elastic Stability II. *Prerequisite: Eng. Mech. 518.* II. *(3).*
Linear instability theory of plates and shells. Postbuckling analysis. Dynamic stability criteria. General instability theory in three-dimensional elasticity.

719(229). Theory of Plasticity II. *Prerequisite: Eng. Mech. 519.* I. *(3).*
Plastic theory for materials with isotropic hardening, kinematic hardening, and time dependence. Theories based on crystal slip; variational theorems; range of validity of total deformation theories. Theory of generalized stresses applied to circular plates; behavior at finite deflection; limit analysis of shells. Plane stress, plane strain, and axial symmetry. Plastic response to impact loads. Minimum weight design.

721(241). Mechanics of Inviscid Fluids II. *Prerequisite: Eng. Mech. 522 and 527; others by permission.* I. *(3).*
Theory of large-amplitude motion of fluids with variable density and entropy in a gravitational field, flow of heterogeneous fluids in porous media, gravity and sound waves in stratified fluids, stability of stratified fluids. Flow in a rotating system or a magnetic field.

723(243). Mechanics of Viscous Fluids II. *Prerequisite: Eng. Mech. 523.* II. *(3).*
Treatment of hydrodynamic equations in general co-ordinates by tensorial methods; gravitational, hydromagnetic, and surface-tension instabilities; instability of rotating fluids and of flow in porous media. Tollmien-Schlichting waves; instability of free-surface flows.

741(231). Theory of Vibrations. *Prerequisite: Eng. Mech. 441, Math. 447 and 450.* II. *(2).*
Transient motion in linear systems caused by forces or motions which are functions of time. Methods of treating the motions of nonlinear mechanical systems of one degree of freedom.

745(235). Wave Motion in Continuous Media. *Prerequisite: Eng. Mech. 441 or equivalent and permission of instructor.* II. *(3).*
Wave propagation in bounded and extended elastic media, including transmission, reflection, and refraction phenomena, transient stress states, and analogies with acoustical and optical effects. Forced motion of continuous elastic systems such as plates, membranes, shells, and other forms.

801(100). Seminar in Engineering Mechanics. *Prerequisite: permission.* I and II. *(1 or 2).*
A series of weekly seminars. Students who contribute may elect one or two hours credit.

911(120). Research in Mechanics of Solids. I and II.
Research in theory of elasticity, plasticity, photoelasticity, structures, and materials. Special problems involving application of theory and experimental investigation.

921(140). Research in Mechanics of Fluids. I and II.
Analytical or experimental investigation of special problems in fluid flow, or intensive study of a special subject in fluid mechanics.

941(130). Research in Dynamics. I and II.
Original investigations in the field of body motions such as vibrations of mechanical systems, control problems, and other fundamental problems in the mechanics of rigid body motion.

991. Doctoral Thesis. I and II.
For doctoral candidates only, under supervision of the doctoral committee. Credit hours to be arranged.

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 Assistant Dean who, with the student's program adviser and the chairman of the Department of English, may prescribe additional study.

GROUP I: BASIC COURSES

Courses in this group provide basic instruction and practice in writing and speaking. English 111 and 121 are elected during the first semester of the freshman year and English 112 during the second semester. Students with outstanding ability can be exempted from one or more of these courses, whereas students who are not prepared for English 111 may be required to take English 110 before taking English 111.

110(10). Preparatory Composition. I and II. *(3)*.

A course in composition and reading for those in need of further preparation. Study and drill in diction, spelling, grammar, and punctuation; in the structure of the sentence, paragraph, and short essay; and in the techniques of reading.

111(11). Freshman Composition I. I and II. *(3)*.

A course in the essentials of composition with stress on sentence structure, paragraph development, and theme organization. Spelling, diction, punctuation, and grammatical usage are considered as the need arises. Essays and some imaginative literature are analyzed to provide models and ideas for themes and to develop skill in reading.

112(12). Freshman Composition II. I and II. *(2)*.

A continuation of English 111 with further stress on the essentials of composition but with the chief emphasis on various techniques of exposition and argument, such as analysis, analogy, comparison, and definition. The student also receives instruction and practice in writing research papers and reports. As in English 111 essays and some imaginative literature are read and analyzed.

121(21). Introductory Speech. I and II. *(1)*.

A course in the preparation and delivery of short expository and persuasive speeches. It is intended to help the student develop the ability to present his ideas to a group in an orderly and effective manner. Two hours of classwork.

GROUP I-A: NONTECHNICAL ELECTIVES FOR FRESHMEN (AND OTHERS WITH PERMISSION)

To serve the need for three-hour nontechnical electives in the humanities for freshmen (and others by permission of the instructor), the English Department offers these three courses. They differ from Group II courses in three respects: (1) there are no prerequisites; (2) they focus almost entirely on reading and discussion;

(3) they use literature as a means of broadening the student's interest in and awareness of other humanistic subjects.

114(14). Quest for Utopia. II. *(3)*.
Reading and discussion of some of the major efforts to chart the good society from Plato's *Republic* to Orwell's *1984*. The chief purpose of this survey of utopias and anti-utopias is to help the student assess the values in the present order.

115(15). Literature and Philosophy. II. *(3)*.
Reading and analysis of literature as a means of introducing the student to some major philosophical issues. Authors to be read include Swift, Voltaire, Dostoevsky, and Mark Twain.

116(16). Literature and Art. II. *(3)*.
Reveals and explains the close connections between the literature of a given period and its painting, sculpture, and architecture. The primary emphasis will be on reading with parallels illustrated in the fine arts.

GROUP II: INTERMEDIATE COURSES

Prerequisite: English 111 and 121.

Group II includes courses in composition, speech, and literature. 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. The composition course (English 235) presupposes that the student has mastered the essentials of exposition and is ready for specialized types of writing. The speech course (English 241) with its emphasis on persuasive speaking, presupposes that the student has gained from Group I the ability to organize ideas, use the library, and select evidence from his reading. The literature courses are designed to help the student read with insight as well as pleasure and gain thereby a richer understanding of the nature of man and his world. Themes, outlines, or written analyses are required in each of the courses.

235(35). The Technical Article. *Prerequisite: English 111 and 112.* I and II. *(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 *Scientific American*.

241(41). Public Speaking. *Prerequisite: English 111 and 121.* I and II. *(2)*.
Preparation and delivery of persuasive speeches. Frequent opportunity for practice and class criticism.

251(51). Contemporary Literature. *Prerequisite: English 111 and 121.* I and II. *(2)*.
Reading and analysis of contemporary fiction, drama, and poetry.

255(55). Modern Biography. *Prerequisite: English 111 and 121.* I and II. *(2)*.
Reading and analysis of twentieth-century biographies and autobiographies.

256(56). Short Story. *Prerequisite: English 111 and 121.* I and II. *(2)*.
Reading and analysis of contemporary short stories.

263(63). Contemporary Drama. *Prerequisite: English 111 and 121.* I and II. *(2)*.
Study of representative drama from Ibsen to the present day.

265(65). Contemporary Novel. *Prerequisite: English 111 and 121.* I and II. *(2)*.
Reading and discussion of outstanding European and American novels from about 1890 to the present.

275(75). Contemporary Poetry. *Prerequisite: English 111 and 121.* I and II. *(2)*.
Study of the principal British and American poetry of the twentieth century.

GROUP III: ADVANCED COURSES

Prerequisite: English 111, 112, 121 and one course in Group II.

Group III courses in composition, speech, and literature are specialized and intensive and require more maturity of the student than the courses in Group II. To satisfy the Group III requirement, the student must elect one of these courses, which are open only to juniors, seniors, and graduate students, or present a satisfactory equivalent. The courses may also be taken for credit as nontechnical electives. All courses in this group may be taken for graduate credit, provided that the student has the approval of the instructor and his program adviser and provided that he completes additional work. In each of these courses a considerable amount of writing is required.

419(119). Major Speeches in American History. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2; 3 with permission of instructor*).

A study of selected American speakers and their speeches in relation to the history of the times.

436(136). Scientific and Technical Writing. *Prerequisite: English 111, 112, 121 and one course in Group II.* I and II. (*2*).

The fundamentals of scientific and technical writing with emphasis on clear and orderly exposition.

441(141). Argumentation and Debate. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2*).

Training in the organization and the delivery of the principal types of persuasive speeches, with emphasis on conference speaking and debating.

455(155). American Folklore. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2*).

The life and spirit of the American people as reflected in their folksongs and ballads, tales, legends, superstitions, proverbs and sayings, games, and customs. Extensive use will be made of regional and type collections and of recordings.

457(157). Great Poetry. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*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.

458(158). Literature of Science. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*3*).

Reading and discussion of some classics of scientific literature, such as Darwin's *Origin of Species* and Freud's *A General Introduction to Psychoanalysis,* as well as writings by contemporary scientists on the nature of the scientific method, its application in various fields, and its limitations. The course is designed to extend the student's awareness of the impact of science, especially on man's conception of himself, his society, and his place in the universe.

461(161). Shakespeare. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2*).

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.

462(162). Drama. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2*).

Significant drama in classical, Elizabethan, neoclassic, and modern western civilizations.

467(167). The Novel. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2*).

Significant works of fiction from *Robinson Crusoe* to *Moby Dick,* such as *Tom Jones, Pride and Prejudice,* and *Vanity Fair,* with emphasis upon reading with understanding and delight.

475(175). American Literature. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2*).

Readings in the works of leaders in American thought from the early eighteenth century to the present. The course concentrates on those authors who best represent the changing ideals that have dominated American life in the past and that are important for an understanding of the contemporary American scene.

485(185). Literary Masterpieces. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*2 or 3*).

Distinguished literary works in the Western tradition, from the Greeks to our own day. Typical of the works that have been used are plays by Sophocles, Shakespeare, Ibsen, and Shaw; dialogues by Plato, selections from the Bible and from Machiavelli; poetry by Homer, Dante, Wordsworth, and Frost; fiction by Turgenev, Maupassant, and Katherine Mansfield.

488(188). Literature and Modern Thought. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*3*).

A study of selected works of writers such as Steinbeck, Koestler, and Sartre in the perspective of modern thought.

492(192). Major American Writers. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*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 expression, and their literary significance. Writers are chosen who make possible an integrated exploration of significant cultural developments.

493(193). Major European Writers. *Prerequisite: English 111, 112, 121, and one course in Group II.* I and II. (*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, Kellum, Kesling, Landes, Stumm, Turneaure, and Zumberge; Associate Professors Briggs, Dorr, and Eschmann; Assistant Professors Cloke, DeNoyer, and Kelly.

111(11). Introductory Geology. *Not open to those who have had Geol. 219.* I. (*4*).

An introduction to science through geology. The study of the materials making up the earth, the processes which act upon them, and the effects these processes have on the earth's surface; the development of the tools for the interpretation of the history of the earth; and the major geologic concepts which make geology unique from the other natural sciences. One or more Saturday field trips will be required. Lectures, laboratory, and field trips for an average weekly total of seven hours.

218(98). Geology for Engineers. II. (*4*).

Geologic processes with special emphasis on structural geology, ground water, soil genesis, and the relation of geology to engineering problems. Laboratory

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includes rock and mineral identification, and the interpretation of geologic and topographic maps and aerial photographs. Geol. 218 is required of students in civil engineering and is open to others as an elective. Lectures, laboratory, and field trips.

219(99). Geology and Man. *Not open to freshmen, or to those who have had Geol. 111. (4).*

Geologic processes and their effect of civilization. Lectures and demonstrations.

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 Geol. 112, Introductory Geology; Geol. 280, Minerals and World Affairs; and Geol. 447, Ground Water Geology, are especially useful for engineering students.

INDUSTRIAL ENGINEERING*

400(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 selection, methods, work measurement, methods of wage payment, inspection, organization procedures, production and material control, budgets. A Business Game is used to study dynamic aspects of industrial decisions.

401(170). Introduction to Management Sciences. *Prerequisite: preceded or accompanied by Math. 462 and Ind. Eng. 472, or permission of department.* II. *(3).*

Current studies in management problems, including management games, management design and control of research programs, organization and information theories.

***431(135). Management Control.** *Prerequisite: Ind. Eng. 400 and 463.* I and II. *(3).*

A study of problems in the application of principles of industrial engineering to management personnel, including such things as training, working conditions, safety, wage administration, suggestion systems, employment procedures, labor relations, and nonindustrial application.

***433(125). Human Factors in Engineering Design.** *Prerequisite: Ind. Eng. 400 or permission of instructor.* I. *(3).*

The application by engineers of the data available concerning vision, illumination, color, noise, atmospheric conditions, physical measurements, and the arrangement of controls and equipment in the areas of work place and equipment design. Emphasis will be placed on sources and method of collection of the available data.

434(127)(Psych. 563). Psychology of Management. *Prerequisite: Psych. 101 or graduate standing. Permission of instructor. Credit is not given for both Psych. 263 and 563.*

Primarily for advanced students in psychology, engineering, and business administration. The application of psychological principles to the management of personnel in business and industry. Conference leadership, face-to-face contacts,

*Students not enrolled in the industrial engineering program and not presenting the usual prerequisite may elect courses indicated by * with the permission of the department.

and interviewing situations are analyzed in terms of principles and skill requirements.

***441(140). Production Control.** *Prerequisite: Ind. Eng. 400.* 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.

***445(130). Wage Administration.** *Prerequisite: Ind. Eng. 400.* 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.

***447(110). Plant Layout and Materials Handling.** *Prerequisite: Ind. Eng. 400.* 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.

451(150). Engineering Economy. *Prerequisite: Econ. 401 and Bus. Ad., General 454.* I and II. (*2*).

Economic selection of equipment, consideration of cost, methods of financing, depreciation methods, and the planning of future production.

461. Engineering Statistics II. *Prerequisite: Math. 461.* II. (*3*).

Analysis of variance and regression analysis are developed and applied to a number of industrial experiments. Two-hour lecture and two-hour demonstration.

***463(120). Work Measurement.** *Prerequisite: Ind. Eng. 400.* I and II. (*3*).

Operating methods, work-center layout according to the laws of motion economy, and time-study techniques. Recitations, problems, and demonstrations.

464. Work Simplification. *Prerequisite: Ind. Eng. 463 or permission of department.* II. (*3*).

Application of tools and techniques of work simplification to improve work systems requiring the integration of people, machines, methods, and procedures. Current literature and cases are studied.

466. Quality Control. *Prerequisite: Ind. Eng. 461.* II. (*3*).

Surveys of current practices in acceptance sampling and control charts. Some of the more important quality measuring equipment is discussed and used in experiments. Emphasis is placed on the economics of alternative quality control procedures. Two-hour lecture and two-hour demonstration.

472(160). Operations Research. *Prerequisite: one year of calculus.* 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, and linear programing.

473(165). Data Processing. *Prerequisite: one year of calculus.* I and II. (*3*).

Digital computer arithmetic operations, circuit logic, simple programing, computer data processing in industry, and introduction to computer simulation of industrial operations. Two-hour lecture and two-hour demonstration.

491(190). Study in Selected Industrial Engineering Topics I. *Prerequisite: permission of department.* I and II. (*To be arranged, 3 maximum*).

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 industrial engineering including management, work measurement, methods, organization, industrial sciences, industrial mathematics, systems, and procedures.

522. Theories of Administration. *Prerequisite: Ind. Eng. 431.* II. (*3*).

*Students not enrolled in the industrial engineering program and not presenting the usual prerequisite may elect courses indicated by * with the permission of the department.

Provides insight into theories concerning administration of research and industrial organizations. Wages, rewards and sanctions, delegation concepts, management functions, and labor relations are discussed.

*524(220). **Industrial Management—Field Work.** *Prerequisite: Ind. Eng. 463.* I and II. (*3*).

Principles of production are applied to specific problems in factory management. Inspection trips to manufacturing plants, with problems and discussions based on these trips. A fee is required.

527(245). **Management Games.** *Prerequisite: Ind. Eng. 472 and 473 or permission of department.* I. (*2 or 3*).

Analysis of the structure of representative total enterprise and functional management games, problems of development, the role of the computer, study of applications in research education, and system design .

528(210). **Industrial Engineering Problems.** *Prerequisite: Ind. Eng. 400.* I and II. (*3*).

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.

533(226). **Problems Concerning Human Factors in Engineering Design.** *Prerequisite: Ind. Eng. 534 or 433.* II. (*3*).

Problems and field exercises on the application of human factors to engineering problems. Students will formulate problems, select the experimental or other procedures for their solution, and report the findings.

534(124)(Psych. 560). **Human Performance in Man-Machine Systems.** *Prerequisite: Psych. 101 or 521, or permission of instructor.* II. (*3*).

Introduction to human performance theory, including human capabilities and limitations in man-machine systems. Emphasis on principles applicable in engineering psychology.

541(233). **Inventory Theory I.** *Prerequisite: Ind. Eng. 472 or permission of department.* I. (*3*).

A survey of models of inventory and production control assuming that demand is known. Seasonal demand situations are considered and formulated. Problems involving changing demand and specific cost structure are also considered.

542. **Inventory Theory II.** *Prerequisite: Ind. Eng. 541 and one year of statistics.* II. (*3*).

Inventory problems are considered when demand can only be described in terms of probabilities. Conditions for the optimality of S, s policies are studied. Stability of inventory against random demands is discussed.

546(230). **Industrial Procurement.** *Prerequisite: Ind. Eng. 400.* I. (*3*).

Inventory management, selection of sources, price analysis, standards and specification, organization of a purchasing department, buying policies.

547. **Plant Flow Analysis.** *Prerequisite: Ind. Eng. 447, 472 and 473, or permission of department.* II. (*3*).

Study of assembly line balancing and machine loading, optimal path and network flow analysis using integral linear programing approaches. Equipment and activity location problems. Use of simulation in plant layout and scheduling studies.

551(254). **Advanced Engineering Economy.** *Prerequisite: Ind. Eng. 451.* II. (*2*).

Economic analysis procedures, consideration of replacement, expansion, product and new enterprise analysis and expenditures, capital budgeting, case problems.

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*562(221). **Industrial Systems—Field Work.** *Prerequisite: Ind. Eng. 431.* I. (*3*).
Principles of industrial systems and instrumentation are applied to specific problems in factory operation. Inspection trips to manufacturing plants with problems and discussion based on these trips. A fee is required.

563(223). **Advanced Work Measurement.** *Prerequisite: Ind. Eng. 463.* I. (*2*).
Application of work sampling and memo-motion techniques as methods of work measurement; use of standard data time standards and their determination by actual time study, motion pictures, predetermined time standards systems. Recitations and demonstrations.

571(255). **Queueing Theory I.** *Prerequisite: one year of statistics.* I. (*3*).
An introduction to mathematical probability theory from the industrial engineering point of view. Simple Markov queueing processes are considered.

572. **Optimization in General Systems.** *Prerequisite: Ind. Eng. 401 or permission of department.* II. (*3*).
The problem of searching for an optimum policy when it cannot be solved by a standard programing code. Various general extreme value search procedures with and without estimation errors and self-improving codes are considered.

573. **Simulation.** *Prerequisite: Ind. Eng. 473.* I. (*3*).
The use of a digital computer as a simulator of industrial processes. Construction of flow charts, fixed time increment and time status register methods of organization. Experimental designs for computer experiments are considered and students will run simple simulations.

575. **Linear Programing.** *Prerequisite: Ind. Eng. 472 or permission of department.* I. (*3*).
An introduction to programing. Primary attention is focused on linear programing. The abstract structure of the problem is discussed. A number of examples of uses of linear programing are introduced. Machine codes for solution are discussed and used.

591(200). **Study in Selected Industrial Engineering Topics II.** *Prerequisite: Ind. Eng. 491.* I and II. (*To be arranged*).
Continuation of Ind. Eng. 491.

631. **Advanced Management Controls.** *Prerequisite: Ind. Eng. 431 or permission of department.* I. (*3*).
Studies of current information devoted to formal methods for analyzing management control problems. The course uses actual cases as well as current publications and consists of further investigations and solution of those cases.

641. **Advanced Production Control II.** *Prerequisite: Ind. Eng. 541.* I. (*2*).
The use of operations research techniques in production smoothing and scheduling. Applications of mathematical methods of sequencing and loading to optimization of facility utilization, interaction with inventory policies, and design of complex production control systems.

644. **Production Design.** *Prerequisite: Ind. Eng. 447 and 524 or permission of department.* II. (*3*).
The co-ordination of product design with the necessary manufacturing processes. Evaluation of the available facilities is made with possible alternative facilities for management decision. Case studies are selected from actual industrial situations.

645. **Executive Compensation and Incentives.** *Prerequisite: Ind. Eng. 445.* I. (*3*).
Considerations in the selection and design of executive salary and fringe benefit policies. Problems of motivation and morale, development, recruitment and performance measurement. Effect of management environment on performance.

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649. Automatic Process Control I. *Prerequisite: Math. 372, Mech. Eng. 381, Ind. Eng. 473.* I. (*3*).
Introduction to automatic control of manufacturing processes; Laplace transformations and their application to design of process control systems; numerically controlled machine tool synthesis, application and programing problems.
722(260). Great Works of Scientific Management. *Prerequisite: permission of department.* II. (*3*).
Acquaints the industrial engineer with the origins of his profession and develops an understanding of the creative process in this area. The works of the founders of scientific management and original papers by outstanding men in the field will be studied and discussed.
806(240). Seminar in Special Industrial Engineering Topics. *Prerequisite: Ind. Eng. 463 or permission of department.* II. (*2*).
876(250). Seminar in Operations Research I. *Prerequisite: permission of department.* I. (*1 or 2*).
878(251). Seminar in Operations Research II. *Prerequisite: permission of department.* II. (*1 or 2*).

INSTRUMENTATION ENGINEERING

510(175). Applications of the Electronic Differential Analyzer I. *Prerequisite: a course in differential equations.* I and II. (*3*).
Basic theory and principles of operation of electronic differential analyzers. Applications to one and two degree-of-freedom vibration problems, automatic control systems, heatflow, eigenvalue problems, nonlinear vibration problems, and other selected topics. Lecture and laboratory. Laboratory consists of the solution of problems on the electronic differential analyzer.
530(177). Probability in Instrumentation. *Prerequisite: a course in differential equations.* I and II. (*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.
570(174). Principles of Automatic Control. *Prerequisite: Eng. Mech. 343, Elec. Eng. 210 or 315 and a course in differential equations.* I and II. (*3*).
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.
571(174a). Automatic Control Laboratory. *Prerequisite: to be taken concurrently with or following Instr. Eng. 570.* I and II. (*1*).
Laboratory experiments covering the automatic control theory presented in Instr. Eng. 570. Use of the electronic differential analyzer for simulation and as a design tool.
610(275). Applications of the Differential Analyzer II. *Prerequisite: Instr. Eng. 510 or equivalent.* (*3*).
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.

612(178). Design of Electronic Analog Computers. *Prerequisite: Elec. Eng. 438 or equivalent and Instr. Eng. 570 or Elec. Eng. 445. (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 servo-multipliers, time-division multipliers, function-generators, drift-stabilized power supplies, and other selected topics. Lectures and laboratory.

620(250). Introduction to Nonlinear Systems. *Prerequisite: Math. 404 and 450.* I and II. *(3).*

Study of systems represented by nonlinear autonomous (unforced) differential equations, including the following: concept of phase space; singular points and their stability; conservative systems; limit cycles; jump phenomena; Van der Pol's equation; index of Poincare; theorems of Bendixson. Many physical examples are used to illustrate the theory. Solutions are illustrated on the electronic differential analyzer.

621(252). Simulation and Solution of Nonlinear Systems. *Prerequisite: Instr. Eng. 510 and preceded or accompanied by Instr. Eng. 620 or permission of instructor. (1).*

Supervised work on assigned problems and problems of interest to the student of the types treated in Instr. Eng. 620 and 720. The principal tool used is the electronic differential analyzer.

640(214). Information Theory and Data Transmission. *Prerequisite: Instr. Eng. 530, Elec. Eng. 438, and Math. 548. (3).*

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

641(215). Radio Telemetry Laboratory. *Prerequisite: to be taken concurrently with or following Instr. Eng. 640. (1).*

Laboratory experiments involving the various modulation and multiplex methods and associated instrumentation described in Instr. Eng. 640.

660(210). Theory and Design of Measuring Systems. *Prerequisite: Instr. Eng. 530 and Math. 548.*

Static response, static sensitivity, calibration. Analysis of dynamic response. Statistical aspects of measurement including estimation of statistical parameters, theory of random processes, correlation, and spectral functions. Instrument errors and their propagation. Application of information theory to design of measuring systems. Analysis and laboratory investigation of instruments to measure such things as displacement, velocity, acceleration, pressure, temperature, stress, and strain. Lectures and laboratory.

670(248). Feedback Control. *Prerequisite: Instr. Eng. 570 or Elec. Eng. 445 and Math. 548.* I and II. *(2).*

Alternating current carrier systems; design and use of operational amplifiers as control system elements. Analysis and synthesis of nonlinear control systems; phase plane and describing function methods. Sampled data feedback systems and z transforms. Response of linear control systems to random inputs; correlation functions and spectral densities; optimum linear filtering.

671(249). Feedback Control Laboratory. *Prerequisite: to be taken concurrently with or following Instr. Eng. 670.* I and II. (*1*).

Laboratory experiments covering the feedback control theory given in Instr. Eng. 670.

672(274). Sampled Data Systems. *Prerequisite: Instr. Eng. 570 and Math. 548 or equivalent.* (*2*).

Concept and implications of sampling, interpolation and extrapolation; operational methods for analysis of linear systems with sampled data inputs including transforms, modified z transforms, stability determination, and evaluation of dynamic and steady state response; analysis and synthesis of sampled data feedback systems by time and frequency domain techniques; synthesis of compensation transfer functions with digital computers and lumped element linear systems; multiple rate systems; finite width sampling; analysis and synthesis of linear systems with sampled random inputs; z-transform and z-form techniques for numerical analysis.

700(273). Theory of Linear Time-Variant Systems. *Prerequisite: Math. 548.*

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 electronic differential analyzer for the solution of problems is demonstrated.

720(251). Theory of Nonlinear System Response. *Prerequisite: Instr. Eng. 620.* (*2*).

Principally considered are forced systems with 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 response and synchronization and entrainment of oscillatory systems are considered. Various methods of analysis are treated.

730(277). Random Processes in Instrumentation and Control. *Prerequisite: Instr. Eng. 530 or equivalent and Math. 450 or equivalent.* (*3*).

Introduction to random processes; behavior of time-invariant linear systems with stationary random inputs; optimum filtering and prediction for stationary processes; treatment of time varying and nonlinear systems with random inputs; interpolation and filtering of sampled data.

732(278). Special Topics in Random Processes. *Prerequisite: Math. 548 or equivalent; Instr. Eng. 730 or Elec. Eng. 634 or equivalent.*

Topics of current research interest to be selected from among the following: detection theory, nonlinear devices with random inputs, generalizations of Wiener optimum filtering, estimation of spectra, noise in sampled data systems.

770(276). Special Topics in Automatic Control. *Prerequisite: Instr. Eng. 570 or Elec. Eng. 445 or equivalent, and Math. 548 or equivalent.* (*3*).

Minimum mean-square or integral-square design of linear feedback systems; multipole control systems; final value controllers; perturbation methods for control of complex nonlinear systems; optimalizing control; optimizing control; adaptive control systems; other selected topics taken from recent literature.

800(385). Seminar. (*To be arranged*).

810(170). Seminar on Electronic Analog Computers. *Prerequisite: 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.

900(183). Directed Study. (*To be arranged*).

Individual study of specialized aspects of instrumentation engineering.

902(184). Research. *(To be arranged).*
Specialized individual or group problems of research or design instrumentation supervised by a member of the staff.

MATHEMATICS*

Professor Hay; Professors Bartels, Carver, Cesari, Churchill, Coburn, Copeland, Craig, Darling, Dolph, Dwyer, Fischer, Heins, P. S. Jones, Kaplan, LeVeque, Lyndon, Nesbitt, Piranian, Rainville, Reade, Rothe, Savage, Thrall, and Wilder; Associate Professors Brumfiel, Dushnik, Gehring, Harary, Higman, Kazarinoff, Mayerson, McLaughlin, Ritt, Schaefer, Shields, Titus, Wendel, and Wesler; Assistant Professors Addison, Brown, Clarke, Dickson, Galler, Griffin, Halpern, Hughes, D. A. Jones, Kincaid, Leisenring, Livingstone, Minty, and Ullman; Instructors Al-Amiri, Bragg, Cohn, Courtney, Dubinsky, Eggan, Hedstrom, Hicks, Kister, Lee, Low, Ramanujan, Rosen, and Stoddard; Lecturers Arden, Evans, Jebe, Mrowka, Patil, Shimrat, and Sleator.

100(6). Solid Euclidean Geometry. *Prerequisite: one year of plane geometry.* I and II.
Postulates; basic constructions and propositions; original exercises, mensuration.

101(7). Algebra and Trigonometry. *Prerequisite: one year of plane geometry.*
Review of elementary operations; linear equations; exponents; radicals; quadratic equations; simultaneous quadratics, progressions; binomial theorem. Trigonometry—same as in Math. 103.

103(8). Trigonometry. I and II.
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.

233(33). Analytic Geometry and Calculus I. *Prerequisite: one and one-half years of high school algebra; one year of plane geometry; one-half year of trigonometry.* I and II. *(4).*
Review of school algebra, binominal theorem; functions and graphs; straight lines and conics; derivatives, differential of algebraic functions, applications; introduction to integration.

234(34). Analytic Geometry and Calculus II. *Prerequisite: Math. 233.* I and II. *(4).*
Inequalities; theory of equations and curve tracing; differentiation and integration of trigonometric, logarithmic, and exponential functions; polar co-ordinates; moments; formal integration.

241(13). Algebra and Analytic Geometry. *Prerequisite: one and one-half years of high school algebra; one year of plane geometry; one-half year of trigonometry.* 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.

242(14). Plane and Solid Analytic Geometry. *Prerequisite: Math. 241.* I and II. *(4).*
Properties of conics involving tangents and asymptotes; parametric equations; surface tracing and locus problems in space; plane; straight line; quadric surfaces; space curves; introduction to calculus, differentiation of algebraic functions.

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243(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. 233 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.

298, 299(17, 18). Analytic Geometry and Calculus. *Prerequisite: permission of chairman of the department, 3220 Angell Hall.* 298, I; 299, II. (*4 each*).

For better students who would normally take Math. 241, 242, and 363. There is deeper penetration into many topics and some acceleration. Followed by Math. 397.

335,336,337(35,36,37). Analytic Geometry and Calculus. *Prerequisite: permission of chairman of department, 274 West Engineering or 3220 Angell Hall.* 335, I; 336, II; 337, I. (*4 each*).

For students well qualified in mathematics. Material covered is approximately that included in Math. 233, 234, 371, and 372.

352(52). Calculus I. *Prerequisite: Math. 222.* 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. 363. Followed by Math. 369 or 371.

363(53). Calculus I. *Prerequisite: Math. 242.* I and II. (*4*).

Functions; limits; continuity; derivative; differentiation of trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; integration.

364(54). Calculus II. *Prerequisite: Math. 363 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 integral; introduction of differential equations.

371(55). Analytic Geometry and Calculus III. *Prerequisite: Math. 234.* I and II. (*4*).

Arc length, curvature; elements of solid analytic geometry; partial derivatives, multiple integrals, complex numbers.

372(56). Analytic Geometry and Calculus IV. *Prerequisite: Math. 371.* I and II. (*4*).

Infinite series, first order differential equations, linear differential equations with constant coefficients; permutations and combinations; elementary probability and statistics; additional topics in algebra and analysis.

373(73). Elementary Computer Techniques. *Prerequisite: to be taken concurrently with Math. 299, 336, 352, 363, 371 or equivalent.* I and II. (*1*).

To cover mathematical methods used on electronic computers and the ways one communicates with a computer. Students will have the opportunity to write a program for the computer.

403(103). Introduction to Differential Equations. *Prerequisite: Math. 364 or 372.* I and II. (*3*).

Solutions and applications of differential equations of the first order; linear equations with constant coefficients; linear equations of the second order; solution by the power series method applications.

404(104). Differential Equations. *Prerequisite: Math. 372.* I and II. (*3*).

Systems approach to linear differential equations and physical applications. Simultaneous linear equations, solution by matrices. Power series solutions. Numerical methods. Phase plane analysis of nonlinear differential equations.

415(113). Introduction to Matrices. *Prerequisite: Math. 412 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.

445(145). Celestial Mechanics. *Prerequisite: Math. 403 and 441 or equivalent.* I. (*3*).

Mathematical theory of the motion of astronomical bodies. Problems of two, three, and n bodies.

447(147). Modern Operational Mathematics. *Prerequisite: Math. 403 or 404 or 450 or 551.* I and II. (*2*).

Laplace transformation, with emphasis on its application to problems in ordinary and partial differential equations or engineering and physics; vibrations of simple mechanical systems, of bars and shafts; simple electric circuits, transient temperatures, and other problems.

450(150). Advanced Mathematics for Engineers. *Prerequisite: Math. 364 or 372 and preferably Math. 403 or 404.* I and II. (*4*).

Topics in advanced calculus including infinite series, Fourier series, improper integrals, partial derivatives, directional derivatives, line integrals, Green's theorem, vector analysis. Students cannot receive credit for both Math. 450 and 551.

452(152). Fourier Series and Applications. *Prerequisite: Math. 450 or 551.* I and II. (*3*).

Orthogonal functions, Fourier series, Bessel functions, Legendre polynomials and their application to boundary value problems in mathematical physics.

455(155). Introduction to Functions of a Complex Variable with Applications. *Prerequisite: Math. 450 or 551.* I and II. (*3*).

Complex numbers; limit, continuity; derivative; conformal representation; integration; Cauchy theorems; power series; singularities; applications to engineering and mathematical physics.

461(161). Statistical Methods for Engineers. *Prerequisite: Math. 364 or 372.* I and II. (*3*).

Statistical methods of quality control; normal, binomial, and Poisson distributions; Shewhart control chart; sampling methods in scientific acceptance inspection. Math. 461 and 462 together form an introductory course especially designed for the needs of engineers in both experimental work and the flow of production.

462(162). Statistical Methods for Engineers II. *Prerequisite: Math. 461 or 561.* I and II. (*3*).

Significance tests; tests valid for small samples; introduction to linear correlation; elementary design of experiments.

473(173). Introduction to Digital Computers. *Prerequisite: Math. 364 or 372 and 373 or permission of instructor.* I and II. (*3*).

Characteristics and logic of general purpose high-speed digital computers; introduction to logical design. The concept of algorithm, language, and symbol manipulation as applied to computer instruction. Computational methods for linear systems, differential equations, linear programing, etc. Laboratory work in programing and operating the IBM 704 computer.

474(174). Numerical Analysis. *Prerequisite: Math. 403 or 404 and 415 and 473 or equivalent.* I. (*3*).

The mathematics used with high-speed electronic computing machines. Presents attacks on: integration of ordinary differential equations, solution of large-scale linear systems, determination of eigenvalues and eigenvectors, integration of partial differential equations, functions evaluation; coding and solution of problems on IBM 704 computer.

475(175). Theory of the Potential Function. *Prerequisite: Math. 450 or 551.* II. (*3*).

Newtonian attraction, Newtonian and logarithmic potentials, equations of Laplace and Poisson, harmonic functions, principle of Dirichlet, problems of Dirichlet and Neumann, and Green's function.

476(176). Vector Analysis. *Prerequisite: Math. 364 or 372.* I and II. (*2*).

The formal processes of vector analysis with applications to mechanics and geometry.

517(117). Introduction to Linear Algebra and Its Application. *Prerequisite: one course beyond calculus or permission of instructor.* I and II. (*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 social sciences.

518(118). Optimization in Linear Systems. *Prerequisite: Math. 517 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. 727.

548(148). Operational Methods for Systems Analysis. *Prerequisite: preferably Math. 403 or 404 and 450 or 551.* I and 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.

551(151). Advanced Calculus. *Prerequisite: Math. 364 or 373 and preferably Math. 403 or 404.* 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. Students cannot receive credit for both Math. 450 and 551.

557(157). Intermediate Course in Differential Equations. *Prerequisite: Math. 403 or 404 and 450 or 551 or equivalent.* 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.

561(163). Theory of Statistics I. *Prerequisite: Math. 364 or 372.* 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 Math. 562. Students cannot receive credit for both Math. 451 and 561.

562(164). Theory of Statistics II. *Prerequisite: Math. 561.* I and II. (*4*).

Significant tests and confidence limits for large samples; exact sampling theory including derivation and the use of Student-Fisher t; variance ratio and $\chi 2$; correlation and regression; the bivariate normal distribution; introduction to multivariate analysis. Students cannot receive credit for both Math. 462 and 562.

566(166). Analysis of Variance and Experimental Design. *Prerequisite: Math. 562 or permission of instructor.* I. (*3*).

Introduction to the theory of significance tests. Exact significance tests in samples from normal. The likelihood ratio principles; the method of least squares. Randomized complete blocks, Latin squares, factorial designs; incomplete blocks. The analysis of covariance; variance components; principles of experimental design.

742(242). Problems in Heat Conduction and Diffusion. *Prerequisite: equivalent of two of courses Math. 447, 452, 455, and 749.* (*2*).

Equations of diffusion and boundary conditions. Illustrations of methods of analyzing transient and steady diffusion in solids. Applications of Fourier methods and their generalizations; various integral transforms, Green's functions. Conformal mapping. Properties of flow; scaled methods.

747(247). Mathematical Elasticity. *Prerequisite: Math. 441, 442, 455.* 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. Curvilinear co-ordinates. Plane problems, and the method of conformal mapping. Airy's stress function and the biharmonic equation; thin plates and shells.

749(249). Methods of 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.

750(250). Methods of Mathematical Physics I. *Prerequisite: Math. 450, 452 and 455 or the equivalent.* I. (*3*).

Regular integral equations, Sturm-Liouville systems. Asymptotic developments by saddle point and stationary phase methods. First order partial differential equations.

751(251). Methods of Mathematical Physics II. *Prerequisite: Math. 750 or permission of instructor.* II. (*3*).

Classification of partial differential equations, representation theorems. Selected topics, such as direct methods and singular differential and integral equations.

757(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.

777(277). Tensor Analysis. II. (*3*).

Definition of tensors; tests for tensor character; manifolds; geodesics, absolute derivatives, covariant and controvariant derivatives; the curvature tensor; relative tensors; Cartesian tensors; applications to mechanics, elasticity, hydrodynamics, heat conduction, electricity, and magnetism.

MECHANICAL ENGINEERING

251(31). Manufacturing Processes I. *Prerequisite: Chem.-Met. Eng. 250 and preceded or accompanied by Eng. Mech. 210.* I and II. (*3*).

Fundamentals of manufacturing processes. Effect of the process on surface condition, residual stresses, strain hardening, wear, and failure. Influence of the mechanical properties of materials on the process. Material selection for processing and design. Two recitations and one three-hour laboratory.

252(2). Engineering Materials and Manufacturing Processes. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 250.* 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; 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.

324(104). Fundamentals of Fluid Machinery. *Prerequisite: Mech. Eng. 335 and Eng. Mech. 324.* I and II. (*4*).

Theory, construction, and operation of the principal types of fluid machinery. Three one-hour lectures and one three-hour laboratory.

333(13). Thermodynamics and Heat Transfer. *Prerequisite: Physics 145 and Math. 371.* I and II. (*4*).

Basic thermodynamics, first law, second law, properties of a pure substance, ideal gases, and gaseous mixtures, application to heat-power machinery. Study of mechanism of heat transfer processes. Conduction, thermal radiation, and convective processes. Not open to mechanical engineering students.

334(14). Heat-Power Laboratory. *Prerequisite: Mech. Eng. 333 or permission of instructor.* I and II. (*1*).

The application of thermodynamics and heat transfer to various types of machinery, equipment, and instrumentation. One three-hour laboratory. Not open to mechanical engineering students.

335(105). Thermodynamics I. *Prerequisite: Physics 145 and Math. 371.* 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.

336(106). Thermodynamics II. *Prerequisite: Mech. Eng. 335 and Math. 372.* I and II. (*4*).

Continuation of Mech. Eng. 335. Power and refrigeration cycles; flow through nozzles and blade passages; general thermodynamic relations, equations of state, and compressibility factors; chemical reactions; combustion; gaseous dissociation. Three one-hour lectures and one three-hour laboratory.

337(17). Mechanical Engineering Laboratory. *Prerequisite: preceded or accompanied by Mech. Eng. 335.* I and II. (*2*).

Demonstration and application of basic principles in various areas of mechanical engineering; instrumentation and the reliability of measurements; behavior and nature of typical machinery and equipment. One four-hour period. Not open to mechanical engineering students.

340(80). Dynamics of Machinery. *Prerequisite: Eng. Mech. 343.* I and II. (*4*).

Mechanical vibrations; problems in kinematic and dynamic analysis of machines; static, friction, and inertial forces in mechanical systems. Three one-hour periods, and one three-hour laboratory.

343(83). Machine Design. *Prerequisite: Eng. Mech. 210 or 310, and 343.* I and II. (*3*).

Introduction to machine design, for students not in Mechanical Engineering. Incorporates elements of Mech. Eng. 340 and 362. Three one-hour periods.

362(82). Machine Design I. *Prerequisite: Eng. Mech. 210 and preceded or accompanied by Chem.-Met. Eng. 270.* I and II. (*3*).

Application of the principles of mechanics, materials, and manufacturing to the design of machine elements. Three one-hour periods.

371(111). Heat Transfer I. *Prerequisite: Mech. Eng. 335 and Eng. Mech. 324.* I and II. (*4*).

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. Three one-hour lectures and one three-hour laboratory.

381(33). Manufacturing Processes II. *Prerequisite: Mech. Eng. 251.* I and II. (*3*).

A study of machining, welding, and plastic forming of materials; analysis of forces, energy requirements, and temperature effects; design specifications economically obtainable in terms of dimensional accuracy, surface finish, and material properties; functional characteristics of equipment. Two recitations and one three-hour laboratory.

398(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.

408(108). **Experimental Research in Mechanical Engineering.** *Prerequisite: Mech. Eng. 324 and 336 or 337 or 340 and 362 and permission of instructor.* I and II. *(3)*. Not for graduate credit.

Individual or group experimental research in a field of interest to the student under the direction of a member of the Mechanical Engineering Department. Topics may be selected from a list offered each semester including such areas as air conditioning, automotive engineering, fluids, heating, heat transfer, machine design, materials, processing, thermodynamics. The student will submit a report. Two four-hour laboratories per week. Time to be arranged.

417(137). **Plastic Forming of Metals I.** *Prerequisite: Mech. Eng. 251 and Math. 403 or 404.* I and II. *(3)*.

Plastic deformation of metals with respect to their mechanical properties and metallurgical characteristics. Introduction to Cartesian tensors; analysis of stress, strain and displacement; elastic stress strain relations; yielding criteria; theory of dislocation and slip mechanism; plastic stress strain relations, theory and experimental data; temperature and strain rate effect; work of deformation; slip line fields.

421(141). **Dynamics and Thermodynamics of Compressible Flow.** *Prerequisite: Mech. Eng. 336 and 371.* 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.

422(142). **Design Theory of Fluid Machinery.** *Prerequisite: Mech. Eng. 324.* I. *(3)*.

The laws of thermodynamics, laws of motion and flow of fluids as applied to the design theory of axial and radial flow turbo-machinery.

432(112). **Combustion.** *Prerequisite: Mech. Eng. 336, preceded or accompanied by Mech. Eng. 371 or equivalent.* II. *(3)*.

Introduction to combustion processes, reaction kinetics, ignition and flame propagation. Combustion of sprays. Detonation, temperature, and radiation. Spectrographic analysis. Optical methods for combustion studies. Otto, diesel, gas turbine, and rocket combustion.

437(107). **Applied Energy Conversion.** *Prerequisite: Mech. Eng. 336 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, nuclear energy power plant economics, load curves, energy rates. Selected power plant problems are assigned.

460(86). **Machine Design II.** *Prerequisite: Mech. Eng. 340 and 362.* I and II. *(3)*.

Independent design of a machine, including layout, analysis, and critical review. Two four-hour periods a week.

461(151). **Instrumentation and Automatic Control.** *Prerequisite: Math. 403 or 404, preceded or accompanied by Elec. Eng. 442 or equivalent.* I. *(3)*.

Methods and instruments for measuring and recording displacement, velocity, acceleration, and force; introduction to the principles of automatic control systems encountered in mechanical engineering; the Laplace transform; the Nyquist criterion; design considerations for feedback control systems.

463(183). **Wear Considerations in Design.** *Prerequisite: Mech. Eng. 362 or 343.* II. (*3*).
Design of machine members to avoid surface damage due to wear, pitting, scoring, frettage, and cavitation. Application to the design of press-fitted, keyed, and bolted assemblies; bearings, gears, cams, pumps, and liners.

465(185). **Mechanical Analysis Laboratory.** *Prerequisite: Mech. Eng. 340.* I and II. (*3*).
Laboratory use of instrumentation to measure forces, stresses, displacement, pressure, etc., in mechanical devices; use of transducers, display and recording devices, and of the analog computer for experimental analysis; short experiments plus squad projects; lectures, laboratory, brief reports. Two three-hour periods per week.

467(187). **Lubrication and Bearing Analyses.** *Prerequisite: Mech. Eng. 362.* II. (*3*).
Viscosity; hydrostatic and hydrodynamic analysis of journal and thrust bearings; lubrication of rolling surfaces; thin-film lubrication; bearing materials; methods of lubrication; bearing design.

480(181). **Design of Manufacturing Equipment.** *Prerequisite: Mech. Eng. 362.* I. (*3*).
Specification, design, construction, and operation of production machines and allied tooling. Consideration of bearings, lubrication, motors, controls and materials. Hydraulic and electric control units and circuits.

481(171). **Dimensional and Quality Control.** *Prerequisite: Mech. Eng. 381.* II. (*3*).
Various methods and instrumentation for inspecting and controlling dimensions of fabricated products. Mechanical, electrical, statistical, and other methods for flaw detection, surface finish, and size control. Two two-hour periods.

482(132). **Manufacturing Engineering.** *Prerequisite: Mech. Eng. 381.* I and II. (*3*).
Application of fundamental principles to problems arising in manufacturing. Particular attention is devoted to planning operations, designing special equipment, statistical quality control, cost analysis and reduction, and similar functions which engineers perform in connection with manufacturing. Two one-hour periods and two two-hour laboratories.

483(133). **Analysis of Manufacturing Processes.** *Prerequisite: Eng. Mech. 210 and Mech. Eng. 340.* I and II. (*3*).
Principles, methods, and instrumentation used in making engineering analyses of product design and machining processes; planning of investigations; design of mechanical dynamometers; electrical strain gages; transducer characteristics; related topics. Two lectures and two three-hour laboratories.

484(173). **Gas Welding.** *Prerequisite: Mech. Eng. 487 or permission of instructor.* I and II. (*2*).
Techniques and gas welding, brazing, flame cutting of ferrous and nonferrous materials. Emphasis on gas welding metallurgy; heat treatment of weldments. Visual, mechanical, and metallurgical inspection of weldments. Study of equipment, accessories, supplies, plant layout, supervision, certification, production procedures, cost analysis, welding safety, and introduction to research problems. One hour recitation and three-hour laboratory. Graduate credit not allowed for mechanical and industrial engineering students.

485(174). **Electric Welding.** *Prerequisite: Mech. Eng. 487 or permission of instructor.* I and II. (*2*).
Scientific study of techniques; filler materials; arc, inert and automatic arc, and resistance welding. Study of welding metallurgy; failures and stress analysis. Destructive and nondestructive weldment tests; micro preparations and examinations. Welding of aluminum, high temperature alloys, pipes, bases, pressure vessels, and structures. Study of designing; symbols, joints, weldments, and introduction to research problems. One hour recitation and three-hour laboratory. Graduate credit not allowed for mechanical and industrial engineering students.

486(182). Manufacturing Considerations in Design. *Prerequisite: Mech. Eng. 362 or 343.* II. (*3*).
Correlation between functional specifications and process capabilities. Study of tolerances on basis of fabricability. Case studies in process engineering, including standards application. Problems in redesign for producibility.

487(172). Welding. *Prerequisite: Mech. Eng. 381.* I. (*3*).
Study of mechanism of surface bonding, welding metallurgy, effect of rate of heat input on resulting micro-structures, residual stresses and distortion, economics and capabilities of the various processes.

490(123). Industrial Air Conditioning. *Prerequisite: Mech. Eng. 335 or 333.* 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.

491(125). Heating and Air Conditioning. *Prerequisite: Mech. Eng. 335.* 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.

492(126). Design of Heating and Air-Conditioning Systems. *Prerequisite: Mech. Eng. 491.* 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.

493(164). Gas Turbine Engines. *Prerequisite: Mech. Eng. 336.* I. (*3*).
Design point analysis of gas turbine powerplants, performance of basic cycle arrangements, aircraft jet propulsion; compressor, turbine and combustor characteristics.

494(166). Design of Gas Turbine Engines. *Prerequisite: Mech. Eng. 493 and 362.* II. (*3*).
Preliminary design of gas turbine powerplants; component matching and off-design performance: compressor, turbine, and combustor design. Two two-hour periods.

495(165). Analysis and Design of Rocket Engines. *Prerequisite: Mech. Eng. 336, preceded or accompanied by Mech. Eng. 324 and 371.* II. (*3*).
Application of gas dynamics and heat transfer to rocket engines; propellant thermo-chemistry, feed system hydraulics, design of liquid and solid propellant rockets; advanced rocket propulsion systems.

496(114). Internal-Combustion Engines. *Prerequisite: Mech. Eng. 336.* I and II. (*3*).
Comparison of characteristics and performance of the several forms of internal combustion engines including the Otto and Diesel types of piston engines, gas turbines, ramjets, and rockets; thermodynamics of cycles, combustion, ignition, fuel metering and injection, supercharging, and compounded engines.

497(155). Automotive Laboratory. *Prerequisite: preceded or accompanied by Mech. Eng. 496.* I and II. (*3*).
Experimental study of automobile and aircraft engines, including horsepower, fuel economy, thermal efficiency, mechanical efficiency, energy balance, indicator cards, carburetion, compression ratio, electrical systems, and road tests for car performance. Laboratory and reports. Four or five hours each week.

498(154). Automotive Chassis. *Prerequisite: Mech. Eng. 362.* I. (*3*).
Design of automobile and truck suspensions, steering, brakes, drive lines, axles, frames, bodies, and cabs. Acceleration, gradability, stability, and ride comfort. Power-weight ratio. Engine-transmission compatibility. Problems of performance and economy.

517(237). Plastic Forming of Metals II. *Prerequisite: Mech. Eng. 417 or equivalent.* II. (*3*).

Application of the principles of plasticity to the forming processes. Analysis of extrusion of ideal plastic materials and strain hardening materials. Analysis of wire drawing, rolling, forging and deep drawing. Application of slip lines to extrusion and forging. Bendability of metals.

524(144). **Fluid Mechanics II.** *Prerequisite: Eng. Mech. 324 and Math. 450 or 551.* I. (*3*).

Dimensional analysis, basic concepts, equations of continuity, stream lines and stream surfaces, vorticity and circulation; equations of motion; irrotational flow theory, mathematical techniques for solution of flow equations; complex variables, conformal mapping with applications to solution of two-dimensional flow problems.

531. **Statistical Thermodynamics.** *Prerequisite: Mech. Eng. 336, Math. 403 or 404.* I. (*3*).

Introduction to statistical methods for evaluating thermodynamic and transport properties. Elements of quantum mechanics, statistical mechanics, and kinetic theory, as applied to engineering thermodynamics.

535(205). **Advanced Thermodynamics.** *Prerequisite: Mech. Eng. 336.* I. (*3*).

Definitions and scope of thermodynamics, first and second laws, Maxwell's relations, Clapeyron relation, equation of state, thermodynamics of chemical reactions, availability.

539(129). **Cryogenics and Refrigeration.** *Prerequisite: Mech. Eng. 336 and preceded or accompanied by Mech. Eng. 371.* II. (*3*).

Theoretical and design aspects of producing temperatures below ambient. Vapor compression systems; absorption systems; liquefaction and separation of air; liquefaction and properties of cryogenic fluids; insulation problems; and unique phenomena at extremely low temperatures.

540(180). **Mechanical Vibrations.** *Prerequisite: Mech. Eng. 340 or 343.* 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.

541(184). **Synthesis of Mechanisms.** *Prerequisite: Math. 372 and Mech. Eng. 340 or 343.* I. (*3*).

Vector and complex function analysis of mechanisms with emphasis on space mechanisms. A survey of various methods used in synthesis of linkages. Kinematically equivalent linkages. Analysis and design of cams. Mechanical computing mechanisms. Mechanism trains.

556(186). **Stress Considerations in Design.** *Prerequisite: Mech. Eng. 362 or 343.* 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.

563(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.

567. **Reliability Consideration in Design.** *Prerequisite: Mech. Eng. 362 or 343, or equivalent.* I. (*3*).

Design of machines and machine members to insure reliability in field and service. The concept of value, system, and system effectiveness. Design reliability versus quality control. Techniques for predicting reliability. Design of experiments. The feedback approach to reliability. Statistical tolerances. Failure analysis.

571(211). Heat Transfer II. *Prerequisite: Mech. Eng. 335, 371, and Math. 403 or 404.* I. (*3*).

Conduction heat transfer in steady and transient state, including heat sources. Analytical, numerical, graphical, and analog methods of solution for steady and fluctuating boundary conditions. Thermal stresses. Dynamics of thermal instrumentation and heat exchangers.

583(273). Machinability. *Prerequisite: Mech. Eng. 482 or 483.* 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.

594(214). Advanced Theory of Internal-Combustion Engines. *Prerequisite: Mech. Eng. 496.* 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.

595(255). Advanced Automobile Testing and Research. *Prerequisite: Mech. Eng. 497 and permission of instructor.* I and II. (*3*).

Advanced experimental and research work. Laboratory and reports.

598(240). Theory of Land Locomotion. *Prerequisite: Math. 403 or 404 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 offroad operation.

599(242). Land Locomotion Laboratory. *Prerequisite: Mech. Eng. 498 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.

600(200). Study or Research in Selected Mechanical Engineering Topics. *Prerequisite: 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. The student will submit a report on his project and give an oral presentation to a panel of faculty members at the close of the semester.

607(207). Advanced Mechanical Engineering Problems. *Prerequisite: preceded by Math. 403 or 404.* 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, processing, and materials.

625(145). Introduction to Viscous Flow Theory. *Prerequisite: Mech. Eng. 524 or Eng. Mech. 422 or permission of instructor.* II. (*3*).

Fundamental concepts, the Navier-Stokes equations, exact and approximate solutions of the Navier-Stokes equations; stability of laminar flow, turbulent flow, basic equations, isotropic turbulence, turbulent diffusion, turbulent shear flow; boundary layers.

672(212). Heat Transfer III. *Prerequisite: Mech. Eng. 335 and 371.* II. (*3*).

Study of the nature of convective processes involving the transfer of heat, mass and momentum. Boundary layer theory. Analogy between heat and momentum transfer. Condensation and boiling phenomena, two-phase flow. Natural convective processes, steady and transient diffusion, mass transfer between phases.

673(213). Heat Transfer IV. *Prerequisite: Math. 403 and Mech. Eng. 371.* I. (*3*).
Thermal radiation process. Physics of monocromatic and total radiation. Emission and absorption. Exchange factors for black and gray surfaces and enclosures. Radiant exchange involving absorbing and emitting media, including gases and flames. Properties of solar radiation and thermal transfer in space.

700(300). Professional Problem. I and II. (*9*).
Professional degree candidate only. Student selects a problem in research, analysis, or design in any field of mechanical engineering and submits a written proposal to the Graduate Committee for approval before enrolling in course. Letter from staff member who will direct work must accompany proposal.

772(312). Heat Transfer IV. *Prerequsite: Mech. Eng. 571 and 672, Math. 452 or equivalents.* II. (*3*).
Generalized methods of analysis applied to advanced problems in heat and mass transfer including the influence of magnetic field phenomena; transient processes in distributed fluid-solid systems having mixed boundary conditions; systems undergoing ablation and melting, transient thermal stresses.

820(304). Fluids Machinery Seminar. *Prerequisite: graduate standing and permission of instructor.* (*To be arranged*). Offered upon sufficient demand.
Reports and discussions on library study and laboratory research in selected topics.

835(305). Seminar in Thermodynamics. *Prerequisite: Mech. Eng. 531 and 535 or permission of instructor.* II. (*3*).
P-V-T behavior of gases and liquids, equilibria, electrochemistry, thermoelectricity, and irreversible thermodynamics.

838(308). Heat-Power Seminar. *Prerequisite: graduate standing and permission of instructor.* (*To be arranged*). Offered upon sufficient demand.
Reports and discussions on library study and laboratory research in selected topics.

METEOROLOGY

202(4)(Geog. 202). Weather, Climate, and Life. I and II. (*3*).
An elementary description of the atmosphere, its characteristics and behavior; weather and climate as basic factors in life and civilization.

404(104)(Geog. 404). Introductory Meteorology—Weather. *Prerequisite: preceded or accompanied by Math. 101 or equivalent. No credit allowed in a degree program in meteorology.* I and II. (*3*).
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, term paper, and field trips.

405(105)(Geog. 405). Introductory Meteorology—Climate. *Prerequisite: Meteor. 202 or 404. No credit allowed in a degree program in meteorology.* II. (*3*).
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 term paper.

408(120). Principles of Meteorology. *Prerequisite: Math. 364 and Physics 146 or equivalent.* I. (*3*).
Introduction to the basic thermodynamic, radiative, and dynamic processes in the atmosphere; physical analysis of wind and turbulence; cloud, precipitation, and evaporation physics; physics of the high atmosphere. Lectures and problems.

412(153). Physical Climatology. *Prerequisite: preceded or accompanied by Meteor. 408 or 432 or 445.* 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.

415(156). Statistical Methods in Meteorology I. *Prerequisite: one year of calculus.* I. *(3).*

Distributions in time and space of meteorological elements; measures of central tendency and dispersion; distributions of scalar and vector quantities; introduction to statistical inference and significance tests; fiducial limits; regression analysis; trends and cycles; forecast verification. Lectures and laboratory exercises.

422(115). Introductory Microclimatology. II. *(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.

***432W(122). Atmospheric Thermodynamics and Radiation.** *Prerequisite: Math. 364 and Physics 146 or equivalent.* I. *(3).*

Composition of the atmosphere; atmospheric statics; thermodynamic diagrams; solar and terrestrial radiation; the heat balance of the earth. Lectures and problems.

***440W(132). Principles of Weather Analysis.** *Prerequisite: preceded or accompanied by Meteor. 408 or 432 or 445.* I. *(3).*

Air mass analysis, representative and conservative properties; 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.

***441W(135). Laboratory in Weather Analysis I.** *Prerequisite: preceded or accompanied by Meteor. 440.* I. *(3).*

Construction of meteorological charts from current and past weather data. Analytical codes; measurement of geostrophic and gradient winds; graphical determination of thickness patterns; jet stream analysis; principles of prognosis from thermodynamic diagrams, isallobaric and isobaric analyses.

***445W(126). Dynamic Meteorology.** *Prerequisite: Math. 364 and Physics 146 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; local change of pressure; atmospheric turbulence; the jet stream; weather prediction by high-speed computing methods.

***452W(144). Physical Meteorology.** *Prerequisite: Meteor. 408 or 432 or 440.* II. *(3).*

Cloud and precipitation physics; aircraft icing; radar meteorology; atmospheric electricity; atmospheric optics and visibility. Lectures and problems.

462(162). Meteorological Instrumentation. *Prerequisite: Meteor. 408 or 432 or 445 or equivalent.* I. *(3).*

Principles of meteorological instruments; methods of measurement of pressure, temperature, humidity, precipitation, evaporation, and wind; analysis of response characteristics; introduction to the design of single instruments and of instrument systems. Lectures, laboratory, and field trips.

***470W(180). Applied Meteorology.** *Prerequisite: Meteor. 404 or 408 or equivalent.* II. *(2).*

Topics in applied meteorology, selected in accordance with the requirements

*The symbol W indicates that extra work is required for graduate credit.

of the class. Representative topics: meteorological aspects of air pollution; atmospheric phases of the hydrologic cycle; wind and precipitation loading of structures. Lectures and problems.

472(182). Hydrology and Hydrometeorological Design. *Prerequisite: Eng. Mech. 324 and Meteor. 440.* I. (*4*).

The hydrograph and the various factors that affect and determine its characteristics; precipitation, evaporation, transpiration, infiltration; the unit hydrograph; maximum flood flows and frequency of occurrence; normal flow and low flow; hydrological and hydrometeorological aspects of the design of structures. Lectures, laboratory, computation, and drawing.

475(186). Meteorological Analysis and Design Criteria. *Prerequisite: preceded or accompanied by Meteor. 408 or 432 or 445 or equivalent.* II. (*4*).

Analysis of meteorological aspects of engineering problems; use of meteorological design criteria for air pollution control through specification of plant location, design and layout, and operation; meteorological design factors in determining wind and precipitation loading of structures; etc. Lectures, laboratory, and computation.

500(110). Meteorology for Teachers. Not open to engineering students. (*2-3*).

Lectures and discussions on elementary meteorology, combined with workshop on problems of introducing meteorology into individual school programs; survey of material sources, demonstration methods, laboratory and field exercises and equipment design. For science teachers of all levels.

541(136). Laboratory in Weather Analysis II. *Prerequisite: Meteor. 441.* II. (*3*).

Application of prognostic methods from analyses of vorticity patterns; trajectories and fallout computations; streamlines and isogons as used in tropical analyses; vertical cross sections; vertical motion calculation; introductory demonstration of numerical weather prediction; long waves and hemispheric weather.

566(166). Micrometeorological Instrumentation. *Prerequisite: permission of instructor.* II. (*3*).

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.

605(295). Current Topics in Meteorology. *Prerequisite: permission of instructor.* I and II. (*2*).

Advances in specific fields of atmospheric science, as revealed by recent research. Lectures, discussion, and assigned reading.

615(256). Statistical Methods in Meteorology II. *Prerequisite: permission of instructor.* II. (*3*).

Homogeneity of climatometric series; forecast economics; stochastic prediction; multiple regression; statistical screening; orthogonal representations; harmonic analysis; filtering and rectification of time series; power spectra; extreme values. Lectures and the solution of problems on desk calculators and on the IBM 704.

622(215). Micrometeorology. *Prerequisite: Meteor. 432 or 445 or permission of instructor.* II. (*3*).

Physical processes in the atmosphere near the ground; laminar and turbulent flow; transfer of heat, mass and momentum; eddy diffusion; evaporation from natural surfaces. Lectures and problems.

701(291). Special Problems in Atmospheric Science. *Prerequisite: permission of instructor.* I and II. (*To be arranged*).

Supervised analysis of selected problems in various areas of meteorology and associated fields.

804(297). Interdisciplinary Seminar on Atmospheric Sciences. *Prerequisite: permission of instructor.* I and II. (*1-3*).
Reading, preparation of term papers, and seminar discussion of fundamental atmospheric properties and characteristics and their relation and interaction with other disciplines. Course credit assigned each student on registration.

990(293). Meteorological Research. *Prerequisite: permission of graduate adviser.* I and II. (*To be arranged*).
Assigned work in meteorological research; may include field measurements, analysis of data, development in physical or applied meteorology.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

200(11). Introduction to Practice. *Prerequisite: sophomore standing and Eng. Graphics 101 and 104.* 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.

201(12). Form Calculations I. *Prerequisite: Nav. Arch. 200, Math. 363 or 371 and Eng. Mech. 208.* 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.

300(13). Form Calculations II. *Prerequisite: Nav. Arch. 201 and Math. 373.* I and II. (*2*).
Programing of hydrostatic curves for digital and analog computers. Problems are worked for each type.

310(21). Structural Design I. *Prerequisite: Eng. Mech. 210 and Nav. Arch. 201.* 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.

330(141). Marine Propulsion Machinery. *Prerequisite: Mech. Eng. 335 and preceded or accompanied by Eng. Mech. 324.* I. (*3*).

331(147). Marine Auxiliary Machinery. *Prerequisite: Nav. Arch. 330 and preceded or accompanied by Elec. Eng. 315.* II. (*3*).
Piping systems; electrical distribution; engine room auxiliaries, deck machinery; steering gear; and emergency apparatus.

400(137). Shipbuilding Contracts and Cost Estimating. *Prerequisite: junior standing.* I. (*2*).
Principal features of ship specifications and contracts; methods and practices of cost estimating and production control of ships.

401(136). Small Craft Design I. *Prerequisite: Nav. Arch. 201.* II. (*2*).
Design of small commercial and pleasure craft.

410(127). Stress Analysis of Structures in Ship Design. *Prerequisite: Eng. Mech. 411.* I. (*2*).
Beams under action of axial and lateral loads, beams on elastic supports; analysis of bulkheads, plating supported by a grillage system of stiffeners; effective width of plating, shear lag effects; stress distribution in superstructures due to bending; closed frame analysis.

420(151). Resistance, Power, Propellers. *Prerequisite: Nav. Arch. 201 and Eng. Mech. 324.* I and II. (*5*).

Fundamentals of the resistance and propulsion of ships including the theory of model testing. Theory and practice of propeller design with reference to model propeller testing. Ship powering predictions and calculations. Four recitations and one three-hour laboratory.

430(146). Design of Marine Power Plants I. *Prerequisite: Nav. Arch. 331.* I and II. (*2*).

Calculations on performance and preliminary design of main and auxiliary machinery.

440(131). Ship Dynamics. *Prerequisite: Nav. Arch. 201, Eng. Mech. 343, and Math. 404.* I. (*2*) .

The motion of ships at sea, rolling, pitching, sea-keeping qualities; steering and maneuvering.

470(132). Ship Design I. *Prerequisite: senior standing.* I and II. (*3*).

Preliminary design methods, general arrangements and outfitting of ships. Given the owner's general requirements, the students block out initial design characteristics for the ship.

471(133). Ship Design II. *Prerequisite: Nav. Arch. 470 and accompanied by Nav. Arch. 472.* I and II. (*2*).

Basing his work on the design started in Nav. Arch. 470, the student prepares the preliminary design drawings and final calculations for the subject vessel.

472(134). Structural Design II. *Prerequisite: Nav. Arch. 310 and accompanied by Nav. Arch. 471.* I and II. (*2*).

Student develops the "Midship Section" for the vessel designed in Nav. Arch. 470 and Nav. Arch. 471 and makes freeboard, strength, and steel weight calculations.

473(144). Design of Marine Power Plants II. *Prerequisite: Nav. Arch. 430.* 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.

474(142). Design of Marine Steam Generators. *Prerequisite: Nav. Arch. 430.* I and II. (*3*).

Heat transfer calculations. Design and layout drawings are prepared for a marine steam generator.

475(143). Design of Marine Propulsion Machinery. *Prerequisite: Nav. Arch. 430 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.

510(123). Advanced Structural Design. *Prerequisite: Nav. Arch. 410.* I and II. (*To be arranged*).

511(124). Directed Research in Ship Structure. *Prerequisite: Nav. Arch. 510.* I and II. (*To be arranged*).

520(152). Advanced Ship Model Testing. *Prerequisite: Nav. Arch. 420.* I and II. (*2 to 3*).

Special problems and ship model testing will be investigated varying with the student's interest.

521(153). Research in Ship Hydrodynamics. *Prerequisite: Nav. Arch. 520.* I and II. (*To be arranged*).

571(135). Advanced Ship Drawing and Design. I and II. (*To be arranged*).

572(138). Economics of Ship Design and Operation. *Prerequisite: Nav. Arch. 470.* II. (*2*).

Review of mathematics of finance, estimating ship construction and operating costs and income; interpretation of data; profitability; optimum design conditions; replacement; intangible factors.

590(145). Advanced Reading and Seminar in Marine Engineering. I and II. (*To be arranged*).

591(154). Advanced Reading and Seminar in Naval Architecture. I and II. (*To be arranged*).

592(156). Thesis Research. *Prerequisite: Nav. Arch. 470 or design course in Option 2 and Nav. Arch. 420.* I and II. (*3*).

Research and experimental work necessary in connection with thesis required for the degree of Master of Science in Engineering.

620(157). Advanced Propeller Theory and Cavitation. *Prerequisite: Eng. Mech. 422 and Nav. Arch. 420.* I and II. (*2*).

Fundamentals of circulation theory of screw propeller design; propeller cavitation; supercavitating propellers.

630(148). Nuclear Ship Propulsion. *Prerequisite: Nuc. Eng. 400 or 470 or equivalent.* I. (*3*).

A discussion of the basic problems encountered in the application of nuclear reactors; the engineering problems of a reactor. Brief review of the nontechnical problems of nuclear merchant ship propulsion.

NUCLEAR ENGINEERING

400(190). Elements of Nuclear Engineering. *Prerequisite: senior standing or permission of instructor.* I and II. (*3*).

A quantitative 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, and nuclear power plant systems are the principal topics surveyed.

470(191). Introduction to Nuclear Engineering. *Prerequisite: senior standing, preceded or accompanied by Math. 450.* I and II. (*3*).

Designed to give students a background in the aspects of atomic and nuclear physics prerequisite to an understanding of neutron processes. Discussion of Planck's constant and basic properties of the neutron.

550(193). Handling and Use of Radioactive Materials. *Prerequisite: preceded or accompanied by Nuc. Eng. 400 or 470, 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.

560(192). Nuclear Radiation Detection and Measurement. *Prerequisite: Nuc. Eng. 470, preceded or accompanied by a course in electronics.* I and II. (*3*).

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. Lectures and laboratory.

570(294). Quantum Mechanics in Nuclear Engineering. *Prerequisite; Nuc. Eng. 470 and Math. 450.* I and II. (*3*).

The wave mechanical formulation of quantum theory and its applications.

Development of the Schroedinger equation. Barrier transmission. Exact one-dimensional solutions. Theory of alpha decay. The three-dimensional Schroedinger equation and the central force problem. Approximate solutions including perturbation theory and WKB method. Theory of elastic collisions. Introductory theory of nuclear reactions with emphasis on reactions involving neutrons. Continuum and resonance theory and the development of the Breit-Wigner formulae.

630(297). Nuclear Power Plant Engineering. *Prerequisite: preceded or accompanied by Nuc. Eng. 680.* II. (*3*).

Application of reactor core theory, reactor control, fluid flow, heat transfer, thermodynamics, stress and strain and economic parameters to integrated nuclear power plant designs. Examination of significant nuclear power plant concepts and applications.

640(194). Application of the Analog Computer in Nuclear Engineering. *Prerequisite: preceded or accompanied by Nuc. Eng. 680.* I and II. (*2*).

Basic theory and principles of operation of the electronic analog computer. Practice in the operation of the computer. Solution of linear and nonlinear problems in nuclear engineering such as fission product buildup and decay, nuclear reactor kinetics and control. Lecture and laboratory.

641(292). Nuclear Reactor Instrumentation and Control. *Prerequisite: preceded or accompanied by Nuc. Eng. 680.* II. (*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.

660(298). Nuclear Reactor Laboratory. *Prerequisite: Nuc. Eng. 560, preceded or accompanied by Nuc. Eng. 680.* I and II. (*4*).

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. Lectures and laboratory.

670(291). Interaction of Radiation and Matter. *Prerequisite: Nuc. Eng. 570.* I and II. (*3*).

Classical and quantum-mechanical analysis of the processes by which radiation interacts with matter. Review of nuclear structure and properties. Nuclear models. Nuclei as sources of radiation. Interaction of electromagnetic radiation with matter. Interaction of charged particles with matter. Radiative collisions and theory of bremsstrahlung. Interaction of neutrons with matter. Interaction mechanisms and cross sections are developed.

680(295). Nuclear Reactor Theory I. *Prerequisite: Nuc. Eng. 570 and Math. 548.* I and II. (*3*).

Development of a neutron balance equation and its application in an investigation of the problems of criticality and control of nuclear reactors.

690(299). Master's Project. I and II. (*1-6*).

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 a 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.

700(399). Special Topics in Nuclear Engineering. *Prerequisite: permission of instructor.* I and II. (*2*).

Selected advanced topics such as neutron and reactor physics, reactor core design, and reactor engineering. The subject matter will change from semester to semester.

720(396). Thermonuclear Theory I. *Prerequisite: Nuc. Eng. 680, Elec. Eng. 420, Math. 452, or equivalents.* I. (*3*).
Fundamentals of the physics of fusion and of ionized gases. The basic equations describing the collective behavior of charged particles are formulated. Some general physical implications of these equations are examined.
721(397). Thermonuclear Theory II. *Prerequisite: Nuc. Eng. 720.* II. (*3*).
Investigations in plasma dynamics based on the Boltzmann and Fokker-Planck equations. Development of the equations of magnetohydrodynamics. Study of problems of containment-pinch effect, plasma oscillations, diffusion.
730(398). Advanced Nuclear Power Plant Engineering. *Prerequisite: Nuc. Eng. 630.* I. (*3*).
Detailed analytical investigation and experimental demonstration of specific problems involving the interrelations between nucleonics, heat transfer, thermodynamics, stress and strain parameters, and fluid flow theory which occur in the design of nuclear power plants.
750(293). Radiation Shielding. *Prerequisite: Nuc. Eng. 560 and 670.* I. (*3*).
A macrosopic 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 attentuation, shield optimization, heat generation and removal in shields, and other related problems.
751(394). Radiation Effects in Solids. *Prerequisite: Nuc. Eng. 670.* I and II. (*3*).
Study of the effects of high energy radiations in solids, such as germanium and silicon. Topics such as the theory of atomic displacements, ionization effects in solids, and others relating to nuclear solid state devices.
780(395). Nuclear Reactor Theory II. *Prerequisite: Nuc. Eng. 680, Math. 452, or Physics 452.* I. (*3*).
General formulation of the transport problem with application to refinements of calculation techniques for studying neutron and gamma ray distributions. Several applications of these calculational techniques are discussed in detail.
991(299). Special Projects. I and II. (*1-6*).
Individual or group investigations in a particular field or on a problem of special interest to the student. The project will be arranged at the beginning of the semester by mutual agreement between the student and a staff member.
999(299). Doctoral Thesis. I and II. (*1-6*).

PHYSICS*

Professor Dennison; Professors Case, Crane, Hazen, Katz, Laporte, McCormick, Parkinson, Sawyer, Wiedenbeck, Wolfe; Associate Professors Ford, Franken, Hough, Jones, Krimm, Lewis, Peters, Terwilliger, Weinreich; Assistant Professors Chagnon, Coffin, Hecht, Meyer, Perl, Sands, Sherman, Sinclair, Uberall; Instructors Fishbeck, Roe, Tickle, Vander Velde.
145(45). Mechanics, Sound, and Heat. *Prerequisite: preceded by Math. 233, or accompanied by Math. 363.* I and II. (*5*).
Two lectures, three recitations, and one two-hour laboratory.
146(46). Electricity and Light. *Prerequisite: Physics 145.* I and II. (*5*).
Two lectures, three recitations, and one two-hour laboratory.

*College of Literature, Science, and the Arts

153(53). Elementary Mechanics. *Prerequisite: preceded or accompanied by Math. 233 or equivalent.* 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.

154(54). Electricity, Light, and Modern Physics. *Prerequisite: Physics 153 and preceded or accompanied by Math. 364 or equivalent.* II. (*4*).

Electricity and magnetism, physical optics, atomic and nuclear structure. One lecture, three recitations, and one laboratory.

303(103). Introduction to the Use of Radioactive Isotopes. *Prerequisite: Physics 126 or 146.* II. (*2*).

Sources, properties, and methods of measuring radiations; determination of safe dosage; tracer techniques and their applications.

305(105). Modern Physics. *Prerequisite: Physics 126 or 146.* I. (*2*).

A discussion of fundamental experiments on the nature of matter and electromagnetic radiation. Survey of special relativity, Bohr's quantum theory, and wave mechanics of simple systems.

307(107). Modern Physics II. *Prerequisite: Physics 126, 146, or 154, calculus or preferably Math. 372.* (*3*).

A survey of modern physics including an introduction to special relativity, wave mechanics and associated particle problems. Not open to students having Physics 305.

347(147). Electrical Measurements. *Prerequisite: Physics 126 or 146 and Math. 364.* I and II. (*4*).

Direct, alternating, and transient currents; measurements of inductance, capacitance, and losses due to hysteresis. Two lectures and one afternoon of laboratory.

401(171). Intermediate Mechanics. *Prerequisite: Physics 126 or 146 and Math. 372 or equivalent.* I and II. (*3*).

Study of the motion of particles and rigid bodies using Newtonian force methods. Such topics as harmonic oscillators, coupled oscillators, and planetary motion will be considered.

402(186). Light. *Prerequisite: Physics 126 or 146 and Math. 372 or equivalent.* I. (*3*).

The phenomena of physical optics, reflection, refraction, dispersion, interference, diffraction, polarization, etc., interpreted in terms of the wave theory of light.

403(188). Light Laboratory. *Prerequisite: to accompany or follow Physics 402.* I. (*2*).

Experiments in interference, diffraction, and polarization, with use of photography and optical instruments.

405(180). Intermediate Electricity and Magnetism. *Prerequisite: Physics 126 or 146 and Math. 372 or equivalent.* II. (*3*).

The laws and principles of electrostatics, moving electric charges, and electromagnetism; alternating current circuit theory, including transients.

406(181). Heat and Thermodynamics. *Prerequisite: Physics 126 or 146 and Math. 403.* II. (*3*) .

Thermal expansion, specific heats, changes of state, and van der Waals' equation; elementary kinetic theory and the absolute scale of temperature.

407(183). Heat Laboratory. *Prerequisite: to follow or accompany Physics 406.* II. (*2*).

Use of modern methods and instruments for the measurement of thermal quantities.

411(172). Mechanics of Fluids. *Prerequisite: Physics 401.* II. (*3*).
The Navier-Stokes equation is developed and is used to treat several classical problems. The student is introduced to elementary aspects of turbulence, shock waves, and hydramagnetics.

417(177). Applications of Physical Measurements to Biology. *Prerequisite: Physics 126 and eight hours of biological science.* I. (*3*) .
A review of physical instruments and techniques which are applicable to the study of biological materials.

418(178). Introduction of Physics of Macromolecules. *Prerequisite: Math. 364 and Physics 402 or permission of instructor.* II. (*3*).
Physical principles underlying the behavior and characterization of macromolecular systems, with emphasis on applications to biological processes.

423, 424(193, 194). Applied Spectroscopy. *Prerequisite: Physics 453.* 423, I; 424, II. (*4 each*).
Equipment and methods for spectrochemical analysis, with laboratory practice. Lecture and laboratory.

425(185). Introduction to Infrared Spectra. *Prerequisite: Physics 126 or 146 and Math. 364.* I. (*2*).
The elements of infrared spectroscopy and the basic principles involved in the interpretation of Raman and infrared data in terms of molecular structure.

451, 452(191, 192). Introduction to Theoretical Physics. *Prerequisite: Physics 401 and Math. 450 or 554.* 451, I; 452, II. (*3 each*).
A survey of mathematical methods employed in theoretical physics, e.g. vectors, tensors, matrices, tensor fields, boundary value problems, approximation and variational methods.

453(196). Atomic and Molecular Structure. *Prerequisite: Physics 126, Chem. 106, Math. 403, and five hours of intermediate physics or physical chemistry.* I and II. (*3*).
A critical discussion of developments in atomic and molecular structure based upon fundamental experiments and interpreted in part in terms of Schroedinger's equation.

455(165). Electron Tubes. *Prerequisite: Physics 405 and Math. 403.* I. (*4*).
The characteristics of electron tubes and transistors, and their functions in electric circuits such as amplifiers and oscillators. Three lectures and a laboratory.

456(166). Electronic Circuits. *Prerequisite: Physics 455.* II. (*3*).
A study of circuit elements, amplifiers, coincidence and scaling circuits, and the various types of detectors and circuits used in experimental nuclear physics. Two lectures and a laboratory.

457(197). Nuclear Physics. *Prerequisite: Physics 453.* II. (*3*).
Properties and systematics of nuclei; nuclear forces and nuclear models; understood from an experimentalist's point of view.

458(199). Laboratory in Nuclear Physics. *Prerequisite: to accompany or follow Physics 457.* II. (*2*).
Equipment is available for a large variety of measurements on the characteristics of different nuclear transformations.

461(198). Introduction to Quantum Theory. *Prerequisite: Physics 401 and 453.* II. (*3*).
An introduction to the concepts of quantum theory. Development of Schroedinger's wave mechanics and Heisenberg's matrix mechanics with applications to simple systems.

463(173). Introduction to Physics of the Solid State. *Prerequisite: Physics 453 or permission of instructor.* II. (*3*).
Structure and physical properties of crystalline solids. Ionic crystals. Free electron theory of metals. Band theory of solids. Effects of impurities and imperfections. Theories of magnetism.

505, 506(205, 206). Electricity and Magnetism. *Prerequisite: Physics 405 and Math. 450 or 554.* 505, I; 506, II; (*3 each*).
Electromagnetic theory; Maxwell's equations and the radiation from a Hertzian oscillator; connections with the special relativity theory.

507(207). Theoretical Mechanics. *Prerequisite: an adequate knowledge of differential equations; an introductory course in mechanics is desirable.* I. (*3*).
Lagrange equations of motion; the principle of least action, Hamilton's principle, the Hamilton-Jacobi equation; Poisson brackets.

509(209). Thermodynamics. *Prerequisite: Physics 406.* II. (*3*).
The two laws and their foundation; gas equilibria and dilute solutions; phase rule of Gibbs; theory of binary mixtures.

510(210). Kinetic Theory of Matter. *Prerequisite: Physics 509.* 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; fluctuation phenomena.

511, 612, 613(211, 212, 213). Quantum Theory. *Prerequisite: Physics 453. Physics 511 is a prerequisite for Physics 612.* 511, I; 612, II. (*3 each*).
Wave mechanics, matrix mechanics, and methods of quantizations, with applications.

715, 716(215, 216). 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.

718(218). Physics of Continuous Media. II. (*3*).

719(219). Physics of the Solid State. I. (*3*).

724(224). Cosmic Radiation. II. (*3*).

725(225). Theory of Neutron Diffusion. I. (*3*).

726(226). High Energy Nuclear Physics. II. (*3*).

731(231). Advanced Electromagnetic Theory with Application to Modern Diffraction Problems. I. (*2*).

733(233). Special Problems in Fluid Dynamics. I. (*3*).

734(234). Random Processes in Physical Theory and Computation. II. (*3*).

738(238). Nuclear Theory. II. (*3*).

741(241). Magnetic Resonance. I. (*2 or 3*).

742(242). Advanced Atomic Physics. II. (*2 or 3*).

756(256). Molecular Spectra and Molecular Structure. II. (*3*).

806, 807(306, 307). Seminar. Topic to be announced each semester. I and II. (*2 or 3*).

809, 810(309, 310). Advanced Nuclear Physics Seminar. I and II. (*2 or 3*).

811, 812(311, 312). Experimental Seminar. I and II. (*2 or 3*).

813, 814(313, 314). Advanced Theoretical Physics Seminar. I and II. (*2 or 3*).

815, 816(315, 316). High Energy Physics Seminar. I and II. (*2 or 3*).

SCIENCE ENGINEERING

The following courses have been developed through interdepartmental co-operation specifically for the Science Engineering degree program. Since 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.

330(110). **Thermodynamics.** *Prerequisite: Math. 371 and Chem. 194 or 265.*
Introduction to thermodynamic properties, generalized gas equations, mass, energy, and entropy balances, with examples from various fields of engineering.

340(112). **Rate Processes.** *Prerequisite: Sci. Eng. 330 and Math. 372.*
A unified study of heat, mass, and momentum transfer, and chemical kinetics, with emphasis on description, measurement, correlation, and process design.

Committees and Faculty*

EXECUTIVE COMMITTEE

Dean S. S. Attwood, *Chairman*
ex officio

L. N. Holland, term, 1959-61
L. M. Legatski, term, 1958–62
A. Marin, term, 1959–63
S. K. Clark, term, 1960–64

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G. L. Alt, *Chairman*, K. W. Hall, A. R. Hellwarth, L. F. Kazda, E. J. Lesher, D. R. Mason, and J. G. Young.

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L. C. Maugh, *Chairman*, J. G. Eisley, A. B. Macnee, J. Ormondroyd, and J. R. Pearson.

*Listed for the academic year, 1960-61.

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AERONAUTICAL AND ASTRONAUTICAL ENGINEERING

WILBUR CLIFTON NELSON, M.S.E., *Professor of Aeronautical Engineering and Chairman of the Department of Aeronautical and Astronautical Engineering*
ARNOLD MARTIN KUETHE, Ph.D., *Felix Pawlowski Professor of Aerodynamics*
LAWRENCE LEE RAUCH, Ph.D., *Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*
ROBERT MILTON HOWE, Ph.D., *Professor of Aeronautical Engineering*
RICHARD BOYD MORRISON, Ph.D., *Professor of Aeronautical Engineering*
GABRIEL ISAKSON, Sc.D., *Professor of Aeronautical Engineering*
MAHINDER SINGH UBEROI, Dr.Eng., *Professor of Aeronautical Engineering*
VI-CHENG LIU, Ph.D., *Professor of Aeronautical Engineering*
EDGAR JAMES LESHER, M.S.E., *Associate Professor of Aeronautical Engineering*
WILLIAM WALTER WILLMARTH, Ph.D., *Associate Professor of Aeronautical Engineering*
THOMAS CHARLES ADAMSON, JR., Ph.D., *Associate Professor of Aeronautical Engineering*
DONALD THEODORE GREENWOOD, Ph.D., *Associate Professor of Aeronautical and Astronautical Engineering*
HARM BUNING, M.S. (Ae.E.), *Associate Professor of Aeronautical Engineering*
ELMER GRANT GILBERT, Ph.D., *Associate Professor of Aeronautical and Astronautical Engineering*
FREDERICK JOSEPH BEUTLER, Ph.D., *Associate Professor of Aeronautical and Astronautical Engineering*
JOE GRIFFIN EISLEY, Ph.D., *Associate Professor of Aeronautical Engineering*
RUDI SIONG-BWEE ONG, Ph.D., *Associate Professor of Aeronautical Engineering*
EDWARD OTIS GILBERT, Ph.D., *Associate Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*

LAURENCE EUGENE FOGARTY, Ph.D., *Associate Professor of Aeronautical Engineering*

JAMES ARTHUR NICHOLLS, Ph.D., *Associate Professor of Aeronautical Engineering*

ROBERT EUGENE CULLEN, M.S.E. (Ae.E.), *Assistant Professor of Aeronautical Engineering*

PAULINE MONT SHERMAN, M.S., *Assistant Professor of Aeronautical and Astronautical Engineering*

JACK RAYMOND JENNINGS, M.S.E., *Instructor in Aeronautical Engineering*

FREDERICK LESTER WILLIAM BARTMAN, M.S., *Lecturer in Aeronautical Engineering and Research Engineer, Sponsored Research*

HAROLD FREDERICK ALLEN, Ph.D., *Lecturer in Aeronautical Engineering and Research Engineer, Sponsored Research*

LESLIE MCLAURY JONES, B.S.E. (E.E.), *Lecturer in Aeronautical Engineering and Research Engineer, Sponsored Research*

DAVID ROGER GLASS, M.S.E. (Ae.E), *Lecturer in Aeronautical Engineering and Research Engineer, Sponsored Research*

ROGER DUNLAP, Ph.D., *Lecturer in Aeronautical Engineering*

PREM N. MATHER, Ph.D., *Lecturer in Aeronautical Engineering*

CARMEN JOSEPH PALERMO, M.S., *Lecturer in Aeronautical Engineering*

RICHARD LANG PHILLIPS, M.S.E., *Lecturer in Aeronautical Engineering*

SHELDON NORMAN SALZMAN, M.S., *Lecturer in Aeronautical Engineering*

CHEMICAL AND METALLURGICAL ENGINEERING

DONALD LAVERNE KATZ, Ph.D., *Professor of Chemical Engineering and Chairman of the Department of Chemical and Metallurgical Engineering*

RICHARD SCHNEIDEWIND, Ph.D., *Professor of Metallurgical Engineering*

LARS THOMASSEN, Ph.D., *Professor of Chemical and Metallurgical Engineering*

CLARENCE ARNOLD SIEBERT, Ph.D., *Professor of Chemical and Metallurgical Engineering*

RICHARD A. FLINN, Sc.D., *Professor of Metallurgical Engineering*

LLOYD EARL BROWNELL, Ph.D., *Professor of Chemical and Metallurgical Engineering and of Nuclear Engineering*

JAMES WRIGHT FREEMAN, Ph.D., *Professor of Metallurgical Engineering and Research Engineer, Sponsored Research*

MAURICE JOSEPH SINNOTT, Sc.D., *Professor of Metallurgical Engineering*

JOSEPH J. MARTIN, D.Sc., *Professor of Chemical and Metallurgical Engineering*

GEORGE BRYMER WILLIAMS, Ph.D., *Professor of Chemical and Metallurgical Engineering*

STUART WINSTON CHURCHILL, Ph.D., *Professor of Chemical Engineering*

JESSE LOUIS YORK, Ph.D., *Professor of Chemical and Metallurgical Engineering*

LAWRENCE H. VAN VLACK, Ph.D., *Professor of Materials Engineering, Department of Chemical and Metallurgical Engineering*
LLOYD L. KEMPE, Ph.D., *Professor of Chemical Engineering and of Sanitary Engineering, Department of Civil Engineering*
EDWIN HAROLD YOUNG, M.S.E., *Professor of Chemical and Metallurgical Engineering*
GUISEPPE PARRAVANO, Ph.D., *Professor of Chemical and Metallurgical Engineering*
JOHN CROWE BRIER, M.S., *Professor Emeritus of Chemical Engineering*
LEO LEHR CARRICK, Ph.D., *Professor Emeritus of Chemical Engineering*
DONALD WILLIAM MCCREADY, Ph.D., *Associate Professor of Chemical Engineering*
RICHARD EMORY TOWNSEND, Ch.E., *Associate Professor of Chemical and Metallurgical Engineering*
DONALD ROMAGNE MASON, Ph.D., *Associate Professor of Chemical Engineering*
DAVID VINCENT RAGONE, Sc.D., *Associate Professor of Metallurgical Engineering*
EDWARD ERNEST HUCKE, Sc.D., *Associate Professor of Metallurgical Engineering*
KENNETH FRASER GORDON, Sc.D., *Associate Professor of Chemical Engineering*
WILBUR CHARLES BIGELOW, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*
MEHMET RASIN TEK, Ph.D., *Associate Professor of Chemical Engineering*
WILLIAM ALLEN SPINDLER, M.S., *Assistant Professor of Metallurgical Engineering*
WALTER BERTRAM PIERCE, *Assistant Professor of Foundry Practice, Department of Chemical and Metallurgical Engineering*
KEITH HAL COATS, Ph.D., *Assistant Professor of Chemical Engineering*
DALE FREDERICK RUDD, Ph.D., *Assistant Professor of Chemical Engineering*
ROBERT DONALD PEHLKE, Sc.D., *Assistant Professor of Metallurgical Engineering*
RICHARD EARL BALZHISER, Ph.D., *Assistant Professor of Chemical Engineering*
PAUL KARL TROJAN, M.S.E., *Instructor in Metallurgical Engineering*
JAMES ARTHUR FORD, M.S.E., *Instructor in Chemical and Metallurgical Engineering*
JAMES OSCROFT WILKES, M.S.E., *Instructor in Chemical Engineering*
DAVID LESTER SPONSELLER, M.S.E., *Instructor in Chemical and Metallurgical Engineering*
JACK JOSEPH FAMULARO, M.Ch.E., *Instructor in Chemical Engineering*
JOHN GRENNAN, *Instructor Emeritus in Foundry Practice*
BETZALEL AVITZUR, Ph.D., *Lecturer in Metallurgical Engineering*
BRICE CARNAHAN, M.S., *Lecturer in Engineering, Ford Foundation—Project on Computers*
PETER BERND LEDERMAN, M.S.E., *Lecturer, Ford Foundation—Project on Computers*

CIVIL ENGINEERING

EARNEST BOYCE, M.S., C.E., *Professor of Municipal and Sanitary Engineering and Chairman of the Department of Civil Engineering, and Professor of Public Health Engineering, School of Public Health*

LAWRENCE CARNAHAN MAUGH, Ph.D., *Professor of Civil Engineering*

WILLIAM STUART HOUSEL, M.S.E., *Professor of Civil Engineering*

BRUCE GILBERT JOHNSTON, Ph.D., *Professor of Structural Engineering*

ERNEST FREDERICK BRATER, Ph.D., *Professor of Hydraulic Engineering*

VICTOR LYLE STREETER, Sc.D., *Professor of Hydraulics*

JOHN CLAYTON KOHL, B.S.E. (C.E.), *Professor of Civil Engineering and Director of the Transportation Institute*

RALPH MOORE BERRY, B.C.E., *Professor of Geodesy and Surveying*

LEO MAX LEGATSKI, Sc.D., *Professor of Civil Engineering*

GLENN LESLIE ALT, C.E., *Professor of Civil Engineering*

JACK ADOLPH BORCHARDT, Ph.D., *Professor of Civil Engineering*

LLOYD L. KEMPE, Ph.D., *Professor of Sanitary Engineering and of Chemical Engineering*

WALTER JOHNSON EMMONS, A.M., *Professor Emeritus of Highway Engineering, Associate Dean Emeritus and Secretary Emeritus of the College of Engineering*

CLARENCE THOMAS JOHNSTON, C.E., *Professor Emeritus of Geodesy and Surveying*

ARTHUR JAMES DECKER, B.S. (C.E.), *Professor Emeritus of Civil Engineering*

WILLIAM CHRISTIAN HOAD, B.S. (C.E.), *Professor Emeritus of Civil Engineering*

CHESTER OWEN WISLER, M.S.E., *Professor Emeritus of Hydraulic Engineering*

ROBERT HENRY SHERLOCK, B.S. (C.E.), *Professor Emeritus of Civil Engineering*

EDWARD YOUNG, B.S. (C.E.), *Professor Emeritus of Geodesy and Surveying*

WARD KARCHER PARR, B.S.E. (Ch.E.), *Associate Professor of Highway Engineering*

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HAROLD JAMES MCFARLAN, B.S.E. (C.E.), *Associate Professor of Geodesy and Surveying*

FRANK EVARISTE LEGG, JR., M.S., *Associate Professor of Construction Materials*

DONALD NATHAN CORTRIGHT, M.S.E., *Associate Professor of Civil Engineering*

GLEN VIRGIL BERG, Ph.D., *Associate Professor of Civil Engineering*

MING L. PEI, Ph.D., *Visiting Associate Professor of Civil Engineering* (first semester only)

CLIFTON O'NEAL CAREY, C.E., *Associate Professor Emeritus of Geodesy and Surveying*

EUGENE ANDRUS GLYSSON, M.S.E., *Assistant Professor of Civil Engineering*

Wadi Saliba Rumman, Ph.D., *Assistant Professor of Civil Engineering*
George Dismukes May, M.S.C.E., *Visiting Assistant Professor of Civil Engineering* (first semester only)
George Moyer Bleekman, M.S.E., *Assistant Professor Emeritus of Geodesy and Surveying*
George Donald Brandt, M.S.C.E., *Visiting Assistant Professor, Ford Foundation—Project on Computers* (second semester only)
Robert Oscar Goetz, M.S.E. (C.E.), *Instructor in Civil Engineering*
Ulrich W. Stoll, M.S.E., *Instructor in Civil Engineering*
Harold Joseph Welch, M.S.E., *Instructor in Geodesy and Surveying*
Robert J. Henry, B.S., *Visiting Instructor, Ford Foundation—Project on Computers* (second semester only)
Bruce Douglas Greenshields, Ph.D., *Lecturer in Transportation Engineering and in Engineering Mechanics, and Assistant Director of the Transportation Institute*
Clinton Louis Heimbach, M.S.C.E., *Lecturer in Civil Engineering*
Joe Edward O'Neal, M.S.E., LL.B., *Lecturer in Civil Engineering*

ELECTRICAL ENGINEERING

William Gould Dow, M.S.E., *Professor of Electrical Engineering and Chairman of the Department of Electrical Engineering*
Stephen Stanley Attwood, M.S., *Professor of Electrical Engineering and Dean of the College of Engineering*
Arthur Dearth Moore, M.S., *Professor of Electrical Engineering*
Melville Bigham Stout, M.S., *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*
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 and Associate Dean of the College of Engineering*
Raymond Fred Mosher, S.M., *Professor of Electrical Engineering*
Keeve Milton Siegel, M.S., *Professor of Electrical Engineering*
William Kerr, Ph.D., *Professor of Nuclear Engineering and of Electrical Engineering and Associate Director, Michigan Memorial — Phoenix Project*
Gordon E. Peterson, Ph.D., *Professor of Electrical Engineering, Professor of Communication Sciences, Department of Speech in the College of Literature, Science, and the Arts, and Director of the Communication Sciences Laboratory*

*Deceased October 30, 1960.

JOSEPH AUBREY BOYD, Ph.D., *Professor of Electrical Engineering and Director of the Institute of Science and Technology*
NELSON WARNER SPENCER, M.S.E. (E.E.), *Professor of Electrical Engineering*
FRED T. HADDOCK, M.S., *Professor of Electrical Engineering and Professor of Astronomy, College of Literature, Science, and the Arts*
RICHARD KEMP BROWN, Ph.D., *Professor of Electrical Engineering*
JOHN A.M. LYON, Ph.D., *Professor of Electrical Engineering*
NEWBERN SMITH, Ph.D., *Professor of Electrical Engineering*
LOUIS FRANK KAZDA, M.S.E., *Professor of Electrical Engineering*
JOSEPH EVERETT ROWE, Ph.D., *Professor of Electrical Engineering*
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*
WALTER ALFRED HEDRICH, Ph.D., *Associate Professor of Electrical Engineering*
CHARLES BRUCE SHARPE, Ph.D., *Associate Professor of Electrical Engineering*
JAMES RICHIE BLACK, B.A. (Chem.), *Associate Professor of Electrical Engineering*
CHIAO-MIN CHU, Ph.D., *Associate Professor of Electrical Engineering*
ARLEN R. HELLWARTH, M.S., *Associate Professor of Electrical Engineering and Assistant Dean and Secretary of the College of Engineering*
DALE MILLS GRIMES, Ph.D., *Associate Professor of Electrical Engineering*
HANFORD WHITE FARRIS, Ph.D., *Associate Professor of Electrical Engineering*
EDWARD ANTHONY MARTIN, Ph.D., *Associate Professor of Electrical Engineering and of Nuclear Engineering*
HERSCHEL WEIL, Ph.D., *Associate Professor of Electrical Engineering*
CHARLES WARREN MCMULLEN, Ph.D., *Visiting Associate Professor of Electrical Engineering*
HARVEY LOUIS GARNER, Ph.D., *Associate Professor of Electrical Engineering*
WILLIAM MILTON BROWN, Dr. Eng., *Associate Professor of Electrical Engineering*
B. JAMES LEY, M.E.E., *Visiting Associate Professor of Electrical Engineering* (second semester only)
WILLIAM TOWNES KITTINGER, JR., M.S.E.E., *Visiting Associate Professor of Electrical Engineering* (second semester only)
MURRAY HENRI MILLER, Ph.D., *Assistant Professor of Electrical Engineering*
KUEI CHUANG, Ph.D., *Assistant Professor of Electrical Engineering*
ANDREJS OLTE, Ph.D., *Assistant Professor of Electrical Engineering*
EDWARD LAWRENCE MCMAHON, Ph.D., *Assistant Professor of Electrical Engineering*
HOWARD DIAMOND, Ph.D., *Assistant Professor of Electrical Engineering*
RICHARD F. SCHWARTZ, Ph.D., *Visiting Assistant Professor of Electrical Engineering*
ARCH W. NAYLOR, Ph.D., *Assistant Professor of Electrical Engineering*

*Deceased October 27, 1960.

WILLIAM WOLSEY RAYMOND, M.S.E. (E.E.), *Instructor in Electrical Engineering*
ANTHONY JAMES PENNINGTON, M.S.E., *Instructor in Electrical Engineering*
DALE CARNEY RAY, M.S.E. (E.E.), *Instructor in Electrical Engineering*
VICTOR LEW WALLACE, B.E.E., *Instructor in Electrical Engineering*
LEONARD J. PORCELLO, M.S., *Instructor in Electrical Engineering*
MICHAEL A. HARRISON, M.S. (E.E.), *Instructor in Electrical Engineering*
DAVID KENDALL ADAMS, M.A., *Instructor in Electrical Engineering*
GEORGE I. HADDAD, M.S.E., *Instructor, U.S. Office of Education—Plasma Engineering and Solid-State*
SHU-YUN CHAN, M.S.E., *Instructor in Electrical Engineering*
HAROLD C. EARLY, M.S., *Lecturer in Electrical Engineering and Research Engineer, Sponsored Research*
HAL FREDERIC SCHULTE, JR., M.S.E., *Lecturer in Electrical Engineering and Associate Research Engineer, Sponsored Research*
GILBERT HALL, M.S., *Lecturer in Electrical Engineering and Research Engineer, Institute of Science and Technology*
ANDREW FRANCIS NAGY, M.Sc., *Lecturer in Electrical Engineering and Assistant Research Engineer, Sponsored Research*
WILLIAM ALONZA PORTER, M.S.E., *Lecturer in Electrical Engineering and Research Associate, Institute of Science and Technology*
WILSON P. TANNER, JR., Ph.D., *Lecturer in Electrical Engineering and Research Psychologist, Sponsored Research*
ARTEMUS WILBUR WREN, JR., M.S., *Lecturer in Electrical Engineering and Research Engineer, Sponsored Research*
CHAI YEH, D. Sc., *Lecturer in Electrical Engineering and Research Engineer, Institute of Science and Technology*

ENGINEERING GRAPHICS

HERBERT THEODORE JENKINS, M.S.E., *Professor of Engineering Graphics and Chairman of the Department of Engineering Graphics*
JULIUS CLARK PALMER, B.S., *Professor of Engineering Graphics*
FRANK HAROLD SMITH, M.S.E., *Professor of Engineering Graphics*
PHILIP ORLAND POTTS, M.S.E., *Professor of Engineering Graphics*
FRANK RICHARD FINCH, Ph.B., *Professor Emeritus of Engineering Drawing*
HENRY WILLARD MILLER, M.E., *Professor Emeritus of Engineering*
ROBERT CARL COLE, A.M., *Professor Emeritus of Engineering Drawing*
MARTIN J. ORBECK, C.E., M.S.E., *Professor Emeritus of Engineering Drawing*
DEAN ESTES HOBART, B.S., *Professor Emeritus of Engineering Drawing*
MAURICE BARKLEY EICHELBERGER, B.S., *Associate Professor of Engineering Graphics*
ROBERT HORACE HOISINGTON, M.S., *Associate Professor of Engineering Graphics and Assistant to the Dean, College of Engineering*

ROBERT SEATON HEPPINSTALL, M.S. (M.E.), *Associate Professor of Engineering Graphics*

DONALD CRAIG DOUGLAS, B.S.M.E., *Associate Professor of Engineering Graphics*

ALFRED WILLIAM LIPPHART, B.S.E. (Ae.E.), LL.B., *Associate Professor of Engineering Graphics*

HERBERT JAY GOULDING, B.S. (M.E.), *Associate Professor Emeritus of Mechanism and Engineering Drawing*

FRANCIS X. LAKE, Ph.D., *Assistant Professor of Engineering Graphics*

RAYMOND CLARE SCOTT, M.Ed., *Assistant Professor of Engineering Graphics*

ALBERT LORING CLARK, JR., B.S.E. (M.E.), *Assistant Professor Emeritus of Engineering Drawing*

WILLIAM HAVILAND STEELE, M.S.E., *Instructor in Engineering Graphics*

PHILIP EDWARD WEBB, M.S.E., *Instructor in Engineering Graphics*

MARVIN EUGENE MCCOY, B.C.E., *Instructor in Engineering Graphics*

WARREN GEORGE LAMBERT, M.S., *Instructor in Engineering Graphics*

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*

RICHARD THOMAS LIDDICOAT, Ph.D., *Professor of Engineering Mechanics*

ROBERT LAWRENCE HESS, Ph.D., *Professor of Engineering Mechanics and Associate Director, Institute of Science and Technology*

ERNEST FRANK MASUR, Ph.D., *Professor of Engineering Mechanics*

CHIA-SHUN YIH, Ph.D., *Professor of Engineering Mechanics*

SAMUEL KELLY CLARK, Ph.D., *Professor of Engineering Mechanics*

ROBERT MORPHET HAYTHORNTHWAITE, Ph.D., *Professor of Engineering Science*

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FERDINAND NORTHRUP MENEFEE, C.E., D.Eng., *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*

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FRANKLIN L. EVERETT, Ph.D., *Associate Professor of Engineering Mechanics*

JOHN HERMANN ENNS, Ph.D., *Associate Professor of Engineering Mechanics*

EDWARD AXEL YATES, M.S.E., *Associate Professor of Engineering Mechanics*

HADLEY JAMES SMITH, Ph.D., *Associate Professor of Engineering Mechanics*

WALTER RALPH DEBLER, Ph.D., *Assistant Professor of Engineering Mechanics*

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Movses Jeremy Kaldjian, Ph.D., *Assistant Professor of Engineering Mechanics*

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William Walter O'Dell, Jr., M.S.E., *Instructor in Engineering Mechanics*

David Richard Jenkins, M.S. (Eng.Mech.), *Instructor in Engineering Mechanics*

George Hazen Stickney, M.B.A., M.S.E., *Instructor in Engineering Mechanics*

Dean Tritchler Mook, M.S., *Instructor in Engineering Mechanics*

Bruce Douglas Greenshields, Ph.D., *Lecturer in Engineering Mechanics, Lecturer in Transportation Engineering, Department of Civil Engineering, and Assistant Director of the Transportation Institute*

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Harold Edward Gascoigne, M.S.E., *Lecturer in Engineering Mechanics*

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Albert Nelson Dingle, Sc.D., *Associate Professor of Meteorology*

Gerald Clifford Gill, M.A., *Associate Professor of Meteorology*

Frank Rolland Bellaire, M.S., *Lecturer in Meteorology and Associate Research Meteorologist, Sponsored Research*

David Lloyde Jones, Ph.D., *Lecturer in Meteorology and Associate Research Meteorologist, Sponsored Research*

Floyd Chalmers Elder, M.S., *Lecturer in Meteorology and Associate Research Meteorologist, Sponsored Research and Institute of Science and Technology*

Edward S. Epstein, Ph.D., *Lecturer in Meteorology and Associate Research Meteorologist, Sponsored Research*

Harold Wilbert Baynton, M.S., A.M., *Lecturer in Meteorology*

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*

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*

Thomas Mitchell Sawyer, Jr., Ph.D., *Associate Professor of English, College of Engineering*

Robert Percy Weeks, Ph.D., *Associate Professor of English, College of Engineering*

Donald Arthur Ringe, Ph.D., *Associate Professor of English, College of Engineering*

Stephen Sadler Stanton, Ph.D., *Associate Professor of English, College of Engineering*

William Byrom Dickens, Ph.D., *Associate Professor of English, College of Engineering*

Robert D. Brackett, A.M., *Associate Professor Emeritus of English, College of Engineering*

William Henry Egly, A.M., *Associate Professor Emeritus of English, College of Engineering*

Chester Fisher Chapin, 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*

Warne Conwell Holcombe, Ph.D., *Assistant Professor of English, College of Engineering*

Richard John Ross, Ph.D., *Assistant Professor of English, College of Engineering*

Edmund Pendleton Dandridge, Jr., Ph.D., *Assistant Professor English, College of Engineering*

W. Harry Mack, A.M., *Assistant Professor Emeritus of English, College of Engineering*

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Peter Roberts Klaver, M.A., *Instructor in English, College of Engineering*

Richard Emerson Young, M.A., *Instructor in English, College of Engineering*

Dwight Ward Stevenson, M.A., *Instructor in English, College of Engineering*

William Victor Holtz, M.A., *Instructor in English, College of Engineering*

Donald Aloys Herman, M.A., *Lecturer in English, College of Engineering*

*Deceased January 2, 1961.

INDUSTRIAL ENGINEERING

WYETH ALLEN, B.M.E., D.Eng., *Professor of Industrial Engineering and Chairman of the Department of Industrial Engineering*

MERRILL MEEKS FLOOD, Ph.D., *Professor of Industrial Engineering, Senior Research Mathematician, Mental Health Research Institute, and Professor of Mathematical Biology in the Medical School*

ROBERT MCDOWELL THRALL, Ph.D., Sc.D., *Professor of Operations Analysis, Department of Industrial Engineering, Professor of Mathematics, College of Literature, Science, and the Arts and Research Mathematician, Institute of Science and Technology*

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*

JAMES ARNOLD GAGE, M.S. (M.E.), *Professor of Industrial Engineering*

CHARLES BURTON GORDY, Ph.D., *Professor Emeritus of Industrial Engineering*

JOHN THOMPSON ELROD, Ph.D., *Visiting Professor of Industrial Engineering* (second semester only)

QUENTIN C. VINES, M.E., *Associate Professor of Industrial Engineering*

WILBERT STEFFY, B.S.E. (Ind.-Mech.), B.S.E. (M.E.), *Associate Professor of Industrial Engineering*

EDWARD LUPTON PAGE, M.S.E. (I.E.), *Associate Professor of Industrial Engineering*

CLYDE WIMOUTH JOHNSON, A.B., *Associate Professor of Industrial Engineering*

WALTON MILTON HANCOCK, D.Eng., *Associate Professor of Industrial Engineering*

RICHARD WATSON BERKELEY, B.S.E. (M.&I.E.), *Assistant Professor of Industrial Engineering*

RICHARD VIRDIN EVANS, D.Eng., *Assistant Professor of Industrial Engineering and Lecturer in Mathematics, College of Literature, Science, and the Arts*

BRINTON EDMONDS FREEMAN, B.S.E. (Ch.E.), B.S.I.E., *Assistant Professor of Industrial Engineering* (second semester only)

RICHARD CHRISTIAN WILSON, M.S., *Instructor in Industrial Engineering*

JOSEPH ELBERT HOAGBIN, M.S., *Lecturer in Industrial Engineering and Research Engineer, Institute of Science and Technology*

DEAN H. WILSON, B.S., *Lecturer in Industrial Engineering and Research Engineer, Institute of Science and Technology*

MECHANICAL ENGINEERING

GORDON JOHN VAN WYLEN, Sc.D., *Professor of Mechanical Engineering and Chairman of the Department of Mechanical Engineering*

AXEL MARIN, B.S.E. (M.E.), *Professor of Mechanical Engineering*
RICHMOND CLAY PORTER, M.S., M.E., *Professor of Mechanical Engineering*
LESTER VERN COLWELL, M.S., *Professor of Mechanical Engineering*
JAY ARTHUR BOLT, M.S., M.E., *Professor of Mechanical Engineering*
JOSEPH EDWARD SHIGLEY, M.S.E., *Professor of Mechanical Engineering*
GLENN VERNON EDMONSON, M.E., *Professor of Mechanical Engineering and Associate Dean of the College of Engineering*
RUNE L. EVALDSON, Ph.D., *Professor of Mechanical Engineering and Associate Director, Institute of Science and Technology*
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*
KEITH WILLIS HALL, B.S.M.E., *Professor of Mechanical Engineering*
HERBERT HERLE ALVORD, M.S.E., *Professor of Mechanical Engineering*
RANSOM SMITH HAWLEY, M.E., *Professor Emeritus of Mechanical Engineering*
ORLAN WILLIAM BOSTON, M.S.E., M.E., *Professor Emeritus of Mechanical Engineering and of Production Engineering*
WALTER EDWIN LAY, B.M.E., *Professor Emeritus of Mechanical Engineering*
HUGH EDWARD KEELER, M.S.E., M.E., *Professor Emeritus of Mechanical Engineering*
EDWARD THOMAS VINCENT, B.Sc., *Professor Emeritus of Mechanical Engineering*
FLOYD NEWTON CALHOON, M.S., *Professor Emeritus of Mechanical Engineering*
ARNET BERTHOLD EPPLE, M.S., *Associate Professor of Mechanical Engineering*
JOSEPH REID AKERMAN, Ph.D., *Associate Professor of Mechanical Engineering*
JOSEPH DATSKO, M.S.E., *Associate Professor of Mechanical Engineering*
ARTHUR GENE HANSEN, Ph.D., *Associate Professor of Mechanical Engineering*
WILLIAM MIRSKY, Ph.D., *Associate Professor of Mechanical Engineering*
ROBERT CHARLES JUVINALL, M.S.M.E., *Associate Professor of Mechanical Engineering*
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LESLIE E. WAGNER, M.A., *Assistant Professor of Mechanical Engineering*
FREDERICK JOHN VESPER, 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*
LELAND JAMES QUACKENBUSH, M.S.E. (M.E.), *Assistant Professor of Mechanical Engineering*

JULIAN ROSS FREDERICK, Ph.D., *Assistant Professor of Mechanical Engineering*
FREDERICK KENT BOUTWELL, Ph.D., *Assistant Professor of Mechanical Engineering*
VEDAT S. ARPACI, Sc.D., *Assistant Professor of Mechanical Engineering*
JOSEPH CASMERE MAZUR, M.S.E., *Assistant Professor of Mechanical Engineering*
FRANKLIN HERBERT WESTERVELT, Ph.D., *Assistant Professor of Mechanical Engineering and Research Associate, Computing Center*
RICHARD EDWIN SONNTAG, Ph.D., *Assistant Professor of Mechanical Engineering*
HERMAN MERTE, JR., Ph.D., *Assistant Professor of Mechanical Engineering*
HARRY JAMES WATSON, B.M.E., *Assistant Professor Emeritus of Mechanical Engineering*
KENNETH C. LUDEMA, M.S.E., *Instructor in Mechanical Engineering*
RICHARD JOHN LABOTZ, M.S.E., *Instructor in Mechanical Engineering*
JAMES ROBERT CAIRNS, M.S.E., *Instructor in Mechanical Engineering*
JOHN ALLAN SULLIVAN, M.S., *Instructor in Mechanical Engineering*
ALEXANDER HENKIN, M.S., *Instructor in Mechanical Engineering*
ROBERT FREDERICK TIMM, M.S.E., *Instructor in Mechanical Engineering*
ROBERT MACORMAC CADDELL, B.S. (Mech. Eng.), M.S. (Ind. Eng.), *Lecturer in Mechanical Engineering*
EDWARD RUSSELL LADY, S.M., *Instructor in Mechanical Engineering*
BENJAMIN MINGLI MA, M.S.M.E., *Lecturer in Mechanical Engineering*
WILLIAM OSCAR HERMANSON, M.S.E., *Lecturer in Mechanical Engineering*
WILLIAM TELFER, *Instructor Emeritus in the Working, Treating and Welding of Steel*

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*
HARRY BELL BENFORD, B.S.E. (Nav. Arch. & Mar. E.), *Professor of Naval Architecture and Marine Engineering*
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FINN CHRISTIAN MICHELSEN, Ph.D., *Assistant Professor of Naval Architecture and Marine Engineering*
RAYMOND A. YAGLE, M.S.E., *Assistant Professor of Naval Architecture and Marine Engineering*

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HENRY JACOB GOMBERG, Ph.D., *Professor of Nuclear Engineering and Chairman of the Department of Nuclear Engineering, and Director, Michigan Memorial–Phoenix Project*

WILLIAM KERR, Ph.D., *Professor of Nuclear Engineering and of Electrical Engineering and Associate Director, Michigan Memorial–Phoenix Project*

LLOYD EARL BROWNELL, Ph.D., *Professor of Nuclear Engineering and of Chemical and Metallurgical Engineering*

RICHARD KENT OSBORN, Ph.D., *Professor of Nuclear Engineering*

CHIHIRO KIKUCHI, Ph.D., *Professor of Nuclear Engineering*

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TERRY B. KAMMASH, Ph.D., *Associate Professor of Nuclear Engineering*

DIETRICH HERMANN VINCENT, Dr. Rer. Nat., *Associate Professor of Nuclear Engineering*

GEZA LESLIE GYOREY, Ph.D., *Assistant Professor of Nuclear Engineering*

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, 1961-1962

WEDNESDAY SEPTEMBER 13, 1961

A.M.			P.M.		
8:00— 8:10	Warl	—Watr	1:00—1:10	Arl	—Bab
8:10— 8:20	Wats	—Webe	1:10—1:20	Bac	—Baq
8:20— 8:30	Webf	—Weir	1:20—1:30	Bar	—Bas
8:30— 8:40	Weis	—Wer	1:30—1:40	Bat	—Bec
8:40— 8:50	Wes	—Weste	1:40—1:50	Bed	—Benr
8:50— 9:00	Westf	—Wh	1:50—2:00	Bens	—Bes
9:00— 9:10	Wi	—Wild	2:00—2:10	Bet	—Blac
9:10— 9:20	Wile	—Willi	2:10—2:20	Blad	—Boe
9:20— 9:30	Willj	—Wing	2:20—2:30	Bof	—Bot
9:30— 9:40	Winh	—Wolc	2:30—2:40	Bou	—Bra
9:40— 9:50	Wold	—Woodb	2:40—2:50	Brb	—Brown, F.
9:50—10:00	Woodc	—Wre	2:50—3:00	Brown, G.	—Buc
10:00—10:10	Wrf	—Yat	3:00—3:10	Bud	—Bur
10:10—10:20	Yau	—Yz	3:10—3:20	Bus	—Cam
10:20—10:30	Za	—Zic	3:20—3:30	Can	—Car
10:30—10:40	Zid	—Zz	3:30—3:40	Cas	—Cha
10:40—10:50	Aa	—Ada	3:40—3:50	Chb	—Ci
10:50—11:00	Adb	—Alc	3:50—4:00	Cj	—Cohe
11:00—11:10	Ald	—Alo	4:00—4:10	Cohf	—Con
11:10—11:20	Alp	—Anderse	4:10—4:20	Coo	—Cou
11:20—11:30	Andersf	—Ark	4:20—4:30	Cov	—Cro

THURSDAY SEPTEMBER 14, 1961

A.M.			P.M.		
8:00— 8:10	Crp	—Dam	1:00—1:10	Harriso	—Hd
8:10— 8:20	Dan	—Daz	1:10—1:20	Hea	—Henl
8:20— 8:30	Db	—Deng	1:20—1:30	Henm	—Hile
8:30— 8:40	Denh	—Din	1:30—1:40	Hilf	—Holl
8:40— 8:50	Dio	—Dou	1:40—1:50	Holm	—How
8:50— 9:00	Dov	—Dup	1:50—2:00	Hox	—Hur
9:00— 9:10	Duq	—Eg	2:00—2:10	Hus	—Jack
9:10— 9:20	Eh	—En	2:10—2:20	Jacl	—Jog
9:20— 9:30	Eo	—Fan	2:20—2:30	Joh	—Jones, J.
9:30— 9:40	Fao	—Fil	2:30—2:40	Jones, K.	—Kam
9:40— 9:50	Fim	—Foc	2:40—2:50	Kan	—Kea
9:50—10:00	Fod	—Fran	2:50—3:00	Keb	—Ker
10:00—10:10	Frao	—Fz	3:00—3:10	Kes	—Kiq
10:10—10:20	Ga	—Gau	3:10—3:20	Kir	—Kni
10:20—10:30	Gav	—Gill	3:20—3:30	Knj	—Koth
10:30—10:40	Gilm	—Goldl	3:30—3:40	Koti	—Krug
10:40—10:50	Goldm	—Grah	3:40—3:50	Kruh	—Lami
10:50—11:00	Grai	—Gri	3:50—4:00	Lamj	—Lawre
11:00—11:10	Grj	—Had	4:00—4:10	Lawrf	—Leis
11:10—11:20	Hae	—Ham	4:10—4:20	Leit	—Lewi
11:20—11:30	Han	—Harrisn	4:20—4:30	Lewj	—Lit

FRIDAY SEPTEMBER 15, 1961

A.M.			P.M.		
8:00— 8:10	Liu	—Luca	1:00—1:10	Poq	—Pri
8:10— 8:20	Lucb	—M(a)cClel	1:10—1:20	Prj	—Ram
8:20— 8:30	M(a)cClem	—M(a)cGi	1:20—1:30	Ran	—Reid, S.
8:30— 8:40	M(a)cGj	—M(a)cMa	1:30—1:40	Reid, T.	—Richa
8:40— 8:50	M(a)cMb	—Mall	1:40—1:50	Richb	—Robertsn
8:50— 9:00	Malm	—Marsg	1:50—2:00	Robertso	—Rot
9:00— 9:10	Marsh	—Mat	2:00—2:10	Rou	—Sarg
9:10— 9:20	Mau	—Mere	2:10—2:20	Sarh	—Schwartz, R.
9:20— 9:30	Merf	—Miller, E.	2:20—2:30	Schwartz, S.	—Shel
9:30— 9:40	Miller, F.	—Miz	2:30—2:40	Shem	—Sk
9:40— 9:50	Mj	—Moro	2:40—2:50	Sl	—Sol
9:50—10:00	Morp	—Munm	2:50—3:00	Som	—Steu
10:00—10:10	Munn	—Nax	3:00—3:10	Stev	—Sup
10:10—10:20	Nay	—Ne	3:10—3:20	Suq	—Thomp
10:20—10:30	Nf	—Nz	3:20—3:30	Thomq	—Tup
10:30—10:40	Oa	—Opa	3:30—3:40	Tuq	—Ver
10:40—10:50	Opb	—Pak	3:40—4:00	Ves	—Wark
10:50—11:00	Pal	—Pats			
11:00—11:10	Patt	—Pere			
11:10—11:20	Perf	—Pick			
11:20—11:30	Picl	—Pop			

SATURDAY SEPTEMBER 16, 1961

Any student may register from 9:00 to 10:30 A.M. Saturday registration is inadvisable, however, as many sections of course offerings will be closed. It is essential that registration and classification be completed according to schedule.

SECOND SEMESTER, 1961-1962

WEDNESDAY FEBRUARY 7, 1962

A.M.			P.M.		
8:00— 8:10	Aa	—Ada	1:00—1:10	Bof	—Bot
8:10— 8:20	Adb	—Alc	1:10—1:20	Bou	—Bra
8:20— 8:30	Ald	—Alo	1:20—1:30	Brb	—Brown, F.
8:30— 8:40	Alp	—Anderse	1:30—1:40	Brown, G.	—Buc
8:40— 8:50	Andersf	—Anf	1:40—1:50	Bud	—Bur
8:50— 9:00	Ang	—Ark	1:50—2:00	Bus	—Cam
9:00— 9:10	Arl	—As	2:00—2:10	Can	—Car
9:10— 9:20	At	—Bab	2:10—2:20	Cas	—Cha
9:20— 9:30	Bac	—Bake	2:20—2:30	Chb	—Ci
9:30— 9:40	Bakf	—Baq	2:30—2:40	Cj	—Cohe
9:40— 9:50	Bar	—Barn	2:40—2:50	Cohf	—Con
9:50—10:00	Baro	—Bas	2:50—3:00	Coo	—Cou
10:00—10:10	Bat	—Beal	3:00—3:10	Cov	—Cro
10:10—10:20	Beam	—Bec	3:10—3:20	Crp	—Dam
10:20—10:30	Bed	—Bell	3:20—3:30	Dan	—Daz
10:30—10:40	Belm	—Benr	3:30—3:40	Db	—Deng
10:40—10:50	Bens	—Berm	3:40—3:50	Denh	—Din
10:50—11:00	Bern	—Bes	3:50—4:00	Dio	—Dou
11:00—11:10	Bet	—Bin	4:00—4:10	Dov	—Dup
11:10—11:20	Bio	—Blac	4:10—4:20	Duq	—Eg
11:20—11:30	Blad	—Boe	4:20—4:30	Eh	—En

THURSDAY FEBRUARY 8, 1962

A.M.			P.M.		
8:00— 8:10	Eo	—Fan	1:00—1:10	Joh	—Jones, J.
8:10— 8:20	Fao	—Fil	1:10—1:20	Jones, K.	—Kam
8:20— 8:30	Fim	—Foc	1:20—1:30	Kan	—Kea
8:30— 8:40	Fod	—Fran	1:30—1:40	Keb	—Ker
8:40— 8:50	Frao	—Fz	1:40—1:50	Kes	—Kiq
8:50— 9:00	Ga	—Gau	1:50—2:00	Kir	—Kni
9:00— 9:10	Gav	—Gill	2:00—2:10	Knj	—Koth
9:10— 9:20	Gilm	—Goldl	2:10—2:20	Koti	—Krug
9:20— 9:30	Goldm	—Grah	2:20—2:30	Kruh	—Lami
9:30— 9:40	Grai	—Gri	2:30—2:40	Lamj	—Lawre
9:40— 9:50	Grj	—Had	2:40—2:50	Lawrf	—Leis
9:50—10:00	Hae	—Ham	2:50—3:00	Leit	—Lewi
10:00—10:10	Han	—Harrisn	3:00—3:10	Lewj	—Lit
10:10—10:20	Harriso	—Hd	3:10—3:20	Liu	—Luca
10:20—10:30	Hea	—Henl	3:20—3:30	Lucb	—M(a)cClel
10:30—10:40	Henm	—Hile	3:30—3:40	M(a)cClem	—M(a)cGi
10:40—10:50	Hilf	—Holl	3:40—3:50	M(a)cGj	—M(a)cMa
10:50—11:00	Holm	—How	3:50—4:00	M(a)cMb	—Mall
11:00—11:10	Hox	—Hur	4:00—4:10	Malm	—Marsg
11:10—11:20	Hus	—Jack	4:10—4:20	Marsh	—Mat
11:20—11:30	Jacl	—Jog	4:20—4:30	Mau	—Mere

FRIDAY FEBRUARY 9, 1962

A.M.			P.M.		
8:00— 8:10	Merf	—Miller, E.	1:00—1:10	Sa	—Sarg
8:10— 8:20	Miller, F.	—Miz	1:10—1:20	Sarh	—Schl
8:20— 8:30	Mj	—Moro	1:20—1:30	Schm	—Schwartz, R.
8:30— 8:40	Morp	—Munm	1:30—1:40	Schwartz, S.	—Send
8:40— 8:50	Munn	—Nax	1:40—1:50	Sene	—Shel
8:50— 9:00	Nay	—Ne	1:50—2:00	Shem	—Sk
9:00— 9:10	Nf	—Nz	2:00—2:10	Sl	—Sol
9:10— 9:20	Oa	—Opa	2:10—2:20	Som	—Steu
9:20— 9:30	Opb	—Pak	2:20—2:30	Stev	—Sup
9:30— 9:40	Pal	—Pats	2:30—2:40	Suq	—Thomp
9:40— 9:50	Patt	—Pere	2:40—2:50	Thomq	—Tup
9:50—10:00	Perf	—Pick	2:50—3:00	Tuq	—Ver
10:00—10:10	Picl	—Pop	3:00—3:10	Ves	—Wark
10:10—10:20	Poq	—Pri	3:10—3:20	Warl	—Wer
10:20—10:30	Prj	—Ram	3:20—3:30	Wes	—Willi
10:30—10:40	Ran	—Reid, S.	3:30—3:40	Willj	—Wre
10:40—10:50	Reid, T.	—Richa	3:40—4:00	Wrf	—Zz
10:50—11:00	Richb	—Robertsn			
11:00—11:10	Robertso	—Rop			
11:10—11:20	Roq	—Rot			
11:20—11:30	Rou	—Rz			

SATURDAY FEBRUARY 10, 1962

Any student may register from 9:00 to 10:30 A.M. Saturday registration is inadvisable, however, as many sections of course offerings will be closed. It is essential that registration and classification be completed according to schedule.

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University of Michigan Official Publication

The University of Michigan Official Publication is the title given to the series of administrative bulletins published by the University. This series includes the following:

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The prospective student should have, in addition to a copy of the bulletin 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.

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- Architecture and Design, College of
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  - Graduate
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- Flint College
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- Graduate Studies, Horace H. Rackham School of
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