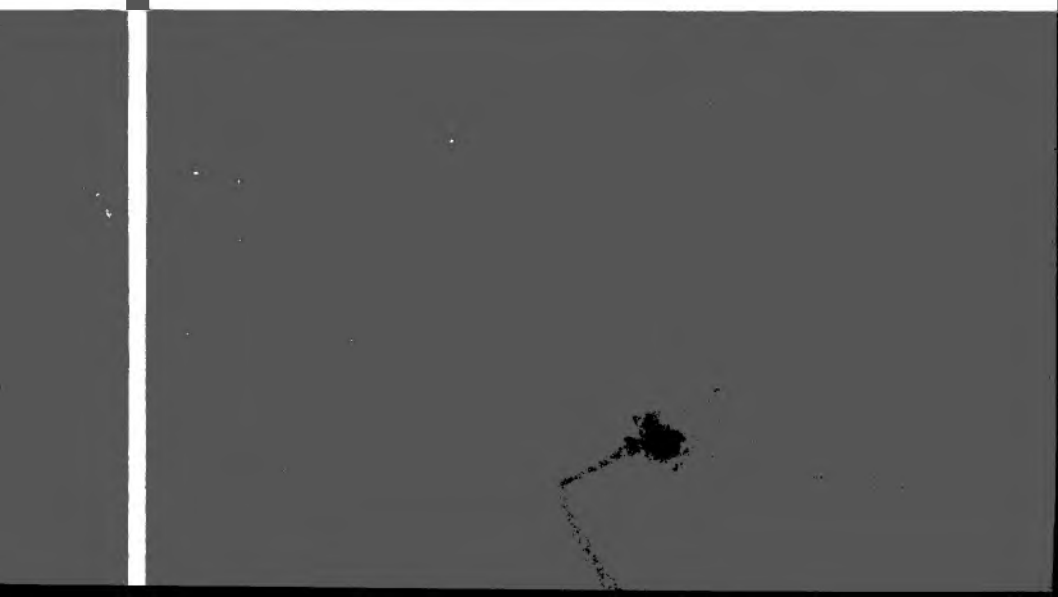
CORNELL UNIVERSITY ANNOUNCEMENTS

ENGINEERING COURSES & CURRICULA

September 17, 1962

COLLEGE OF ENGINEERING



ACADEMIC CALENDAR (Tentative)

1962–1963		1963–1964
Sept. 15....S	Freshman Orientation	Sept. 21....S
Sept. 17...M	Registration, new students	Sept. 23...M
Sept. 18....T	Registration, old students	Sept. 24...T
Sept. 19...W	Instruction begins, 1 p.m.	Sept. 25...W
Nov. 7....W	Midterm grades due	Nov. 13...W
	Thanksgiving recess:	
Nov. 21...W	Instruction suspended, 12:50 p.m.	Nov. 27...W
Nov. 26....M	Instruction resumed, 8 a.m.	Dec. 2.....M
Dec. 19....W	Christmas recess	Dec. 21.....S
	Instruction suspended at 10 p.m. in 1962, at 12:50 p.m. in 1963	
Jan. 3....Th	Instruction resumed, 8 a.m.	Jan. 6.....M
Jan. 19.....S	First-term instruction ends	Jan. 25.....S
Jan. 21....M	Second-term registration, old students	Jan. 27....M
Jan. 22....T	Examinations begin	Jan. 28....T
Jan. 30....W	Examinations end	Feb. 5.....W
Jan. 31...Th	Midyear recess	Feb. 6....Th
Feb. 1.....F	Midyear recess	Feb. 7.....F
Feb. 2.....S	Registration, new students	Feb. 8.....S
Feb. 4.....M	Second-term instruction begins	Feb. 10....M
Mar. 22....F	Midterm grades due (12 noon)	Mar. 27....F
	Spring recess:	
Mar. 23....S	Instruction suspended, 12:50 p.m.	Mar. 28....S
Apr. 1.....M	Instruction resumed, 8 a.m.	Apr. 6.....M
May 25.....S	Second-term instruction ends	May 30.....S
May 27....M	Examinations begin	June 1....M
June 4.....T	Examinations end	June 9.....T
June 10...M	Commencement Day	June 15...M

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CORNELL UNIVERSITY

ENGINEERING COURSES AND CURRICULA

SEPTEMBER, 1962

COLLEGE OF ENGINEERING:
- **AEROSPACE ENGINEERING**
- **AGRICULTURAL ENGINEERING**
- **BASIC STUDIES**
- **CHEMICAL ENGINEERING**
- **CIVIL ENGINEERING**
- **ELECTRICAL ENGINEERING**
- **ENGINEERING MECHANICS AND MATERIALS**
- **ENGINEERING PHYSICS AND MATERIALS SCIENCE**
- **INDUSTRIAL ENGINEERING**
- **MECHANICAL ENGINEERING**
- **METALLURGICAL ENGINEERING**

Prospective freshmen interested in engineering should write for a special illustrated booklet entitled Engineering at Cornell. *Requests should be addressed to the Announcements Office, Day Hall, Cornell University, and should mention that the writer is a prospective freshman.*

CONTENTS

ENGINEERING AT CORNELL

THE OBJECTIVE of the College of Engineering is to provide students with high-quality education, combining competence in engineering science and technology with appreciation of the humanities and social sciences, and utilizing the intellectual and cultural resources of Cornell University. To attain this goal now, and to meet the future requirements of the engineering profession, the College builds upon a long Cornell tradition of significant contributions to engineering education.

From the founding of the University, the College of Engineering has recognized the need for strong undergraduate and graduate programs. Many early Cornell engineering graduates became educators who were instrumental in establishing the pattern of development of modern engineering education. Cornell granted the first doctorate in engineering in the country and established the nation's first separate program granting degrees in electrical engineering. The introduction of the five-year undergraduate program in 1946 reflected the need for engineers with a better foundation in basic science and mathematics, greater competence in engineering science and technology, and broader exposure to the humanities and social sciences. Today the five-year course provides flexibility for more than 1800 undergraduate students, enabling them to prepare effectively either for graduate work or for engineering practice. Programs of graduate study provide opportunities for nearly 300 graduate students to explore new areas of technology in a scholarly atmosphere.

The more than 130 permanent members of the faculty reflect varied interests in the problems of education, the challenges of new fields of research, and the advancement of the engineering profession. Each year this staff is supplemented by several outstanding visiting professors. The engineering faculty last year conducted budgeted and contract research covering the entire range of engineering science and technology from the phenomena of outer space to the subatomic properties of materials, and from the decision models for computer simulation to hot gasdynamics. Such research, essential to education in an age of dynamic technology, creates opportunities for teachers to keep abreast of the latest developments at the frontiers of engineering, and provides an intellectually stimulating atmosphere for attracting outstanding engineering educators.

Eight modern buildings on the engineering campus provide over 600,000 square feet of floor space for teaching and research. Many of these buildings have been the gifts of distinguished Cornell alumni:

Leroy R. Grumman '16: Graduate School of Aerospace Engineering
Franklin W. Olin '86: Chemical Engineering
Spencer T. Olin '21: Civil Engineering
Ellis L. Phillips '95: Electrical Engineering
Maxwell M. Upson '99: Mechanical Engineering
Walter S. Carpenter, Jr. '10: Engineering Library and Administration

Bard Hall for metallurgical engineering, now under construction, the gift of Francis N. Bard '04, will add 50,000 square feet of space for classrooms and laboratories devoted to expanded programs in metallurgy when it is ready for occupancy in the fall of 1963.

With the newly completed nuclear reactor laboratory, the College of Engineering has in operation a reactor facility unique among educational institutions. One reactor has a moderate power core capable of being pulsed to very high power for brief periods, thereby affording an intense pulse of neutrons for investigations of various radiation effects. In addition, the facility has a zero power critical assembly for studies of reactor design and associated problems. The reactor building also houses a gamma irradiation cell, laboratories, classrooms, and offices. Opportunities exist for study and research in such areas of nuclear technology as nuclear metallurgical problems, fuel processing, radiation effects on chemical reactions, heat transfer, design of reactor structures, and analysis of electric power plant systems. The pulsing feature of the reactor permits special kinds of radioisotope tracer work in biological research.

A Center for Radiophysics and Space Research has been organized to conduct graduate programs and research in:

1. Radio investigations of the atmosphere, moon, Venus, Mars, and properties of space in the vicinity of the earth and near-by planets.
2. The development of space vehicle instrumentation for the study of the gases of the solar system.
3. The use of radio astronomy for investigating solar, galactic, and extragalactic phenomena.

A radar antenna 1000 feet in diameter, designed for use in many of these investigations, is under construction. In addition, numerous laboratory studies will be carried on. The Center provides opportunities for faculty and graduate students in astronomy, engineering physics, electrical engineering, physics, and aerospace engineering to collaborate in advancing the understanding of space.

A newly established interdisciplinary Materials Science Center offers graduate study and research in the broad field of materials science, integrating the perspectives of the basic and engineering sciences. Investigations will be conducted to obtain a better understanding of the general laws governing the behavior of materials, to determine methods for improving the engineering properties of materials, and to develop entirely new kinds of materials. Such unified teaching and research efforts will benefit both undergraduate and graduate instruction, and will enable Cornell to maintain its prominent reputation in the materials science field.

In recognition of the growing impact of electronic computers on every area of engineering analysis, the Cornell Computing Center has added a large-scale, magnetic-core, magnetic-type Burroughs 220 digital computer for use by students and faculty. The Center will install during 1962–1963 a Control Data Corporation 1604–160A computer system. Courses are offered in the operation and principles of the computer, enabling both undergraduate and graduate engineering students to obtain the advantages of this powerful computational tool in project and thesis work.

In the spring of 1961, the Ford Foundation made a grant of $4,350,000 to Cornell University to advance graduate study and research in the College of

Engineering. This grant has made possible the establishment of new professorships, additional research facilities, expanded financial assistance for graduate students, and other special projects within the College. Resulting strengthened programs of teaching and research are enabling the College of Engineering to meet more effectively the educational and research requirements of rapidly expanding modern technology. The Ford Foundation grant is having a significant and pervasive influence upon the future development of engineering at Cornell.

As of July 1, 1962, two new professorships, the Given Foundation Professorship in Engineering, endowed by the Given Foundation in memory of John LaPorte Given, Class of 1896, and the IBM Professorship in Engineering, endowed by International Business Machines Corporation, Inc., have been established. The chairs are held by William R. Sears, Director of the Graduate School of Aerospace Engineering, and Henry G. Booker, Director of the School of Electrical Engineering, respectively.

The accelerating expansion of modern science and technology poses a complex challenge for engineering education to keep pace with the demands of the future. The programs described above are representative of the continuing efforts of every division of the College to improve undergraduate programs and to develop graduate education and research, in order to provide Cornell engineering graduates with sound preparation for rewarding professional careers.

UNDERGRADUATE CURRICULA, REQUIREMENTS, AND DEGREES

Prospective freshmen interested in engineering should write for a special illustrated booklet entitled Engineering at Cornell. *Requests should be addressed to the Announcements Office, Day Hall, Cornell University, and should mention that the writer is a prospective freshman.*

CORNELL University confers seven baccalaureate degrees in engineering:

Bachelor of Agricultural Engineering (B.Agr.E.)
Bachelor of Chemical Engineering (B.Ch.E.)
Bachelor of Civil Engineering (B.C.E.)
Bachelor of Electrical Engineering (B.E.E.)
Bachelor of Engineering Physics (B.Eng.Phys.)
Bachelor of Mechanical Engineering (B.M.E.)
Bachelor of Metallurgical Engineering (B.Met.E.)

The degrees are conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms, must have satisfied the University requirements in physical education, and must have paid his tuition and fees.
2. He must have completed to the satisfaction of the faculty of the College of Engineering all the subjects and the elective hours prescribed in the course of study as outlined by that faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements of the class with which he graduates.
4. Each student in the first term of the freshman year in the College of Engineering must attend regularly the lectures in orientation for students in engineering.

The first two years of undergraduate work are substantially the same for students expecting to study chemical, civil, electrical, mechanical, or metallurgical engineering, or engineering physics. The freshman and sophomore courses of study therefore are administered by the Division of Basic Studies described on pages 23–25. Choice of a specific degree program in most cases does not have to be made until the second year.

After the second year, a student contemplating a transfer within the College of Engineering, or to another division of the University, should discuss his plans first with his adviser. If he decides to transfer to another school within the College of Engineering, the student must apply to the director of that school during the term preceding the one in which he wishes to make the change. Transfers made after the beginning of the third year, while still possible, may require one or more additional terms of study in order to meet degree requirements. In general, transfers early in the college program result in fewer complications and less time lost.

SPECIAL UNDERGRADUATE PROGRAMS OF STUDY

UNDERGRADUATE PROGRAM IN AEROSPACE ENGINEERING

DURING the fourth and fifth years, students with good scholastic records in electrical engineering, engineering physics, or mechanical engineering may elect courses in the Graduate School of Aerospace Engineering. They may carry out senior projects in the aerospace field under the direction of the School's staff. Students who elect this program graduate with an unusually sound aerospace education in addition to their broad, undergraduate engineering education. These specialized aerospace studies are of a type usually reserved for graduate students.

The student planning to follow this course of studies should consult with W. R. Sears, Director of the Graduate School of Aerospace Engineering, by the beginning of his third year in engineering so as to plan his program to best advantage.

This same program prepares the student planning to work for the Master of Aeronautical Engineering degree. It is also a basic program, along with his other engineering course work, for the student planning study in this field beyond the Master's degree. (See page 6.)

NUCLEAR TECHNOLOGY

Qualified students in the fourth and fifth years of chemical, civil, electrical, mechanical, and metallurgical engineering, and engineering physics, may elect a series of coordinated courses in nuclear technology. The courses, introductory, advanced, and supplementary, comprise a relatively complete coverage of the field of nuclear engineering.

Introductory: 8301 (or Physics 243), 8311, 8351, 3605 (or 3665 or 5505), 5760, 6872

INDUSTRIAL COOPERATIVE PROGRAM

During the fourth term, above-average students in electrical and mechanical engineering and in engineering physics are invited to be interviewed for admission to the Industrial Cooperative Program.

The Cooperative Program provides three term-length work periods (about sixteen weeks each) in one of the following industries operating the plan with the University: American Electric Power Service Corporation, Anaconda Wire & Cable Company, Cornell Aeronautical Laboratory, Emerson Electric Company, General Dynamics/Telecommunication, General Electric Company, General Radio Company, the Gleason Works, International Business Machines Corporation, Philco Corporation, Procter and Gamble Manufacturing Company, Raytheon Manufacturing Company.

The program incorporates the summer vacation periods after Term 4 into the student's work-study schedule. The cooperative student completes the regular academic study for his Bachelor's degree, pursues his work program, totaling one year in industry, and still graduates with his regular class. He remains on campus with his regular classmates except during the fifth and eighth terms. The work of these terms he takes in the summer co-op term.

The schedule for the Cooperative Program, beginning after the fourth term, is as follows:

Third Year

Summer: Fifth term courses
Fall: Industry
Spring: Sixth term courses

Fourth Year

Summer: Industry
Fall: Seventh term courses
Spring: Industry

Fifth Year

Summer: Eighth term courses
Fall: Ninth term courses
Spring: Tenth term courses

The objective of the program is educational rather than remunerative, although the student receives a substantial salary from industry during his three work periods.

The work program of each student is arranged to advance his individual interests and aptitudes within the regular activity of the company with which he is affiliated. He has no industry assignment the first summer, and he does his industrial work in one company throughout the entire program. These two requirements enable him to pursue his engineering objectives in work areas seldom available through ordinary summer placement. The individual coun-

seling and appraisal of progress that characterize the Program enable the student to pursue his studies and graduate into industry with realistic objectives.

Students are admitted to the Cooperative Program in the fourth term only. Applicants are subject to approval both by the College and by one of the cooperating industries. Admission to the plan involves no obligation on the part of either the student or the industry with regard to future employment.

GRADUATE PROGRAMS OF STUDY

M.S., Ph.D., and M.AERO.E. DEGREES

A GRADUATE student holding a baccalaureate or equivalent degree from a college or university of recognized standing may pursue advanced work leading to a graduate degree in engineering. Such a student may enter as a candidate either for the general degrees (M.S. or Ph.D.) or for the professional degrees (M.Ch.E., M.C.E., M.E.E., M.I.E., M.M.E., M.Met.E.).

The general degrees (M.S. and Ph.D.) are available in all the fields and subdivisions of the College of Engineering. They are administered by the Graduate School and require work in both major and minor fields of study, as well as the completion of a satisfactory thesis, usually involving individual and original research. A prospective graduate student interested in obtaining an M.S. or Ph.D. degree should consult the *Announcement of the Graduate School* for additional information concerning these degrees and should correspond with the professor supervising the particular field of engineering representing his major interest. Students who do not completely meet the entrance requirements for these degrees may be admitted as provisional candidates or without candidacy according to previous preparation, but they must in all cases hold a baccalaureate or equivalent degree.

The degree of Master of Aeronautical Engineering (M.Aero.E.) is granted on the recommendation of the faculty of the Graduate School of Aerospace Engineering. Prospective candidates for this degree should apply directly to the Director of the Graduate School of Aerospace Engineering.

PROFESSIONAL MASTERS' DEGREES

Professional degrees at the Master's level are offered in chemical, civil, electrical, industrial, mechanical, and metallurgical engineering and are administered by the Engineering Division of the Graduate School. These degrees are intended primarily for those persons who wish to enhance their ability in the practice of engineering, and not for those whose expected activities will be in engineering teaching or research. The student with a baccalaureate degree in an area of engineering or science deemed appropriate to his proposed field of study may become a candidate for a professional degree. These professional degrees require at least 45 credit hours of graduate-level course work, or its equivalent, in the principles and practices of the specific field. They do not require the presentation of a thesis based upon research studies. For each candidate a special curriculum of related courses, differing in content among the several professional degrees, is either prescribed or agreed upon in advance. The

prospective student should consult the detailed descriptions of requirements of the various schools elsewhere in this Announcement.

The required number of credit hours in each curriculum may be reduced by allowing credit for graduate-level work completed before entry into the program, or for professional experience approved by the faculty as substantially covering the same area as any part of the curriculum, provided that the total allowance does not exceed fifteen credit hours. Such allowance for work outside the program will be granted only after the candidate is enrolled in the program, and, in order to avoid misunderstanding, no commitments concerning advanced credit can be made by prior correspondence between faculty members and prospective students. The candidate interested in coming into this program from industry should write to the director of the division of engineering he plans to enter. Under a special arrangement, a student with a superior record of performance for four years of undergraduate engineering studies at Cornell may enroll in the program during his fifth undergraduate year and begin the accumulation of professional degree credits for certain advanced courses taken during this year. The minimum time required for a Cornell student to obtain the professional degree will be one term beyond the baccalaureate degree.

The professional degrees are considered to be at the five-and-one-half to six-year level of university work, requiring from one to two years of additional study beyond a four-year baccalaureate program.

COMBINED PROGRAMS IN LAW, BUSINESS AND PUBLIC ADMINISTRATION, AND CITY AND REGIONAL PLANNING

Qualified students may apply for admission to special programs permitting completion of both a Bachelor's degree in engineering and a graduate or advanced degree in law, business or public administration, or city and regional planning, in one year less than the normal period. Interested students should consult their advisers during their third year, in order to plan appropriate elective courses during the fourth and fifth years.

Ordinarily such a combined program, leading to two degrees, would constitute an eight-year course of study in the case of law and seven years in the case of business and public administration or city and regional planning. By choosing as electives courses acceptable to the other schools or colleges and by being permitted to count certain other courses as meeting requirements in both areas, students will be able to acquire the two degrees in the shortened period.

Arrangements for one or more such combined programs of study are possible for selected students in chemical, civil, electrical, mechanical, and metallurgical engineering. Applications will be accepted at any time prior to the fifth year, but, for maximum flexibility and ease of program planning, the choice should be made as early as possible. Applications must be approved by both participating schools or colleges.

GRADUATE SCHOLARSHIPS AND FELLOWSHIPS

Graduate students whose major subjects are in the various branches of engineering and who wish to be candidates for scholarship or fellowship aid should

consult the *Announcement of the Graduate School* and make application to the Dean of the Graduate School. Those who are candidates for the degree of M.Aero.E. should apply to the Director of the Graduate School of Aerospace Engineering.

STUDENT PERSONNEL SERVICES

STUDENT PERSONNEL OFFICE

THE ADMISSION of new students, the administration of scholarships in the College of Engineering, and the placement of graduates are activities of the College which are coordinated in the Student Personnel Office. The Personnel Office, in addition to other facilities, is also available at all times to students who wish to discuss any question relating to their life in the College.

STUDENT COUNSELING

In general, the counseling of students rests with the class advisers to whom the students are assigned primarily for assistance in planning and scheduling their academic work, but who will welcome students at any time to discuss other personal matters. In each school of the College, students are referred to the chairman of the scholarship committee when in financial need and to a placement adviser for assistance in vocational choice and postgraduate employment. Also, the students are free to consult with the dean, directors, department heads, and instructors, not only on matters pertinent to their education and future plans, but also on personal matters. In addition, the University's Dean of Students and staff may be consulted by students regarding their nonacademic problems.

SCHOLARSHIPS, GRANTS-IN-AID, AND PRIZES

SCHOLARSHIPS FOR FRESHMEN

SOME OF THE scholarships listed below are paid for from the income of endowments; others derive from revolving funds established by industries, foundations, or individuals. Many of the revolving funds provide generous gifts to the University in support of the costs of educating students not covered by tuition and fees. Their gifts to the University are made in addition to the scholarship grants, and, in the list below, the amounts are indicated in parentheses following the amounts paid the students.

CHARLES R. ARMINGTON SCHOLARSHIPS IN ENGINEERING . . . Gift of Mr. and Mrs. R. Q. Armington, in memory of their son who was a student in the School of Mechanical Engineering at the time of his death in 1956. Open to men students in any branch of engineering. One scholarship

annually with annual stipend up to $2000 ($1000). Tenure, not limited. Selection based on balance of academic and extracurricular interests with outstanding personal characteristics.

JOHN HENRY BARR SCHOLARSHIP . . . Gift of Mrs. Mabel R. Barr, for a deserving student to be chosen by the University from recommendations of the Cornell Club of the Lehigh Valley. Annual award, up to $2000. Tenure, not limited.

EDWARD P. BURRELL SCHOLARSHIPS . . . Gift under the will of Katherine W. Burrell, in memory of her husband. Open to men and women entering the College of Engineering. Award, up to $800 for freshman year only. Need is an important factor in selecting the winners.

GENERAL MOTORS COLLEGE SCHOLARSHIP . . . Established in 1957 by the General Motors Corporation. Available to men or women who are citizens of the United States and are entering the College of Engineering. One scholarship annually with stipend of from $200 to $2000 ($800), depending upon need. Tenure, unlimited. Selection based upon outstanding academic promise, general character, and financial need.

INLAND STEEL FOUNDATION SCHOLARSHIPS . . . Established by the Inland Steel Foundation. Annual award, $1500 ($1000). Tenure, not limited. Selection is based on scholastic attainment, personal characteristics, and financial need. Summer employment may be offered to recipient by the Inland Steel Company.

MARTIN J. INSULL SCHOLARSHIP . . . Gift of his wife, Mrs. Virginia Insull. Open to men entering the College of Engineering. Annual award, $1500. Tenure, not limited. Further provisions as for the McMullen Regional Scholarships (see below), except that financial need is an essential criterion.

LOCKHEED NATIONAL ENGINEERING SCHOLARSHIP . . . Established by the Lockheed Leadership Fund. Open to entering students in the College of Engineering. Annual award, tuition and fees plus $500 ($500). Tenure, unlimited. One award each year to a student who is in a field of engineering applicable to the aerospace industry and whose total personal qualities can be expected upon graduation to offer a significant contribution to the aerospace industry.

JOHN McMULLEN REGIONAL SCHOLARSHIPS . . . Gift under the will of John McMullen. Open to men entering the College of Engineering. Annual award, up to $1500. Tenure, not limited. Fifty or more scholarships awarded annually. Applicants will be selected on the basis of high scholastic achievement and other indications of qualities likely to produce leadership in engineering. Although financial need is not a factor in selecting the winners, full consideration will be given to need in fixing stipends.

OWENS-ILLINOIS SCHOLARSHIP . . . Established by Owens-Illinois. Open to men. Annual award, tuition and fees plus $125 for books and supplies in the freshman year and $100 annually thereafter ($1340). Tenure, not limited. Selection will be based on scholastic achievement, personality, and financial need. Summer employment may be offered by Owens-Illinois.

PROCTER AND GAMBLE SCHOLARSHIPS . . . Established by the Procter and Gamble Company. Open to men or women entering the College of Engineering. Annual award, tuition and fees plus $115 for books and supplies ($600). Tenure, unlimited. Selection based on academic achievement, character, and financial need.

ANNIE F. AND OSCAR W. RHODES SCHOLARSHIPS . . . Gift under the will of Oscar Lynn Rhodes in memory of his mother and father for scholarships to students in engineering. Open to freshmen. Annual award, up to $1500. Tenure, not limited. One or more scholarships to be awarded annually to students on the basis of high scholastic achievement and professional promise. Although financial need is not a factor in selecting the winners, full consideration will be given to need in fixing stipends.

ALFRED P. SLOAN NATIONAL SCHOLARSHIPS . . . Established by the Alfred P. Sloan Foundation. Open to men entering the College of Engineering. Annual award varies from a prize scholarship of $200 to as much as $2000, depending upon financial need ($520). Tenure, not limited. Nine scholarships awarded annually. Applicants will be selected on the basis of high character, sound personality, leadership potential, and professional promise.

UNION CARBIDE ENGINEERING SCHOLARSHIPS . . . Established in 1960 by the Union Carbide Corporation. One scholarship awarded annually to an entering student with a preference for chemical, mechanical, or metallurgical engineering. Award equal to the amount of tuition and fees plus $100 for books and supplies ($600). Tenure, not limited. Same requirements as for the McMullen Regional Scholarships.

JESSEL STUART WHYTE SCHOLARSHIP . . . Gift of Mrs. Anna Jessel Whyte in memory of her son. Open to entering students with a preference for mechanical engineering. Annual award, $1000. Tenure, not limited. Preference will be given to residents of Illinois, Iowa, Michigan, Minnesota, and Wisconsin. Further provision as for McMullen Regional Scholarships.

SCHOLARSHIPS AND GRANTS-IN-AID FOR UPPERCLASSMEN

Students in their sophomore year and beyond may apply for financial assistance through the Office of Scholarships and Financial Aid, Day Hall.

Awards are of two general types: (1) those for which the principal qualification is financial need, and (2) those for which outstanding scholastic achievement is the chief criterion. In the first category are scholarships which are essentially grants-in-aid. Eligibility extends to any student not on scholastic probation.

The second category of awards, based on high scholastic and other attainments, consist of (1) a limited number of scholarships sponsored by industrial companies, mostly for students in their last two years of study, and (2) such vacancies as may occur in scholarships of this type usually awarded to entering students and subject to renewal.

Many of the sponsoring institutions provide generous gifts to the University in support of the costs of educating students not covered by tuition and fees. Their gifts to the University are made in addition to the scholarship grants, and,

in the list below, the amounts are indicated in parentheses following the amounts paid the students.

Below are the scholarships sponsored by industrial companies and foundations.

ALCOA SCHOLARSHIPS . . . Established in 1959 by the Alcoa Foundation. Open to third, fourth, or fifth year students. Five awards annually, one of which shall be for a student in metallurgical engineering. Award, $625 ($125). Tenure, one year.

ALLEGHENY LUDLUM SCHOLARSHIP . . . Established by the Allegheny Ludlum Steel Corporation. Award, $500 ($500). Tenure, three years. Awarded annually to a student in chemical or metallurgical engineering, normally to a student in metallurgical engineering, with primary consideration for academic record, promise of ability, and success in his field of study. Need is a secondary factor.

AMERICAN MACHINE AND FOUNDRY COMPANY SCHOLARSHIPS . . . Established in 1960 by the American Machine and Foundry Company. One scholarship awarded annually to a leading fourth year student in mechanical or electrical engineering. Tenure, two years. Annual award, $500 or $1000 depending upon need (variable).

CHARLES R. ARMINGTON PRIZE SCHOLARSHIP IN ENGINEERING Gift of Mr. and Mrs. R. Q. Armington, in memory of their son who was a student in the Sibley School of Mechanical Engineering at the time of his death in 1956. One scholarship annually to a student entering his fourth year in any branch of engineering, with annual stipend of $500 or more depending upon need ($1000). Tenure, two years. Recipients will be students who in their first three years of college have demonstrated outstanding qualities of personality, notably sportsmanship of a high order.

CARRIER MEMORIAL SCHOLARSHIPS . . . Established in 1961 by the Carrier Air Conditioning Company. Award, $1200. Tenure, three years. One scholarship annually to a student in his third year who has established an outstanding scholastic record, who needs financial assistance or possesses exceptional ability.

CHEMSTRAND SCHOLARSHIP . . . Established in 1958 by the Chemstrand Corporation. Open to a senior in chemical engineering who is a superior student and a U.S. citizen. Annual award, $500.

DOW CHEMICAL COMPANY SCHOLARSHIPS . . . Established by the Dow Chemical Company. Award, $1000. One scholarship to be awarded annually and renewable for the fifth year to a student in chemical engineering. One other scholarship, with a tenure of one year and a stipend of $500, will be awarded annually to an upperclassman in metallurgical engineering.

DRAVO CORPORATION SCHOLARSHIPS . . . Established by the Dravo Corporation. Open to fourth year students in civil, electrical, or mechanical engineering. One new award of $1000 annually ($500); may be renewed for fifth year. Selections based on scholastic ability, need, and personal characteristics.

FOUNDRY EDUCATIONAL FOUNDATION SCHOLARSHIPS . . . Open to all students (except freshmen) in metallurgical and mechanical engineering who are interested in preparing themselves for professional engineering work in the foundry industries. Annual award, up to $600. Tenure, one or more years. Awarded on the basis of leadership, financial need, scholastic standing, and interest in foundry work.

MINNESOTA MINING AND MANUFACTURING COMPANY SCHOLARSHIPS . . . Established in 1962 by the Minnesota Mining and Manufacturing Company. One or more awards to undergraduate students. Award, not to exceed $1000. Tenure, one year.

MONSANTO SCHOLARSHIP . . . Established by the Monsanto Chemical Company. Open to fifth year students in the School of Chemical and Metallurgical Engineering. Award based upon academic standing, interest in chemistry, and probability of success. Financial need not considered. Annual award, $1000.

NIAGARA MACHINE & TOOL WORKS SCHOLARSHIP . . . Established in 1956 by the Niagara Machine & Tool Works. Award, $1000 ($1000). Tenure, two years. One scholarship every two years to a fourth year student in mechanical engineering with principal interest in machine design and development.

THE SCOTT AWARD AT CORNELL . . . Established by the Scott Paper Company. One scholarship awarded annually to an outstanding fourth year student in mechanical engineering who intends to follow an industrial career. Tenure, two years. Award, tuition ($500). The recipient must have demonstrated those high qualities of intellect, personality, and physical vigor associated with the Rhodes Scholars.

STANDARD OIL COMPANY OF CALIFORNIA SCHOLARSHIP . . . Established in 1961 by the Standard Oil Company of California. Award, $1200. Tenure, one year. One scholarship for a student in any undergraduate year.

WESTERN ELECTRIC SCHOLARSHIPS . . . Established by the Western Electric Company. Open to students in any division of the College of Engineering. Three scholarships with annual award up to $800 to be applied against the cost of tuition, fees, and books. Tenure, one year; may be renewed. Selection based upon need and ability in fields of study related to the Company's operations.

PRIZES

Cornell University has a considerable number of funds given for the endowment of prizes to be awarded annually. Some of these prizes are open to competition by any students in the University. The publication, *Prize Competitions,* describing the prizes and the nature of the competitions, may be obtained at the Visitor Information Center, Day Hall. Prizes open to competition particularly by students of the College of Engineering are:

THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS PRIZE is a badge awarded by the School of Chemical Engineering to a junior in chemical engineering for the best scholastic record at the end of the fourth term.

THE AMERICAN SOCIETY OF TESTING MATERIALS PRIZES, consisting of six one-year memberships in the Society, are awarded to students in the College of Engineering for the highest scholastic average in materials.

THE CHARLES LEE CRANDALL PRIZES, founded in 1916 by alumni of the School of Civil Engineering. The prizes of $200 and $100 are awarded each year by a committee appointed by the Director of the School of Civil Engineering for the best papers written by students in the fifth term or above in that School, on suitable subjects, provided that both the substance and the written form of the papers submitted show real merit. The prizes were established to encourage original research, to stimulate interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before April 15 of each year.

THE FUERTES MEDALS, established by the late Professor E. A. Fuertes. The endowment provides for two gold medals. One is awarded annually by the faculty to that student of the School of Civil Engineering who is found at the end of the first term of his senior year to have maintained the highest degree of scholarship in the subjects of this course, provided he has been in attendance at the University for at least two years. The other is awarded annually by the faculty to a graduate of the School of Civil Engineering, or the recipient of a graduate degree with major in civil engineering, who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form, it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction.

THE FUERTES MEMORIAL PRIZES IN PUBLIC SPEAKING, established in 1912, consist of several prizes totaling $200. They are awarded by a committee of seven judges to students in the fifth term or beyond of the Colleges of Architecture and Engineering for proficiency in public speaking.

THE HAMILTON AWARD . . . A suitably engraved Hamilton watch and letter of commendation is awarded annually to the senior in engineering who has most successfully combined proficiency in his major field of study with achievements, either academic, extracurricular, or a combination of both, in the social sciences and humanities.

THE INSTITUTE OF AEROSPACE SCIENCES PRIZE . . . The "Student Branch Scholastic Award" of the Institute of Aerospace Sciences is presented annually to the M.Aero.E. candidate who attains the best scholastic record for that academic year. The award consists of a certificate and a two-year free technical membership in the Institute.

SIBLEY PRIZES . . . Under a gift of Hiram Sibley, made in 1884, the sum of $100 is awarded annually in several prizes to fifth year students in mechanical engineering and electrical engineering, equally distributed, who have received the highest average in the preceding four years.

THE SILENT HOIST AND CRANE COMPANY MATERIALS HANDLING PRIZE, established in 1950 by the Wunsch Foundation, is in an amount approximating $300 and is awarded for the best original paper on the subject of materials handling at the discretion of a College of Engineering faculty committee. This contest is open to undergraduate and graduate students of the College of Engineering.

THE WILLIAM WAYNE KRANTZ AWARD, established by the Class of 1961 in Electrical Engineering in memory of their classmate who died on August 6, 1960, is made to the fifth year student in Electrical Engineering who has demonstrated qualities of perseverance, ambition, courage, and unwavering desire to become an electrical engineer. Award consists of a shingle and enrollment of the winner's name on a plaque in Phillips Hall.

THE J. G. WHITE PRIZES IN SPANISH . . . Through the generosity of James Gilbert White (Ph.D., Cornell, '85), three prizes, established in 1914, each of the value of $100, are offered annually. One of the three, which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the College of Engineering who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University.

COLLEGE HONORS AND ACTIVITIES

DEAN'S HONOR LIST

STUDENTS of the College of Engineering whose weighted average in their studies is 85.00 per cent or better are included annually in an Honor List compiled for the Dean. The honor students comprise approximately the highest tenth of all the students enrolled in the College.

HONOR SOCIETIES

Engineering students may qualify for membership in local and national honor societies, including Tau Beta Pi, Phi Kappa Phi, Sigma Xi, Pi Tau Sigma, Chi Epsilon, Rod and Bob-Pyramid, Atmos, Kappa Tau Chi, and Eta Kappa Nu.

PUBLICATIONS

The *Cornell Engineer,* a magazine containing articles of professional interest for engineering students and alumni, is published monthly throughout the academic year by undergraduates of the College of Engineering.

ENGINEERING SOCIETIES

Many meetings of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of

Automotive Engineers, and Institute of Radio Engineers are held on campus and are attended by students. The College also maintains active student branches of these societies, as well as of the American Institute of Chemical Engineers, American Society of Agricultural Engineers, and the Institute of Aerospace Sciences. The Cornell Metallurgical Society was formed in 1949 and is an affiliate of the American Institute of Mining and Metallurgical Engineers. A student branch of the American Nuclear Society was founded in 1959.

ENGINEERING STUDENT COUNCIL

The Engineering Student Council, consisting of elected student representatives from each division of the College, plans the annual Engineers' Day program for high school visitors to the campus, represents engineering student viewpoints in campus affairs, and conducts studies of the activities of the College. Upperclassmen on the council have participated in an informal tutoring program for freshmen desiring such assistance.

SOURCES OF ADDITIONAL INFORMATION

PROSPECTIVE freshmen interested in engineering should write for a special illustrated booklet entitled *Engineering at Cornell.* Requests should be addressed to the Announcements Office, Day Hall, Cornell University, and should mention that the writer is a prospective freshman.

Detailed information on the following subjects is available in the *Announcement of General Information:* health services and medical care, health requirements, housing, ownership of cars, physical education, loans, part-time employment, tuition, and fees. Information on military training is available in the *Announcement of Military Training.* Both Announcements may be obtained by writing the Announcements Office, Day Hall.

Students on the Cornell campus may obtain copies of the Announcements (catalogs) at the administrative offices of the various schools and colleges.

GRADUATE SCHOOL OF AEROSPACE ENGINEERING

GRUMMAN HALL

AEROSPACE ENGINEERING is the field of engineering that deals with the flight of aircraft, guided missiles, and space vehicles in the atmosphere and in the regions of space adjoining the atmosphere. The primary objective of this School is to educate selected engineering and science graduates in the scientific aspects of this field. The training is intended especially to prepare the students for research and development engineering in the aerospace industry and in related research institutions.

In the School's new quarters, superior facilities are provided for laboratory studies in fluid mechanics, aerodynamics, and gasdynamics. Members of the teaching staff and graduate students are engaged in an active program of fundamental studies in these fields. Emphasis is put upon the scientific and engineering problems of space flight, i.e., of vehicles which leave and re-enter the earth's atmosphere at extreme speeds.

PREPARATION FOR GRADUATE STUDY

The Graduate School of Aerospace Engineering will admit students holding baccalaureate degrees in any branch of engineering, physics, or mathematics, provided that their undergraduate scholastic records are such as to indicate ability to handle graduate study. The Cornell courses of study in engineering physics, electrical engineering, and mechanical engineering are especially recommended to students who expect to enter this School after graduation.

All students who expect to enter the Graduate School of Aerospace Engineering should try to arrange their undergraduate programs to include as much work as possible in applied mechanics, thermodynamics, mathematical analysis, and physics. In most cases, it would be well for engineering students to elect courses in intermediate or advanced physics, such as atomic and molecular physics, kinetic theory of gases, and electricity and magnetism.

It will be possible for Cornell students in the five-year undergraduate programs to complete the requirements for the degree M.Aero.E. in one year of graduate study instead of the normal two years, if they complete a sufficient number of the required graduate courses as electives in their undergraduate programs.

MASTER OF AERONAUTICAL ENGINEERING (M.Aero.E.)

Students who in their undergraduate careers have demonstrated more than average ability in analytical subjects and who have shown adequate promise of carrying on graduate study successfully are eligible to apply for this program in the Graduate School of Aerospace Engineering.

Application for admission to this program should be made to W. R. Sears, Director of the Graduate School of Aerospace Engineering, Grumman Hall, Cornell University. A special application blank for this purpose can be obtained from the Director's office. It should be returned directly to him.

The program of areospace engineering studies is applicable to much of the standard engineering work in the aerospace industry, but beyond that its objective is to increase the student's facility in the use of the basic sciences in engineering and to stimulate his growth in independent research and development work. Because the progress in this field is so rapid, it is an essential objective of this program to go beyond the study of present-day practices and techniques and to prepare the student in the fundamental background and analytical methods that can be adapted to future development.

The successful completion of the work for this degree requires that the student (1) pass a series of courses or examinations in the subjects listed below; and (2) submit an acceptable Master's thesis based upon original research. The subject list constitutes a standard of accomplishment for the M.Aero.E. candidate, but the faculty will modify the list to suit the needs, interests, and background of each individual candidate. Courses are available to permit candidates to study in any of three areas of aerospace engineering: (1) aerodynamics, (2) gasdynamics (aerophysics), and (3) aerospace structures. Active research in the first two of these areas is being carried out in the School. Research in aerospace structures is an important activity of the Department of Engineering Mechanics and Materials. The student electing to concentrate his work in this field will take a considerable portion of his electives in engineering mechanics and materials.

Although the standard list of required subjects, together with the thesis, would ordinarily occupy four terms of graduate study, the residence requirement has been set at one year (two terms) so that students who enter the School with exceptional preparation, or who are able otherwise to pass the required examinations, may be able to qualify for the degree in one year.

If the student wishes to satisfy a requirement by examination rather than by passing a course, he should request the faculty of the School to schedule such an examination.

It is suggested that each candidate supplement his required program of courses, e.g., the standard list below, by additional courses either in aerospace engineering or in other fields of study in order to achieve a balanced program of twelve to sixteen credit hours per term.

The candidate must pass a final examination, either oral or both oral and written, administered by the faculty of aerospace engineering. The faculty frequently invites other members of the University staff to attend and to participate in such examinations.

STANDARD LIST OF REQUIRED SUBJECTS FOR THE M.AERO.E. DEGREE

	CREDIT HOURS
Engineering 1180, 1181, Advanced Engineering Mathematics	6
Engineering 7101, Fundamentals of Aerodynamics	3
Engineering 7102, Fundamentals of Aerodynamics	3
or	
Engineering 4991, Electronic Engineering	3
Engineering 7203 (or 8121) and 7204, Gasdynamics	6
Engineering 7301, Theoretical Aerodynamics I	3
Engineering 1170, Advanced Mechanics	3
Electives chosen from List A below	12

ELECTIVES: LIST A

	CREDIT HOURS
Engineering 7206, Introduction to Magnetohydrodynamics	3
Engineering 7207, Dynamics of Rarefied Gases	3
Engineering 7208, Hypersonic-Flow Theory	2
Engineering 7302, Theoretical Aerodynamics II (Wing Theory)	3
Engineering 7303, Theoretical Aerodynamics III (Compressible Fluids)	3
Engineering 7304, Theoretical Aerodynamics IV (Viscous Fluids)	3
Engineering 1162, Mechanics of Vibration	3
Engineering 1163, 1164, Applied Elasticity	3, 3
Engineering 1165, Mathematical Elasticity	3
Engineering 1167, Plates and Shells	3
Engineering 1168, Plasticity and Stability	3
Engineering 1171, Introductory Space Mechanics	3
Engineering 1172, Selected Topics in Engineering Mechanics	(arranged)
Engineering 1175, Introduction to Nonlinear Mechanics	3
Engineering 1263, Electrical and Magnetic Properties of Materials	3
Engineering 3652, Combustion Theory	3
Engineering 4565, Electromagnetic Theory	3
Mathematics 415–6, Mathematical Methods in Physics	4, 4
Physics 318, Analytical Mechanics	4
Physics 431, Introductory Theoretical Physics	4
Physics 443, Atomic Physics and Introduction to Quantum Mechanics	4
Physics 444, Nuclear and High Energy Particle Physics	4
Physics 454, Electronic Properties of Solids and Liquids	4
Physics 510, Advanced Experimental Physics	3
Physics 571, Classical Mechanics	3
Physics 573, Electrodynamics	4

STUDY LEADING TO THE DEGREE OF Ph.D.

The current *Announcement of the Graduate School* sets forth the requirements for candidacy for the degree of Ph.D. and lists the general requirements—residence, major and minor subjects, foreign languages, qualifying examinations, and thesis. As explained in that Announcement, each candidate must complete a schedule of courses acceptable to his Special Committee.

AGRICULTURAL ENGINEERING

RILEY-ROBB HALL

A JOINT program administered by the Colleges of Agriculture and Engineering leads to the degree of Bachelor of Agricultural Engineering. Students in this curriculum register in the College of Agriculture during the first four years but take courses in the Colleges of Engineering, Arts and Sciences, and Agriculture. Registration for the fifth and final year is in the College of Engineering, which grants the degree.

The purpose of this curriculum is to prepare engineers for a career in the agricultural industry—including such fields as power and machinery, structures, soil and water engineering, electrification, and the processing and handling of agricultural products.

Complete laboratory facilities for teaching and research programs in agricultural engineering and food technology are in Riley-Robb Hall. Because the Department has an active research program supported through the Cornell Agricultural Experiment Station, many students find opportunities for part-time work in research during the academic year and in summer vacations.

PRACTICE REQUIREMENT

Since agricultural engineering students are registered in the College of Agriculture for the first four years, they must meet the farm practice requirement of the College. The basic requirement is 25 units of acceptable farm experience gained at the approximate rate of one unit per week. Twelve of these units must be completed before registration for the sophomore year. The entire 25 units must be completed prior to registration in the fourth year. Unless the student has fulfilled these requirements as a prefreshman, he will usually do so during the summers between the freshman and junior years. The *Announcement of the College of Agriculture* should be consulted for details of the requirement.

A.S.A.E. STUDENT BRANCH

An active student branch of the national American Society of Agricultural Engineers is available to all students in this program. Participation in the organization is a valuable means of gaining first-hand knowledge of the professional field of agricultural engineering, and it also provides opportunities for personal development.

ELECTIVES

There are thirty hours of electives:

1. Six hours in social studies with a two-course sequence.
2. Six hours in humanities with a two-course sequence.

3. Twelve hours of electives in nontechnical courses.
4. Six hours of electives unspecified.

SCHOLASTIC REQUIREMENTS

To remain in good standing, a student must have a weighted average for the term of 70 or above. If the weighted average is 60 or higher, but less than 70, the student will be placed on probation. A student will be dropped from the program if a third consecutive term of probation is indicated or if the weighted average is below 60. In all cases, the student may appeal an action by presenting new information to the Joint Faculty Committee.

CURRICULUM (B.Agr.E.)

(For a complete description of the courses in agriculture, see the *Announcement of the College of Agriculture.*)

			CONTACT HOURS	
		CREDIT HOURS	LECT. REC.	LAB. COMP.
TERM 1	Mathematics 191, Analytic Geometry and Calculus	4	4	0
	Physics 121, Introductory Analytical Physics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introduction to English	3	3	0
	Agr. Engineering 105, Engineering Drawing	4	2	5
	Agriculture 1, Orientation	1	1	0
	Total	18		
TERM 2	Mathematics 192, Analytic Geometry and Calculus	4	4	0
	Physics 122, Introductory Analytical Physics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 112, Introduction to English	3	3	0
	Agr. Engineering 2, Introduction to Agr. Engineering	2	1	2½
	Elective	3		
	Total	18		

In addition to these courses, all freshmen must satisfy the University's requirements in physical education.

TERM 3	Mathematics 293, Engineering Mathematics	4	4	0
	Physics 223, Introductory Analytical Physics	3	3	2½
	Engineering 211, Mechanics of Rigid and Deformed Bodies	4	3	2½
	Engineering 241, Electrical Science	3	2	2½
	Biology 1, General Biology	3	2	2½
	Total	17		
TERM 4	Mathematics 294, Engineering Mathematics	3	3	0
	Physics 224, Introductory Analytical Physics	3	3	2½
	Engineering 212, Mechanics of Rigid and Deformed Bodies	4	3	2½
	Chemistry 276, Introduction to Physical Chemistry	3	3	0
	Biology 2, General Biology	3	2	2½
	Agr. Engineering 220, Surveying	2	1	2½
	Total	18		

In addition to these courses, all sophomores must satisfy the University's requirements in physical education.

The courses of study for terms 5 through 10 will apply only to students who matriculated in 1960 or before. For students matriculating in 1961, new courses of study are being developed and will appear in subsequent Announcements.

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 5	Engineering 1241, Materials of Construction	3	3	0
	Animal Husbandry 10, Livestock Feeding	4	3	2½
	Engineering 2731, Elements of Structural Engineering I	3	2	2½
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Bacteriology 1, General Bacteriology	5	3	5
	Total	18		
TERM 6	Engineering 3341, Machine Design	4	3	2½
	Engineering 1242, Materials of Construction	3	3	0
	Engineering 2301, Elementary Fluid Mechanics	4	3	2½
	Engineering 2732, Elements of Structural Engineering II	3	0	6
	Agronomy 1, Nature and Properties of Soils	4	3	2½
	Total	18		
TERM 7	Engineering 3601, Thermodynamics	3	3	0
	Agronomy 11, Production of Field Crops	4	3	2½
	Engineering 2302, Hydrology	2	2	0
	Extension Teaching 101, Oral and Written Expression	2	3	0
	Electives	6		
	Total	17		
TERM 8	Engineering 3602, Thermodynamics	3	3	0
	Agr. Engineering 221, Soils and Water Engineering	3	2	2½
	Agr. Economics 102, Farm Management	5	3	3
	Agr. Engineering 203, Agricultural Machinery Design	3	2	2½
	Elective	3		
	Total	17		
TERM 9	Engineering 3605, Heat Transfer	3	2	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Agr. Engineering 202, Farm Power Machines	3	2	2½
	Agr. Engineering 253, Special Topics	1	1	0
	Electives	9		
	Total	19		
TERM 10	Engineering 4932, Electrical Engineering	3	2	2½
	Agr. Engineering 231, Farm Structures Design	3	2	2½
	Agr. Engineering 253, Special Topics	1	1	0
	Electives	9		
	Total	16		
	Total for ten terms	176		

GRADUATE STUDY

Flexible programs leading to both the M.S. and the Ph.D. are offered in the following areas of specialization for either a major or minor: agricultural structures, power and machinery, soil and water engineering, and electric power and processing. Minors for those majoring in agricultural engineering may be selected from the engineering, agricultural, or basic sciences depending upon the student's interests and needs. A broad and active research program, supported by the Cornell Agricultural Experiment Station, gives the student an opportunity to select a challenging research project for his thesis. Several assistantships are available with annual stipends ranging from $2400 to $3000. For more detailed information and sample programs, contact the Graduate Field Representative, Riley-Robb Hall, Cornell University.

DIVISION OF BASIC STUDIES

FRESHMEN in the College of Engineering are enrolled, for the first two years of the five-year undergraduate program, in the Division of Basic Studies of the College of Engineering. The Division is responsible for admissions to the College at underclass level, administers a program of courses for its freshmen and sophomores, and assigns each engineering underclassman to a senior member of the College of Engineering faculty as his adviser.

During his freshman year the engineering student undertakes to develop his underlying competence in mathematics, and in the sciences of physics and chemistry, while improving his ability to communicate through a course in English required of nearly all freshmen at the University. Through contact with senior engineering staff, both as advisers and in class discussions in a course in engineering problems and methods, the student is able to arrive at valid educational goals in line with his interest and demonstrated competence. He is made more fully aware of the range of the fields and the functions of the individual in the engineering profession. Instruction in graphics as a means of communication, some aspects of engineering economy, and an introduction to elementary concepts of problem solving, leading toward design at an elementary level which is based on concurrent mathematics and science courses, are also included.

During the sophomore year the student extends his knowledge of mathematics and physics and begins his study of the applications of these sciences to engineering problems in two courses taught by members of the faculty of the College of Engineering in the fields of mechanics and electrical science. He undertakes a course of physical chemistry, tying together his background in physics and chemistry at a level utilizing his strong preparation in mathematics, and laying the foundation for a subsequent course in materials in the junior year of the field of his upperclass work. He also undertakes an elective course, continuing to develop that group of liberal studies requirements, including English, that constitute approximately one-fifth of his engineering education at Cornell. Chemical and metallurgical students delay the studies in mechanics from the sophomore to the junior years in order to establish earlier chemistry sequences during their sophomore program.

Most students select their upperclass objectives before the beginning of the spring term of their sophomore year. The professional schools specify one of the five courses of Term Four, for students planning to enter that specialty. This may normally be taken either during the spring term of the sophomore year or in the summer session preceding the junior enrollment. Through these alternatives students find a change of objective possible as late as the beginning of their junior year.

If a student expresses his interest in a particular branch of engineering at the outset, he will be assigned to a faculty adviser whose major interest is in that field. If he does not express a particular interest, then after he determines his field of study, he may change his adviser to obtain the counsel of a faculty member in his chosen field.

Students in underclass courses are normally enrolled in sections of the various courses which are suitable to their individual level of achievement, and some are thus able to develop more rapidly toward the honors groups or programs of advanced study available in their professional fields. Through cooperation with the advanced placement program of the College Entrance Examination Board and departmental tests given during the orientation period, normally one-fifth of the class is given advanced placement or actual college credit for one or more courses of the freshman year. This makes possible more individual development toward a broader liberal program, or advanced technical study in line with the student's own inclination. For superior students who have achieved advanced placement in mathematics and either chemistry or physics upon graduation from high school, it is possible for enrollment to be achieved at sophomore level through the use of the University summer session prior to their enrollment at the University in September.

FRESHMAN YEAR

Freshman students entering the College of Engineering in the fall of 1962 will take the following program of courses:

	CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
FIRST TERM			
Mathematics 191, Analytic Geometry and Calculus	4	4	0
Physics 121, Introductory Analytical Physics	3	3	2½
Chemistry 105, General Chemistry	3	2	3
English 111, Introduction to English	3	3	0
Engineering 101, Engineering Problems and Methods I	3	2	2½
SECOND TERM			
Mathematics 192, Analytic Geometry and Calculus	4	4	0
or			
Mathematics 122, Analytic Geometry and Calculus	3	3	0
Physics 122, Introductory Analytical Physics	3	3	2½
Chemistry 106, General Chemistry	3	2	3
or			
Chemistry 108, General Chemistry and Inorganic Qualitative Analysis	4	3	3
English 112, Introduction to English	3	3	0
Engineering 102, Engineering Problems and Methods II	3	2	2½

In addition to these courses, all freshmen must satisfy the University's requirements in physical education.

SOPHOMORE YEAR

All engineering sophomore students, except chemical engineering and metallurgical engineering designates, will take the following program of courses:

	CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
THIRD TERM			
Mathematics 293, Applied Mathematics	4	4	0
Physics 223 or 225 or 227, Introductory Analytical Physics	3	3	2½
Electrical Science 241 or 243, Electrical Science I	3	2	2½
Mechanics 211, Mechanics of Rigid and Deformable Bodies I	4	3	2½
Liberal Elective	3 or 4	–	–

	CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
FOURTH TERM			
Mathematics 294, Applied Mathematics	3	3	0
Physics 224 or 226 or 228, Introductory Analytical Physics	3	3	2½
Chemistry 276, Introduction to Physical Chemistry	3	3	0
Mechanics 212, Mechanics of Rigid and Deformable Bodies II	4	3	2½
Designated Course	3 or 4	–	–
Civil Engineering, Liberal Elective or Electrical Science 242 or 244	3	3	2½
Electrical Engineering, Electrical Science 242 or 244	3	3	2½
Mechanical Engineering, Electrical Science 242 or 244	3	3	2½
Engineering Physics, Liberal Elective	3 or 4	–	–

All sophomore engineering students indicating a preference for chemical or metallurgical engineering will take the following program of courses:

	CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
THIRD TERM			
Mathematics 293, Applied Mathematics	4	4	0
Physics 223 or 225 or 227, Introductory Analytical Physics	3	3	2½
Electrical Science 241 or 243, Electrical Science I	3	2	2½
Chemistry 285, Introductory Physical Chemistry	5	3	6
* Chemical Engineering 5101, Material and Energy Balances	3	2	2
† Metallurgical Engineering 6211, Introductory Metallurgical Engineering	3	2	2½
FOURTH TERM			
Mathematics 294, Applied Mathematics	3	3	0
Physics 224 or 226 or 228, Introductory Analytical Physics	3	3	2½
Liberal Elective	3 or 4	–	–
Chemistry 286, Introductory Physical Chemistry	5	3	6
* Chemical Engineering 5102, Equilibria and Staged Operations	3	2	2
† Metallurgical Engineering 6212, Introductory Metallurgical Engineering	3	2	2½

* For chemical engineering designates.
† For metallurgical engineering designates.

CHEMICAL ENGINEERING

OLIN HALL

CHEMICAL Engineering is the application of the principles of the physical sciences, of mathematics, and of engineering judgment to fields in which material is treated to effect a change in state, energy content, or composition. The major application of chemical engineering is in the process industries where raw materials are converted into useful products, such as chemicals, petroleum products, metals, rubber, plastics, synthetic fibers, foods, and paper.

Programs in chemical engineering and in metallurgical engineering are administered by the School of Chemical and Metallurgical Engineering, with facilities in Olin Hall, and in the laboratories for foundry practice and metal working. Chemistry courses are given in the Baker Laboratory of Chemistry. Information on metallurgical engineering begins on page 57.

Instruction in the basic principles of chemical engineering starts in the second year and extends through the fifth year. The project courses in the fifth year are designed to encourage individual work and initiative under conditions equivalent to those found in the process industries.

The chemical engineering curriculum contains 27 credit hours of electives. A minimum of 15 of these elective credit hours must be taken in the fields of humanities, social studies, and languages. In addition, 6 credit hours in both English and history are included in required courses, so that each student must take a minimum of 27 credit hours of nontechnical courses. The remaining 12 elective hours are considered to be free electives, and courses may be chosen to fit a student's particular needs and objectives. They may be added to the minimum requirements in nontechnical courses, or they may be used to take advanced courses in specialized fields of engineering to prepare for careers in such fields. Students planning to enter graduate schools may use the free electives to prepare for graduate study. During the sixth term each student must submit a coordinated plan to his adviser indicating the electives he proposes to take and outlining the objectives to be achieved.

OPTIONS

Specialized work is offered in biochemical engineering, petroleum, plastics and rubbers, business administration, nuclear engineering, instrumentation and automation, industrial and engineering administration, and reaction kinetics. The two-year sequence of electives at an advanced level allows students to

arrange programs that are the equivalent of options in these fields. The exact sequence of courses to be selected for advanced training is not specified, since it depends on the students' interests and capabilities. Exceptional students are allowed to register for graduate courses in these fields.

PREDOCTORAL HONORS PROGRAM

The Predoctoral Honors Program is designed for those undergraduate students who expect to make careers of research and teaching. It has as its principal objective indoctrination in research and the advanced theoretical subject matter normally included as part of the work for the Doctor's degree in chemical engineering. Those graduating from this program should be able to obtain their Doctor's degree in the minimum time required by various graduate schools.

Undergraduates interested in this program may apply for admission during their third year so that they may provisionally preregister for a sequence of courses beginning in the fourth year. Final approval for the program will not be given until the end of the fourth year. During this provisional period the student must demonstrate initiative in selecting and making plans for a research project extending through both the fourth and fifth years of the undergraduate chemical engineering curriculum.

There will be no fixed standards for entry into the program. Students' requests for admission during their third year will be considered by the entire chemical engineering staff and reviewed again at the end of the seventh term. Applicants must state their intentions to study for the doctorate with the objective of a career in research or teaching. Since four of the courses to be taken in the ninth and tenth terms are required of doctoral candidates in the Graduate School, students approved for this program must have demonstrated high levels of scholarship in difficult courses, particularly those that are prerequisites for advanced-level work.

Principal features of the Predoctoral Honors Program are: a year of mathematics beyond differential equations, a three-term research project, and the substitution of theoretical advanced work for some of the design courses in the fifth year. Students are also urged to take a foreign language as part of their electives.

SCHOLASTIC REQUIREMENTS

A student in the School of Chemical and Metallurgical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average of 75, may be dropped or placed on probation.

If, in the opinion of the faculty, a student's general record is unsatisfactory, the student may be refused permission to continue his course even though he has met the minimum requirements of credit hours passed and of grades for those hours. Students who fall behind in their work may be warned, put on probation, or dropped, either from an individual course or from the University, at any time during the term.

CURRICULUM (B.Ch.E.)

Course programs for Terms 1 through 4, administered by the Division of Basic Studies, are described on pages 24–25.

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 5	Chemistry 357, Introductory Organic Chemistry	5	3	6
	Engineering 5203, Chemical Processes	2	2	0
	Engineering 5303, Introduction to Rate Processes	3	3	0
	Engineering 5851, Chemical Microscopy	3 or 0	1	5
	Engineering 3241, Statistics	0 or 3	2	2½
	Engineering 1153, Strength of Materials	3	2	1
	History 165, Science in Western Civilization	3	3	0
	Total	19		
TERM 6	Chemistry 358, Introductory Organic Chemistry	5	3	6
	Engineering 5204, Chemical Processes	2	2	0
	Engineering 5304, Analysis of Unit Operations	3	3	0
	Engineering 5851, Chemical Microscopy	0 or 3	1	5
	Engineering 3241, Statistics	3 or 0	2	1
	Engineering 1152, Dynamics	3	3	0
	History 166, Science in Western Civilization	3	3	0
	Total	19		
TERM 7	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5353, Unit Operations Laboratory	3	2	3
	Engineering 5255, Materials of Construction	3	3	0
	Engineering 4931, Electrical Engineering	3	2	2½
	Electives	6	–	–
	Total	18		
TERM 8	Engineering 5104, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5354, Project Laboratory	3	2	3
	Engineering 5256, Materials of Construction	3	3	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Electives	6	–	–
	Total	18		
TERM 9	Engineering 5503, Fluid Dynamics and Heat Transfer	2	2	0
	Engineering 5106, Reaction Kinetics	2	2	0
	Engineering 5621, Process Economics and Design	5	3	5
	Engineering 5713, Patents	2	2	0
	Electives	6	–	–
	Total	18		
TERM 10	Engineering 5504, Mass Transfer	2	2	0
	Engineering 5622, Plant Design Project	5	3	5
	Chemistry 555, Advanced Inorganic Chemistry	3	3	0
	Electives	6	–	–
	Total	16		
	Total for ten terms	174		

GRADUATE STUDY

REQUIREMENTS FOR THE DEGREE OF M.Ch.E.

A candidate must complete a minimum of 54 credits of which 45 must be in technical subjects from the following list (see page 6 for additional information):

Chemistry: Courses in analytical chemistry numbered 426 or higher; in organic chemistry, 456 or higher; in physical chemistry, 380 or higher; in inorganic chemistry, 410 or higher; in biochemistry, 201 or higher.

Physics: Courses numbered 225 or higher.

Mathematics: Courses numbered 200 or higher (except Course 608).

Chemical Engineering: The following courses are approved: 5105, 5107, 5108, 5205–6, 5503–4, 5505–6, 5507, 5508–9, 5605–6–7–8, 5609, 5621–2, 5741–2–3–4–5, 5746, 5747, 5748, 5752, 5760, 5851, 5853, 5859, 5900, 5955–6.

Other branches of engineering: Any course offered in the College of Engineering which is considered by the school or department to be an advanced course.

Of these courses, a minimum of 18 credit hours must be in the basic sciences, including at least 6 credit hours in mathematics, 3 in chemistry, and 3 in either physics or biology.

Also, 18 credit hours must be taken in the chemical engineering courses listed above. Normally, a student will be expected to complete 5503–4 and six hours in a project course.

To complete the degree requirements, all courses in excess of the 45 hours specified are considered electives. They may be technical or nontechnical but must be approved by the student's adviser.

All courses to be counted toward the degree must be passed with a minimum grade of 75 or a signed statement by the professor in charge attesting that the student's work was of graduate caliber.

CIVIL ENGINEERING

HOLLISTER HALL

THE CIVIL engineer is concerned with the large fixed works and systems that are basic to community living, industry, and commerce, particularly in the areas of water resources, water supplies, sanitation, transportation, structures, and urban complexes. His particular work varies from research and development to planning, design, construction, operation and maintenance, application and sales, analysis and testing, teaching, and administration and management.

Modern well-equipped classrooms and laboratories are available for instruction and research in Hollister Hall, and at the Hydraulic Laboratory at Triphammer Falls, in the following principal areas:

Surveying, mapping, photogrammetry and graphics
Airphoto interpretation and physical environment evaluation
Water resources and hydraulic engineering
Sanitary engineering
Transportation engineering
Structural engineering
Soils engineering
Construction engineering and administration

B.C.E. PROGRAMS

Except as noted otherwise, the curriculum outlined in the following section applies only to students who registered in the School of Civil Engineering before September, 1961. Details of the curriculum which will apply to students who registered in Cornell in 1961 and thereafter will appear in subsequent Announcements. The new curriculum will reduce the number of hours required for graduation and will afford greater flexibility in planning programs to suit the interests, needs, and aptitudes of students. Summer survey camp will be discontinued as a required subject. The curriculum will consist of a core of subjects which all students must take, plus about twenty-one hours of work in subjects related to one or more civil engineering areas such as those listed above, plus twenty-one hours of liberal studies (in addition to those required in the Division of Basic Studies), plus nine hours of free elective courses. In addition, latitude will be allowed in taking courses in other parts of the College of Engineering and the University.

SCHOLASTIC REQUIREMENTS

In order to remain in good standing a student must maintain an average of at least 70 per cent.

CURRICULUM (B.C.E.)

Course programs for Terms 1 through 4, administered by the Division of Basic Studies, are described on pages 24–25. Terms 5 through 10 described below, apply to students matriculating before September, 1961.

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 5	Engineering 1134, Strength of Materials	3	3	0
	Engineering 1152, Mechanics-Dynamics	3	3	0
	Engineering 2701, Elementary Structural Analysis	3	2	2½
	Engineering 2501, Microbiology in Engineering (or Geology 113)	3	2	2½
	Engineering 2301, Fluid Mechanics	4	3	2½
	History 165, Science in Western Civilization	3	3	0
	Total	19		
TERM 6	Engineering 2102, Advanced Surveying	3	2	2½
	Engineering 2302, Hydrology	2	2	0
	Engineering 2702, Steel and Timber Structures	4	2	4
	Engineering 2725, Soil Mechanics (or 2502)	3	2	2½
	Engineering 2901, Construction Methods (or Humanities Elective)	3	3	0
	History 166, Science in Western Civilization	3	3	0
	Total	18		
	Engineering 2105, Summer Survey Camp	5	0	0
TERM 7	Engineering 1241, Materials (or 2503)	3	3	0
	Engineering 2502, Water Supply and Sewerage Systems (or 2725)	3	2	2½
	Engineering 2602, Transportation (or Humanities Elective)	3	3	0
	Engineering 2704, Statically Indeterminate Structures	4	3	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Humanities Elective (or 2901)	3	3	0
	Total	19		
TERM 8	Engineering 2503, Water and Wastes Treatment	3	2	2½
	Engineering 2610, Highway Engineering (or C.E. elective)	3	2	2½
	Engineering 2715, Reinforced Concrete Design (or 2902)	4	2	4
	Engineering 2312, Hydraulic Engineering	3	3	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Humanities Elective (or 2602)	3	3	0
	Total	19		
TERM 9	Engineering 1212, Materials Laboratory (or 2903)	3	1	5
	Engineering 2902, Engineering Law (or 2715)	3	3	0
	Engineering 2720, Foundations (or Humanities Elective)	3	2	2½
	Engineering 3630, Thermodynamics	3	3	0
	C.E. Elective (or 2610)	3	–	–
	Free Elective	3	–	–
	Total	18		

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 10	Engineering 2903, Engineering Economy (or 1212)	3	3	0
	Engineering 3642, Heat Power	2	2	0
	C.E. Elective	3	–	–
	Humanities Elective (or 2720)	3	–	–
	Free Elective	6	–	–
	Total	17		

In addition to these courses, all sophomores must satisfy the University's requirements in physical education.

GRADUATE STUDY

The School offers work leading to the M.C.E. (professional Master's degree), the M.S., and the Ph.D. degrees. In civil engineering the following areas of concentration are available either as majors or minors: geodetic and photogrammetric engineering, hydraulics, hydraulic engineering, construction engineering and administration, sanitary engineering, structural engineering, structural mechanics, soils engineering, transportation engineering, and aerial photographic studies. Descriptions of individual courses are given elsewhere in this Announcement. For professional Masters' degrees, see p. 6.

Prospective graduate students should consult the *Announcement of the Graduate School.* A brochure, *Graduate Programs in Civil Engineering,* is also available upon request from the School of Civil Engineering, Hollister Hall.

ELECTRICAL ENGINEERING

PHILLIPS HALL

THE CURRICULUM leading to the degree of Bachelor of Electrical Engineering is intended to create in the student an understanding of the meaning and the application of those laws of nature that are basic in the practice of electrical engineering and, at the same time, to provide the opportunity for as much nontechnical course work as is consistent with the primary objective of training an electrical engineer. A new curriculum in electrical engineering for students entering the College of Engineering in the fall of 1961 and thereafter is now under development by the faculty. The curriculum described below applies to students expecting to graduate by June, 1965.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Industrial Cooperative Program. See p. 5 for details.

CLASS ADVISERS

Each class is assigned to an adviser who serves in this capacity until the class graduates. In addition to counseling each student about curriculum, registration, scholarship, and other aspects of the academic program, he is available to discuss any serious nonacademic problems the students may have.

Since the class adviser is responsible for approval of the registration of each student, no cancellation of courses or other changes in program may be initiated without his knowledge and approval. If the class adviser does not approve a chosen course of study, the student may seek approval of the program by petition to the faculty of the School of Electrical Engineering.

ELECTIVE COURSES

The curriculum in electrical engineering allows each student to choose a considerable number of elective courses during the later years of the curriculum. Of the fifty-one total elective credit hours, twenty-seven must be nontechnical, fifteen must be technical, and nine are completely free. To achieve both breadth and depth in the student's nontechnical program, the twenty-seven nontechnical elective hours must be selected as follows:

1. Nine hours elected from social studies with a two-course sequence included;
2. Nine hours elected from the humanities with a two-course sequence included;
3. Nine hours elected from any nontechnical course.

Fifteen elective credit hours (of which six may be Project) must be selected from courses in electrical engineering, mathematics, or physics. Of these fifteen hours, nine must be taken in electrical engineering. A course so selected must

not contain a great amount of material that is essentially equivalent to that in required courses in the curriculum.

The courses, elected in fulfillment of the fifteen-hour technical elective requirement, serve as a core for advanced studies in a particular phase of electrical engineering. Students may specialize in radio science, microwave or semiconductor electronics, electric network theory, feedback control systems and computers, nuclear technology, power systems, or applied mathematics and physics. Alternately, some students find it advisable to take advanced courses that lie in more than one of these specialties.

The nine free elective hours may be chosen from among any courses in the University for which prerequisites are satisfied, including those in the foregoing list. By carefully planning the use of electives, students may carry out extensive programs of study in other divisions of the University during the fifth year of the curriculum.

The program of the fifth year includes two three-hour elective courses designated as "Project." A student makes his own selection of the topic or problem that he plans to investigate under the general supervision of a faculty member and prepares a project proposal for submission to his intended project supervisor. In choosing a topic and preparing a proposal, the student is expected to demonstrate the initiative and responsibility he will need to complete the project successfully. It is expected that each student will choose a problem closely related to his major interest in electrical engineering. If his proposal is not approved or if he does not elect to do a project, the student must elect six other technical elective hours.

In many cases students choose to combine all or some portion of the free-elective requirements with the technical-elective requirements in order to emphasize certain studies in electrical engineering. Some of the many fields of studies along with their related courses are listed below. These groupings of courses are not intended to imply that a student must confine his studies to any one field but are presented for general information.

ELECTRIC NETWORK THEORY

4115—Principles of Nonlinear Systems
4563—Signals and Noise in Communication Systems
4564—Transmission of Information
4571—Modern Network Analysis
4572—Modern Network Synthesis
4575—Advanced Topics of System Theory

ELECTRIC POWER SYSTEMS

4351—Unified Theory of Electro-Mechanical Systems
4352—Elements of Power-System Analysis
4353—Transient Analysis of Power Systems

ELECTRONS AND WAVES

4526—Electron Dynamics
4527—Microwave Electronics I
4528—Microwave Electronics II
4521—Microwave Laboratory
4561—Microwave Theory and Techniques
4565—Electromagnetic Theory
4529—Semiconductor Electronics I

4530—Semiconductor Electronics II
4531—Quantum Electronics

FEEDBACK CONTROL SYSTEMS AND COMPUTERS

4711—Feedback Control Systems I
4712—Feedback Control Systems II
4713—Feedback Control Systems Seminar
4810—Analog Computation
4820—Switching Systems I
4821—Switching Systems II
1175—Nonlinear Mechanics

ILLUMINATION

4611—Introductory Illumination
4612—Illumination Engineering
4615—Illumination Seminar
Physics 307—Physical Optics
Psychology 305—Perception

NUCLEAR TECHNOLOGY

(The following courses constitute the core curriculum for the Engineering College Nuclear Technology Program.)

8301—Introduction to Atomic Nuclear Physics
8311—Nuclear and Reactor Physics
8351—Nuclear Measurements Laboratory
3605—Heat Transfer
6872—Nuclear Materials Technology
5760—Nuclear and Reactor Engineering

COMMUNICATION SYSTEMS

4511—Physical Basis of Electronic Engineering
4512—Radio Engineering
4541—Applied Accoustics
4563—Signals and Noise in Communication Systems
4551—Radio Aids to Navigation

RADIO SCIENCE

4565—Electromagnetic Theory
4568—Antennas
4566—Introduction to Plasma Physics
4567—Radio Wave Propagation
4581—Magnetohydrodynamical Processes in the Solar System

Nine credit hours in advanced military science or air or naval science may be counted toward the requirements of the baccalaureate degree. These nine hours are considered to lie within the free-elective area of the curriculum.

SCHOLASTIC REQUIREMENTS

To remain in good standing, a student must either pass the courses for which he is registered two weeks after the beginning of the term and have a weighted average of not less than 70 per cent; or, if one course is failed or is canceled, have a weighted average for the remaining courses of not less than 75 per cent. A student failing to meet this requirement or failing to make satisfactory progress toward his degree, evidenced either by course failures or by low grades in

major courses, may be warned, placed on probation, or dropped from the School.

SPECIAL PROGRAM IN MATHEMATICS

For those students who have a special interest and ability in mathematics an advanced program in mathematics is offered. It is recommended particularly to the students who intend to do graduate work. To allow time for the 15 credits of additional mathematics courses, some of the normal requirements of the curriculum are waived.

CURRICULUM (B.E.E.)

Course programs for Terms 1, 2, 3, and 4, administered by the Division of Basic Studies, are described on pages 24–25. The curriculum described below applies to students matriculating before September, 1961.

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 5	Engineering 1241, Engineering Materials	3	2	2½
	Engineering 1152, Mechanics	3	3	0
	Engineering 4112, Introduction to Linear Network Analysis	3	2	2½
	Engineering 4116, Introductory Electrical Laboratory	3	1	3
	Nontechnical Electives	6	–	–
	Total	18		
TERM 6	Engineering 2331, Fluid Mechanics	3	3	0
	Engineering 4114, Mathematical Analysis of Linear Systems II	3	2	2½
	Engineering 4121, Introduction to Electronic Engineering	4	3	2½
	Engineering 4216, Electric and Magnetic Circuits Laboratory	4	2	3
	Nontechnical Elective	3	–	–
	Total	17		
TERM 7	*Engineering 2331, Fluid Mechanics	3	3	0
	Engineering 4122, Elements of System Theory	4	3	2½
	Engineering 4221, Alternating Current Machinery	4	2	3
	Engineering 4113, Transmission Lines and Waves	3	2	2½
	Nontechnical Elective	3	–	–
	Total	17		
TERM 8	Physics 314, Atomic, Nuclear, and Solid State Physics	3	3	0
	Engineering 4165, Electromagnetic Theory	4	3	2½
	Engineering 4123, Electronics of Signal Transmission	4	3	2½
	Engineering 4226, Electrical Machinery Laboratory	4	2	3
	Nontechnical Elective	3	–	–
	Total	18		
TERM 9	Engineering 4021, Technical Writing and Presentation	3	3	0
	Free Electives	3	–	–
	Nontechnical Elective	3	–	–
	Senior Project 4091 (or Technical Elective)	3	–	–
	Technical Elective	6	–	–
	Nonresident Lectures 4041	1	1	0
	Total	19		

* Applies to students in Term 7 in fall, 1962.

		CONTACT HOURS		
		CREDIT HOURS	LECT. REC.	LAB. COMP.
TERM 10	Free Elective	6	–	–
	Nontechnical Electives	6	–	–
	Senior Project 4092 (or Technical Elective)	3	–	–
	Technical Electives	3	–	–
	Total	18		
	Total for ten terms	170		

GRADUATE STUDY

The regulations and requirements for the degrees of Doctor of Philosophy and Master of Science are described in the *Announcement of the Graduate School.* These are research degrees that involve residence on the campus and submission of a thesis. In the School of Electrical Engineering, research work leading to these degrees may be undertaken in the area of electrophysics including radio propagation, radio and radar astronomy, plasma phenomena, magnetohydrodynamics, physical and microwave electronics, material science in electrical engineering, biomedical electronics, electric power conversion, ionized gases in electromagnetic fields, electrical breakdown phenomena, etc., and in the area of systems theory including information theory, network theory, communications systems, feedback control systems, switching circuits, computers, cognitive systems, etc. A number of fellowships, research assistantships, and teaching assistantships are available to candidates for the degree of Doctor of Philosophy and Master of Science who are doing their thesis research in the School of Electrical Engineering. Assistantship applications and further information can be obtained by writing to the Coordinator of Graduate Studies, School of Electrical Engineering.

The degree of Master of Electrical Engineering is available as a curriculum type of professional degree at the Master's level, the general requirements for which are stated on page 6. Of the forty-five credit hours stated in the general requirements, the M.E.E. degree requires six hours of Project 4091 and 4092, twelve hours of advanced electrical engineering courses (the advanced electrical engineering courses include all the elective and graduate courses listed on pages 90–94 of this Announcement plus 4123, 4165, and 4226), six hours of advanced physics, six hours of advanced mathematics, and fifteen hours from any of the aforementioned groups of electrical engineering, physics, or advanced mathematics courses. All course work to be counted toward the M.E.E. degree requirements must be passed with a minimum grade of 80.

To enter the M.E.E. program, a student must first have been accepted by the Graduate School for admission as a candidate for the M.S. degree. Upon admission he may petition to the Electrical Engineering Graduate Committee for transfer to the M.E.E. program. The M.E.E. program will normally be limited to students who cannot satisfy the residence requirements of the M.S. degree.

ENGINEERING MECHANICS AND MATERIALS

THURSTON HALL

THE DEPARTMENT of Engineering Mechanics and Materials is responsible for undergraduate and graduate instruction and research in applied mechanics, applied mathematics, and materials science. Subject matter in these three fields is of a fundamental nature, and the undergraduate courses provide a substantial part of the basic engineering science education for engineering students. In addition to the required courses in applied mechanics, applied mathematics, and materials science, the undergraduate can elect advanced courses. They are especially suited to students who have demonstrated superior analytical or experimental ability and who wish to extend and develop this ability in one or more of the three areas.

The graduate program in applied mechanics and applied mathematics leads to the M.S. and Ph.D. degrees in engineering mechanics; in materials science it leads to the M.S. and Ph.D. degrees in engineering materials (see p. 6). Advanced theoretical and experimental work is basic in the newest developments in engineering and in applied science and provides a foundation for future needs in these fields. The analytical and scientific nature of the studies permits graduates to participate in attacking problems that cut across varied fields of research, development, and design. Graduate students pursue programs in the following areas of specialization: (1) space mechanics—including research on trajectories and orbits of space vehicles and satellites as well as the theory of light-weight, thin-walled structures; (2) wave propagation in solids—with research on the dynamic response of plates, structures, and machine elements; (3) structural mechanics—including static and dynamic loading, vibrations, and buckling; (4) theory of elasticity and plasticity; (5) theoretical fluid mechanics—with research in magnetohydrodynamics; (6) materials science—with research programs in stress corrosion cracking, fatigue, liquid metal solidification, concrete, and the creep of metals under high pressure.

The flexibility of the graduate study programs at Cornell permits students to draw on several divisions of the University for supporting work in pure and applied science. Graduate students interested primarily in applied mechanics and applied mathematics find these supporting fields of interest: mathematics, structures, engineering physics, servomechanisms, machine design, aerospace engineering, soil mechanics, physics. Graduate students wishing to specialize in materials science find these supporting fields of interest: physics, mathematics, chemistry, metallurgy, solid state physics, mechanics, colloidal chemistry, engineering physics.

ENGINEERING PHYSICS

ROCKEFELLER HALL

THE UNDERGRADUATE program in engineering physics is designed to combine the basic scientific and analytical training of the physicist and the mathematician with knowledge and experience in applying this training to problems in engineering research and engineering development. Accordingly, the curriculum puts major emphasis on mathematics and physics. In addition, the program is planned to develop an appreciation and understanding of the properties of materials from constituent atoms and molecules to bulk physical, electrical, and chemical properties.

For training in engineering research, the fifth year student carries out a semi-research project in his chosen special field under the direction of a faculty member who is an authority in that field. Students may undertake projects in atomic and nuclear physics, nuclear reactor technology, nuclear instrumentation, electron optics and electron microscopy, engineering electronics including communications and servomechanisms, circuit analysis, X-rays and crystal structure, physics of solids, physical metallurgy, radio astronomy and space research, magnetohydrodynamics and aerodynamics, thermodynamics and heat transfer, elasticity and stress analysis, mathematics, and biophysics.

Because of the emphasis on the basic sciences and the freedom to select advanced courses to satisfy electives, the curriculum provides an excellent foundation for graduate study in the sciences or in engineering research.

The Department has fully equipped laboratories for study and research in electron microscopy, solid state and surface physics, and nuclear technology. The Nuclear Reactor Laboratory, a separate building (see page 2), includes facilities for work in nuclear chemistry.

In their project studies students also have access to other engineering laboratories and to those in the College of Arts and Sciences where such laboratories are important to the project.

Including the course work taken in the Division of Basic Studies, the engineering physics undergraduate curriculum requires the student to distribute his total of 165 semester hours of course work as follows:

Mathematics, physics, chemistry, engineering ..... 111 hours
English composition ..... 6 hours

(Students who in the first term show sufficient proficiency to be exempted from the second half of the course must substitute other courses in English or literature.)

Modern foreign language (for classes of 1963, 1964, 1965)..... 6 hours

(Students who pass the proficiency examination of the Department of Modern Languages and who do not wish to continue the study of a language may substitute six hours of liberal electives in place of the language requirement.)

Electives ..... 42 hours

Liberal (18). At least six hours must be taken in the area of humanities; another six hours in the area of social sciences.

Advanced Engineering and Science (15). A minimum of 3 credit hours must be in advanced laboratory work. These 15 hours include six credit hours for the research project.

Unspecified (9). May be taken in any course in the University open to the student. Not more than six hours credit is allowed in advanced military science or in naval science.

By suitable selection of technical electives during his last two years the qualified student may obtain an excellent preparation for a career in one of the many specialized fields of engineering. As examples, four possible programs are outlined:

AEROSPACE ENGINEERING (see p. 16) . . . The undergraduate program in engineering physics is particularly suited for work in aerospace engineering, either at the undergraduate or at the graduate level.

NUCLEAR TECHNOLOGY . . . The student interested in the nuclear energy field, or in nuclear reactor power developments, should choose his electives from courses in reactor physics, nuclear measurements, thermonuclear power principles, advanced heat transfer, and in physics of solids underlying radiation damage problems. His attention is directed to Courses 8311, 8312, 8313, 8351, 8352, and to 3665, 5760, 6872, and 7206, which are described in detail in the section, "Description of Courses." Additional closely related courses such as Physics 444 are also available.

MATERIALS SCIENCE . . . The core program of the engineering physics curriculum combined with electives in engineering physics (e.g., 8262, 8512), engineering materials (e.g., 1244), and metallurgical engineering (e.g., 6411 and 6412) and with specialized seminars provides an excellent preparation for research in materials science, a field that often holds the key to further technological progress. Students can find ample possibilities for senior projects by joining one of the active research groups studying such topics as surface physics, properties of thin films, electron microscopy and diffraction, relaxation phenomena and their relation to dislocations and other defects, photoconductivity, and others.

SPACE SCIENCE AND TECHNOLOGY . . . Engineering physics provides an excellent preparation for undergraduate or graduate specialization in this challenging field. Qualified students may elect courses in gasdynamics, radio wave propagation, optics, astronomy, relativity, and other related courses. Several faculty members have strong research interests in this field and are available to supervise senior research projects related to their areas of specialization. Students may undertake projects as a part of the work of the Center for Radiophysics and Space Research.

Beginning early in his academic career, the student should work out with his adviser the necessary detailed planning of his electives, in order to develop the most effective program in a particular field of interest.

The School participates in the Industrial Cooperative Program (see p. 5).

SCHOLASTIC REQUIREMENTS

The student is urged to regard grades as an indication of his degree of achievement in his field rather than as, in any sense, an end in themselves. The difference of a point or two in grades is never a determining factor in his status in the Department. He is expected to pass every course for which he is registered, to maintain each term a weighted average of about 75 per cent or better, and to demonstrate aptitude and competence in the basic subject matter of the curriculum.

A student failing to satisfy these requirements may be put on probation or refused permission to continue his studies in the Department.

CURRICULUM (B.Eng.Phys.)

Course programs for Terms 1 through 4, administered by the Division of Basic Studies, are described on pages 24–25.

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 5	Mathematics 421, Methods of Applied Mathematics	3	3	0
	Physics 323, Electricity and Magnetism	3	3	0
	Engineering 8121, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4116, Electric-Circuit Laboratory	3	1	3
	Engineering 1153, Mechanics of Materials	3	2	2½
	Elective	3	–	–
	Total	18		
TERM 6	Mathematics 422, Methods of Applied Mathematics	3	3	0
	Physics 318, Analytical Mechanics	4	4	0
	Engineering 8122, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4121, Electron Tubes and Circuits	4	2	5
	Elective	3	–	–
	Total	17		
TERM 7	Mathematics 423, Methods of Applied Mathematics	3	3	0
	Physics 443, Atomic and Molecular Physics	4	4	0
	Engineering 1201, Engineering Materials	4	3	2½
	Engineering 4122, Electronic Circuit Elements	4	2	5
	Elective	3	–	–
	Total	18		
TERM 8	Mathematics 616, Methods of Applied Mathematics	3	3	0
	Physics 454, Electronic Properties of Solids and Liquids	4	4	0
	Physics 410, Advanced Laboratory	4	0	6
	Chemistry 416, Chemical Bonding and Physical Properties of Organic Molecules	3	3	0
	Elective	3	–	–
	Total	17		
TERM 9	Engineering 8252, Selected Topics in Physics of Engineering Materials	3	3	0
	Engineering 8051, Project	3	–	–
	Electives	9	–	–
	Total	15		

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 10	Engineering 8131, Mechanics of Continuum	3	3	0
	Engineering 8052, Project	3	–	–
	Electives	9	–	–
	Total	15		

GRADUATE STUDY

The objective of graduate instruction in engineering physics is to offer concentrated study in a field which crosses conventional subject matter boundaries as well as to deepen and enlarge both the general scientific and the engineering background of the student.

Though engineering physics undergraduate work is the preferred preparation for graduate work in engineering physics, qualified students with a conventional physics or with another engineering background may enroll for graduate work.

The Graduate School imposes few requirements, permits great latitude to the individual in choice of studies, and expects each candidate to utilize all the resources of the University relevant to his work. It encourages him to associate freely with scholars who will give him the aid and direction he needs to develop a sense of responsibility for the wise application of knowledge.

Accordingly there are no specific course requirements or curricula for graduate study in engineering physics. Each student's program, both formal course work and independent individual study, is adjusted to fit his needs and to provide him with a thorough knowledge of a special field and with adequate peripheral competence. General information and regulations are given in the *Announcement of the Graduate School.* A descriptive brochure can be obtained by writing directly to the Office of the Department of Engineering Physics, Rockefeller Hall.

INDUSTRIAL ENGINEERING*

UPSON HALL

INDUSTRIAL ENGINEERING involves the analysis and design of integrated systems of men, materials, and equipment to perform a useful economic function. Examples of systems which are of interest to industrial engineers include systems to manufacture a given product, including the decision rules to control the operation of the enterprise and its equipment; integrated communication-information processing systems to control and direct the activities of a complex organization; and distribution systems that control the location, quantity, and movement of various inventories to serve an uncertain demand or to regulate inventories from a variable supply. While prior to 1950 nearly all industrial engineering work took place in the mechanical manufacturing industries, today this work is almost equally commonplace in the process industries and is found in service industries, government, and institutional operations as well as manufacturing. The scope of the work has tended to outgrow the designation as industrial engineering, and this type of activity also is often identified with the names operations research, operations analysis, management science, systems analysis, and systems engineering.

Following the first two years' work in the Division of Basic Studies, the curriculum leading to the Bachelor of Industrial Engineering degree develops the necessary background in probability theory, modern algebra, statistics, computing, and cost analysis. Then an integrated sequence of courses develops various analytical techniques and a design methodology appropriate for such systems. The required courses, coupled with a well planned elective program allows the student an opportunity to develop a course of study of considerable breadth or depth to suit his own needs.

CLASS ADVISERS

Each class will be assigned an adviser who serves in this capacity until the class graduates. In addition to counseling each student about curriculum, possi-

* Although some work in industrial engineering has been offered at Cornell since 1904, this work has heretofore been located within the Sibley School of Mechanical Engineering, and students have received a mechanical engineering degree. The program and curriculum described here is to be made available to students who matriculate at Cornell in 1961 or later, subject to final approval by the University faculty and the Board of Trustees. This program has been approved by the faculty of the College of Engineering, and the final approvals required are expected to be given during the 1962–1963 academic year. In the meantime, the following members of the School of Mechanical Engineering faculty constitute the faculty of the Department of Industrial Engineering and Administration: PROFESSORS: Robert Eric Bechhofer, A.B., Ph.D.; Henry Phillip Goode, B.S., M.S.; Byron Winthrop Saunders, B.S. in E.E., M.S.; Andrew S. Schultz, Jr., B.S. in A.E., Ph.D.; and Lionel Weiss, B.A., M.A., Ph.D. ASSOCIATE PROFESSORS: John Morton Allderige, B.S., M.S.; Robert Nelson Allen, B.S. in A.E.; Richard Walter Conway, B.M.E., Ph.D.; John Hsu-Kau Kao, B.S.M.E., M.S. in I.E., D.Eng.Sc.; and Martin Wright Sampson, B.S. in A.E., M.S. in Eng. ASSISTANT PROFESSORS: Richard H. Bernhard, B.M.E., M.S., Ph.D.; Frederick S. Hillier, B.S. in I.E., M.S. in I.E., Ph.D., Visiting Assistant Professor in Industrial Engineering for 1962–1963; Donald L. Iglehart, B.E.P., M.S., Ph.D.; William L. Maxwell, B.M.E., Ph.D.; and Peter E. Ney, B.S., M.A., Ph.D.

ble elective sequences to achieve particular objectives, registration, scholarship, and other aspects of the academic program, the adviser is available to discuss any serious nonacademic problems the students may have and to refer them to other offices if such action appears to be in the best interest of the student.

Inasmuch as the class adviser is responsible for approval of the registration of each student, no cancellation of courses or other changes in program may be initiated without his knowledge and approval.

SCHOLASTIC REQUIREMENTS

A student in the Department of Industrial Engineering and Administration who does not receive a passing grade in every course for which he is registered, who fails in any term or summer session to maintain an average grade of 70, or who is not otherwise making substantial and steady progress toward the completion of his degree requirements, may be dropped or placed on probation.

ELECTIVE COURSES

The curriculum in industrial engineering includes forty-two elective hours in addition to those in the basic two-year program. Of these, twenty-one must be in liberal courses, twelve in engineering, and nine are completely free. The curriculum is designed in such a way that the student has a chance to use the elective hours to maximum advantage in meeting his particular objectives. For example, a student desiring to combine the basic program in industrial engineering with work in some phase of electrical engineering would find that he could take as many as six three-hour courses in electrical engineering, in addition to the four required courses in this field. Similarily he could work out strong programs in some area of mechanical engineering, such as machine design to supplement the required work in this field, in various areas of civil engineering such as sanitation or transportation, or in almost any technical engineering area. On the other hand, a student interested in developing a program in some depth in a nontechnical area could combine as many as twelve hours of his liberal electives with the nine free electives and set up a program of as many as twenty-one hours in one of such fields as sociology, psychology, economics, history, or government. A third choice would be to concentrate the technical electives in more basic work in mathematical and statistical analysis in order to prepare for graduate work in the field of industrial engineering and operations research. Of course, a student may also take a broad elective program involving one or two courses in a number of different areas. The only restrictions on the use of the three categories of electives are that in his ten terms a student must have taken a minimum of nine hours of social science including a two-course sequence and nine hours of humanities including a two-course sequence.

CURRICULUM (B.I.E.)

Course programs for Terms 1, 2, 3, and 4, administered by the Division of Basic Studies, are described on pages 24–25. The curriculum which follows is available to students matriculating in September, 1961, or thereafter, subject to final ap-

proval by the Board of Trustees of Cornell University. (See footnote at bottom of page 43.)

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 5	Engineering 9360, Introduction to Probability Theory	3	3	0
	Engineering 9181, Introduction to Digital Computation	3	2	2½
	Engineering: Materials Science I	3	–	–
	Engineering: Electrical Engineering I	3	–	–
	Engineering 3431, Materials Processing	3	1	5
	Elective*	3	–	–
	Total	18		
TERM 6	Engineering 9370, Introduction to Statistical Theory with Engineering Applications	4	3	2½
	Engineering 9350, Principles of Costing & Control	3	2	2½
	Engineering: Materials Science II	3	–	–
	Engineering: Electrical Engineering II	3	–	–
	Engineering 3331, Kinematics and Components of Machines	3	2	2½
	Electives*	3	–	–
	Total	19		
TERM 7	Engineering 9310, Industrial Engineering: Analysis & Design I	4	2	5
	Engineering 9351, Cost Analysis	3	2	2½
	Engineering 3332, Mechanical Systems	3	2	2½
	Engineering 3630, Thermodynamics	3	3	0
	Electives*	3	–	–
	Total	16		
TERM 8	Engineering 9311, Industrial Engineering: Analysis & Design II	4	2	5
	Engineering 3631, Fluid Mechanics	3	3	0
	Engineering Elective	3	–	–
	Electives*	9	–	–
	Total	19		
TERM 9	Engineering 9320, Operations Planning & Analysis	4	3	2½
	Engineering 3632, Heat Transfer	3	3	–
	Engineering 9398, Industrial Engineering Project	3	–	–
	Engineering Elective	3	–	–
	Electives*	6	–	–
	Total	19		
TERM 10	Engineering 9352, Advanced Economic Analysis	3	2	2½
	Engineering 9399, Industrial Engineering Project	3	–	–
	Engineering Electives	6	–	–
	Electives*	6	–	–
	Total	18		

* The elective courses marked with an asterisk must include twenty-one credit hours of "liberal" courses, while nine credit hours can be "free," i.e., courses selected from any open to undergraduates who have the proper prerequisites from among those offered in any school or college at Cornell.

GRADUATE STUDY

Two different types of graduate programs are offered in industrial engineering. The Master of Science and Doctor of Philosophy programs are designed for those primarily interested in teaching or in academic or industrial research. The professional Master of Industrial Engineering degree program is designed for those primarily interested in becoming more proficient in the practice of modern industrial engineering. A student matriculating for one of these graduate degrees may concentrate his studies in any one of several subjects such as industrial engineering, operations research, systems analysis and design, applied statistics and probability, engineering administration, and information processing.

To be accepted as a candidate for the Master of Science or Doctor of Philosophy degrees in one of the subjects of concentration, the applicant must have been graduated from an institution of recognized standing with a Bachelor's degree in engineering, mathematics, or the physical sciences. In addition he must have had a commendable undergraduate scholastic record and other evidence of his interest in and ability to pursue advanced study and research in the selected field. To be accepted as a candidate for the Master of Industrial Engineering degree, an applicant must (1) hold a Bachelor's degree from an institution of recognized standing in one of the fields of engineering, (2) have an adequate preparation for gradate study in the chosen subject of specialization, and (3) show promise of doing well in advanced study as judged by his previous scholastic record or other achievements.

For further information about each of these graduate programs see the earlier references to graduate study on page 6 of this Announcement, the *Announcement of the Graduate School,* and the brochure entitled *Graduate Work in Operations Research, Industrial Engineering, Applied Statistics and Related Areas,* which may be obtained by writing the Department of Industrial Engineering and Administration, Upson Hall.

MECHANICAL ENGINEERING

UPSON HALL

MECHANICAL engineers design and develop diverse systems for power generation, machinery for industrial and private consumption, and enterprises for manufacturing and production.

The Sibley School of Mechanical Engineering consists of five departments of instruction:

Drafting and Industrial Design, R. H. Siegfried, 420 Upson Hall.
Industrial and Engineering Administration, A. S. Schultz, Jr., 324 Upson Hall.
Machine Design, A. H. Burr, 306 Upson Hall.
Materials Processing, W. Pentland, 220 Kimball Hall.
Thermal Engineering, C. O. Mackey, 206 Upson Hall.

Extensive, modern laboratories in each of these departments provide the student with the finest equipment for studying engineering principles. The mechanical engineering laboratories and classrooms are located in Upson Hall. All materials processing laboratories are in Kimball Hall.

REQUIREMENTS FOR THE B.M.E. DEGREE BY SUBJECTS, FOR 1963, 1964, 1965 CANDIDATES

All mechanical engineering students must satisfy course requirements in each of the five M.E. departments, and, in addition, must take specified courses in the Schools of Electrical, and Chemical and Metallurgical Engineering, and in the Department of Engineering Mechanics and Materials. This work accounts for ninety-nine of the 180 credit hours required for the degree and constitutes a basic group of courses offered in the College of Engineering throughout five years.

All mechanical engineering students must take specified courses in mathematics, physics, chemistry, English, and speech. These courses total forty-one of the 180 credit hours required for graduation.

The remaining forty hours of elective courses required for completion of the Bachelor of Mechanical Engineering degree are described in the following outline, which summarizes the degree requirements.

ENGINEERING COURSES OFFERED IN:	CREDITS
Orientation; nonresident lectures	4
Engineering Drawing	6
Industrial and Engineering Administration	17
Machine Design	12
Materials Processing	5
Thermal Engineering	21
Electrical Engineering	9
Chemical and Metallurgical Engineering	4
Engineering Mechanics and Materials	21
	99

SCIENCES, ENGLISH, SPEECH:	CREDITS	
Mathematics	12	
Physics	12	
Chemistry	8	
English	6	
Public Speaking	3	
		41
ELECTIVES:		
Liberal Arts *	12	
Engineering (including Project, 6 hours) †	14	
Unrestricted ‡	14	
		40
Total		180

SCHOLASTIC REQUIREMENTS

A student in the School of Mechanical Engineering who fails in any term to earn a passing grade in fifteen hours, with a grade of 70 or better in eleven hours, may be placed on probation. If he fails in any term to pass twelve hours, he may be dropped from the School.

B.M.E. PROGRAMS FOR 1963, 1964, 1965 CANDIDATES

Candidates for the B.M.E. degree in June, 1963, 1964, and 1965 are expected to fulfill the requirements for that degree according to the curriculum they have been following since their freshman year. The first four terms of this ten-term sequence have been completed and do not appear in this Announcement. The last six terms are:

		CONTACT HOURS		
	CREDIT HOURS	LECT. REC.	LAB. COMP.
TERM 5			
Engineering 1241, Engineering Materials	3	2	2½
Engineering 3351, Mechanism	3	2	2½
Engineering 3601, Thermodynamics	3	3	0
Engineering 1152, Mechanics—Dynamics	3	3	0
Engineering 3246, Industrial Accounting	2	1	2½
Engineering 3404, Production Machine Tools (or Engineering 3405)	2	1	2½
Electives	3	Arr.	Arr.
Total	19		

* May be chosen from the fields of American studies, the classics, economics, English, fine arts, government, history, literature, modern languages, music, philosophy, psychology, sociology and anthropology, and speech and drama. Courses in these fields are available in several colleges of the University and are not limited to the offerings of any single division.

† Includes all courses offered by the College of Engineering which are not the equivalent of any courses specifically required in the M.E. curriculum.

‡ May be chosen from both of the groups mentioned above or from any division of the University, including 6 hours of advanced ROTC or 9 hours of Naval ROTC. These electives may be used to take more course work in mathematics, physics, and chemistry.

		CONTACT HOURS		
		CREDIT HOURS	LECT. REC.	LAB. COMP.
TERM 6				
	Engineering 1242, Engineering Materials	3	3	0
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 3602, Thermodynamics	3	3	0
	Engineering 3603, Fluid Properties and Mass Flow	3	3	0
	Engineering 3247, Principles of Cost Control	3	2	2½
	Engineering 3405, Gage Laboratory (or Engineering 3404)	1	0	2½
	Electives	3	Arr.	Arr.
	Total	19		
TERM 7				
	Engineering 3604, Flow Processes and Energy Transfer	3	2	2½
	Engineering 3605, Heat Transfer	3	2	2½
	Engineering 3353, Design of Machine Members	3	2	2½
	Engineering 1243, Engineering Materials Laboratory	3	2	2½
	Engineering 3263 Production Engineering	3	2	2½
	Electives	3	Arr.	Arr.
	Total	18		
TERM 8				
	Engineering 3354, Design of Machines	3	1	5
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 3264, Production Engineering	3	2	2½
	Engineering 3606, Thermal Engineering Laboratory	3	1	2½
	Engineering 6112, Metallurgy of Casting, Working, and Welding	2	2	0
	Electives (including Engineering 3607 or 3608 or 3609)	6	Arr.	Arr.
	Total	20		
TERM 9				
	Project	3	Arr.	Arr.
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 1154, Strength of Materials	3	3	0
	Electives	10	Arr.	Arr.
	Totals	19		
TERM 10				
	Project	3	Arr.	Arr.
	Engineering 4933, Electrical Engineering	3	2	2½
	Public Speaking 201	3	3	0
	Engineering 3041, Nonresident Lectures	1	1	0
	Electives	9	Arr.	Arr.
	Total	19		
	Total for ten terms	180		

ELECTIVE REQUIREMENTS FOR 1963, 1964, 1965 CANDIDATES

The five-year curriculum allows time for forty hours of elective work, including six hours of project. If the student is to use this extra time and opportunity to best advantage, he must begin as early as his sophomore year to plan so that these elective hours will form an integrated program. He should explore the various possibilities open to him and, with the help of his adviser, set up a complete program for his entire undergraduate program of study.

The elective requirements suggest possibilities that will satisfy a variety of personal desires and interests. It is possible to obtain:

1. Twelve to twenty-six credit hours in liberal arts—all in one area or divided among several areas. This, together with the nine required hours of English and speech, makes possible a total of thirty-five hours in liberal arts.
2. Fourteen to twenty-eight hours in an engineering option to provide concentration and depth in one particular area of engineering; or these hours may be divided among two or more areas. Those students who contemplate graduate study leading to the M.M.E., M.I.E., M.S., or M.Aero.E. degrees should give serious consideration to the courses they elect. Some courses are acceptable as credit toward both the B.M.E. and the professional Masters' degrees.
3. Up to fourteen hours of unrestricted elective credit in any special program of studies which is neither liberal arts nor engineering. This includes advanced ROTC.

Students seeking maximum depth of training in any particular field—whether it be in liberal arts, in engineering, or in some other general area—should study the Announcements of the colleges offering the work and consult with representatives of the particular faculties concerned, as well as with their engineering advisers.

To illustrate what can be accomplished in setting up substantial elective options in engineering, the following sample options are presented.

DRAFTING AND INDUSTRIAL DESIGN

INDUSTRIAL DESIGN	CREDIT HOURS	TERM
Engineering 3116, Introduction to Industrial Design	3	8
Engineering 3198, 3199, Project	6	9, 10
Electives from the following list:	15	5–10
Architecture 330, 331, Sculpture		
400, 401, History of Architecture		
Fine Arts 101, 102, Introduction to Art: Painting and Sculpture		
or		
104 Introduction to Art		
111, 112 Introduction to Art: Architecture		
554 Twentieth-Century Painting		
Home Economics H.D. 100, Color and Design		
Total	24	

INDUSTRIAL AND ENGINEERING ADMINISTRATION

MANUFACTURING ENGINEERING	CREDIT HOURS	TERM
Engineering 3266, Advanced Methods Engineering	3	7
Engineering 3240, Analytical Methods in Operations Research	3	7
Engineering 3242, Statistical Control and Sampling Inspection	3	8
Engineering 3281, Computing Equipment and Industrial Applications	3	8
Engineering 3267, Advanced Production Engineering	3	9
Engineering 3283, Digital Systems Simulation	3	9
Engineering 3265, Production Planning	3	10
Engineering 3298, 3299, Project	6	9, 10
Total	27	

PRODUCTION MANAGEMENT

	CREDIT HOURS	TERM
Engineering 3232, Personnel Management	3	7
Engineering 3280, Introduction to Operations Research	3	7
Engineering 3242, Statistical Control and Sampling Inspection	3	8
Engineering 3265, Production Planning	3	8
Engineering 3254, Analytics of Decision and Control	3	9
Engineering 3281, Computing Equipment and Industrial Applications	3	9 or 10
Engineering 3270, Industrial Marketing	3	10
Engineering 3298, 3299, Project	6	9, 10
Total	27	

SYSTEMS ENGINEERING

Engineering 3240, Analytical Methods in Operations Research	3	7
Engineering 3280, Introduction to Operations Research	3	7
Engineering 3243, Intermediate Industrial Statistics	3	8
Engineering 3281, Computing Equipment and Industrial Applications	3	8
Engineering 3283, Digital Systems Simulation	3	9
Engineering 3265, Production Planning	3	10
Engineering 3254, Analytics of Decision and Control	3	10
Engineering 3298, 3299, Project	6	9, 10
Total	27	

APPLIED INDUSTRIAL STATISTICS

Engineering 3240, Analytical Methods in Operations Research	3	7
Engineering 3242, Statistical Control and Sampling Inspection	3	8
Engineering 3243, Intermediate Industrial Statistics	3	8
Engineering 3244, Advanced Industrial Statistics	3	9
Engineering 3248, Statistical Aspects of Reliability Analysis	3	9
Engineering 3281, Computing Equipment and Industrial Applications	3	10
Engineering 3284, Mathematical Programing and Decision Theory *or* Engineering 3285, Queuing Theory	3	10
Engineering 3298, 3299, Project	6	9, 10
Total	27	

MACHINE DESIGN

MECHANICAL DESIGN (SYNTHESIS)

Engineering 3366, Advanced Kinematics	3	8
Engineering 3367, Design Problems in Vibrations and Dynamics	3	8
Engineering 3374, Creative Design	3	9
Engineering 3375, Automatic Machinery	3	9
Engineering 3398, 3399, Design Projects	6	9, 10
Total	18	

DESIGN DEVELOPMENT (ANALYSIS AND EXPERIMENTATION)

Engineering 3367, Design Problems in Vibrations and Dynamics	3	8
Engineering 3361, Advanced Machine Analysis	3	9
Engineering 3372, Experimental Methods in Machine Design	3	9
Engineering 3362, Mechanical Design of Turbomachinery	3	10
Engineering 3376, Automatic Control	3	10
Engineering 3398, 3399, Analysis or Experimental Projects	6	9, 10
Total	21	

VEHICLES AND PROPULSION

	CREDIT HOURS	TERM
Engineering 3367, Design Problems in Vibrations and Dynamics	3	8
Engineering 3607, Combustion Engines	3	8
Engineering 3377, Automotive Engineering	3	9
Engineering 7101, Mechanics of Airplanes and Missiles	3	9
Engineering 3398, 3399, Vehicle Design Project	6	9, 10
Total	18	

THERMAL ENGINEERING

FLUID DYNAMICS AND HEAT TRANSFER

Engineering 3661, Advanced Thermodynamics	3	7
Engineering 3664, Advanced Fluid Mechanics	3	8
Engineering 3663, Advanced Turbomachinery	3	9
Engineering 3665, Advanced Heat Transfer	3	9
Engineering 3698, 3699, Project	6	9, 10
Total	18	

NUCLEAR ENGINEERING

Engineering 3608, Thermal Power Plants	3	8
Engineering 8301, Atomic and Nuclear Physics	3	9
Engineering 3665, Advanced Heat Transfer	3	9
Engineering 8311, Nuclear and Reactor Physics	3	10
Engineering 8351, Nuclear Measurements Laboratory	3	10
Engineering 3698, 3699, Project	6	9, 10
Total	21	

PROPULSION ENGINES

Engineering 3661, Advanced Thermodynamics	3	7
Engineering 3607, Combustion Engines	3	8
Engineering 3663, Advanced Turbomachinery	3	9
Engineering 3665, Advanced Heat Transfer	3	9
Engineering 3671, Aerospace Propulsion Systems	3	9
Engineering 3698, 3699, Project	6	9, 10
Total	21	

THERMAL ENVIRONMENT

Engineering 3609, Refrigeration and Air Conditioning	3	8
Engineering 3667, Temperature Measuring Instruments	3	8
Engineering 3665, Advanced Heat Transfer	3	9
Engineering 3666, Advanced Air Conditioning	3	9
Engineering 4934, Principles of Automatic Control	3	10
Engineering 3698, 3699, Project	6	9, 10
Total	21	

THERMAL POWER

Engineering 3361, Advanced Thermodynamics	3	7
Engineering 3607, Combustion Engines	3	8
Engineering 3608, Thermal Power Plants	3	8
Engineering 3672, Energy Conversion	3	10
Engineering 3670, Advanced Combustion Engines	3	10
Engineering 3698, 3699, Project	6	9, 10
Total	21	

AEROSPACE ENGINEERING

	CREDIT HOURS	TERM
Mathematics 609, Higher Calculus	3	5
Mathematics 610, Higher Calculus	3	6
Engineering 7101, Mechanics of Airplanes and Missiles	3	7
Engineering 7102, Mechanics of Airplanes and Missiles	3	8
Engineering 7203, Gasdynamics I	3	9
Engineering 7204, Gasdynamics II	3	10
Engineering 7801, Project	6	9, 10
Total	24	

ENGINEERING MECHANICS AND MATERIALS

MECHANICS

Engineering 1154, Advanced Strength of Materials	3	7
Engineering 1162, Mechanics of Vibration	3	8
Engineering 3367, Design Problems in Vibrations and Dynamics	3	8
Engineering 1163, Applied Elasticity	3	9
Engineering 1180, Advanced Engineering Mathematics	3	9
Engineering 4711, Feedback Control Systems I	3	9
Engineering 1159, Advanced Mechanics Laboratory	3	10
Engineering 1198, 1199, Project	6	9, 10
Total	27	

MATERIALS

Physics 314, Atomic and Molecular Physics	3	7
Physics 454, Electronic Properties of Solids and Liquids	3	8
Engineering 1216, Structure and Properties of Matter	2	9
Engineering 6452, Experimental Physical Metallurgy	3	9
Engineering 1244, Theoretical Materials-Mechanical Properties	3	10
Engineering 1298, 1299, Project	6	9, 10
Total	20	

MATERIALS TECHNOLOGY

Engineering 6353, Introductory Metallography	3	8
Engineering 6415, Principles of Materials Processing	3	9
Engineering 3372, Experimental Methods in Machine Design	3	9
Engineering 6661, Metals at High Temperatures	2	9
Engineering 6872, Nuclear Materials Technology	2	10
Project in machine design or metallurgical engineering	6	9, 10
Total	19	

NUCLEAR TECHNOLOGY

Engineering 8301, Introduction to Atomic and Nuclear Physics	3	7
Engineering 8311, Nuclear and Reactor Physics	3	8
Engineering 8351, Nuclear Measurements Laboratory	3	8
Engineering 5760, Nuclear and Reactor Engineering	2	9
Engineering 3665, Advanced Heat Transfer	3	9
Engineering 6872, Nuclear Material Laboratory	3	10
Engineering 8051, 8052, Project	6	9, 10
Total	23	

Some of the elective courses appearing in these suggested options may, under certain conditions, be used to satisfy requirements for both the undergraduate and the graduate degrees. Other electives, including, particularly, advanced mathematics courses, are also essential for graduate work. Prospective graduate students should seek guidance from members of the graduate staff in arranging their elective programs.

B.M.E. PROGRAM FOR CANDIDATES IN 1966 AND THEREAFTER

Students who entered the College of Engineering at the freshman level in September, 1961, or later, are enrolled in the Division of Basic Studies for their freshman and sophomore years (see p. 23). Those who elect to enter the Sibley School of Mechanical Engineering as candidates for the B.M.E. degree may do so at the start of their junior year and will follow a six-term sequence of courses described in the two following sections.

REQUIREMENTS FOR THE B.M.E. DEGREE BY SUBJECTS FOR CANDIDATES IN 1966 AND THEREAFTER

All candidates for the B.M.E. degree after June, 1965, must satisfy certain course requirements in the Departments of Thermal Engineering, Machine Design, Materials Processing, and Industrial and Engineering Administration, in the Sibley School of Mechanical Engineering. In addition, they must take specified courses in the Division of Basic Studies, in the School of Electrical Engineering, and in the Department of Engineering Mechanics and Materials. This work accounts for eighty-five of the 175 hours required for the degree and constitutes a core of courses offered in the College of Engineering throughout five years.

All candidates must also take specified courses in mathematics, physics, and chemistry. These total thirty-six of the 175 hours required for the degree and appear in the Basic Studies program during the freshman and sophomore years.

The remaining fifty-four hours required for the B.M.E. degree includes six hours of English and forty-eight hours of electives distributed over all ten terms.

A breakdown of the requirements in these three categories—engineering, science, and English plus electives—appears in the following outline:

ENGINEERING COURSES	CREDITS
Problems and Methods	6
Engineering Mechanics	8
Electrical Science	6
Materials Science	6
Thermal Science and Thermal Engineering	21
Machine Design	16
Materials Processing	6
Industrial and Engineering Administration	10
Electrical Engineering	6
	85

SCIENCE COURSES	CREDITS	
Mathematics	15	
Physics	12	
Chemistry	9	
		36
ENGLISH AND ELECTIVES		
English	6	
Liberal Electives	24	
Engineering Electives including Project	15	
Unrestricted Electives	9	
		54
Total		175

CURRICULUM—B.M.E. FOR CANDIDATES IN 1966 AND THEREAFTER

TERM 1 *See* Division of Basic Studies Curriculum, p. 24.
TERM 2 *See* Division of Basic Studies Curriculum, p. 24.
TERM 3 *See* Division of Basic Studies Curriculum, p. 24.
TERM 4 *See* Division of Basic Studies Curriculum, p. 25.

TERM 5 NOT OFFERED UNTIL FALL, 1963	CREDIT HOURS	LECT. REC.	LAB. COMP.
Engineering, Materials Science I	3		
Engineering 3621, Thermal Science I	3	3	0
Engineering 3321, Kinematics and Dynamics of Mechanisms	4	3	2½
Engineering, Electrical Engineering I	3	2	2½
Engineering 3241, Industrial and Engineering Statistics	3	2	2½
Liberal elective	3	Arr.	Arr.
Total	19		
TERM 6 NOT OFFERED UNTIL SPRING, 1964			
Engineering: Materials Science II	3		
Engineering 3622, Thermal Science II	3	3	0
Engineering 3623, Thermal Science III	3	3	0
Engineering: Electrical Engineering II	3	2	2½
Engineering 3421, Processing of Materials I	3	2	2½
Liberal elective	3	Arr.	Arr.
Total	18		
TERM 7 NOT OFFERED UNTIL FALL, 1964			
Engineering 3624, Thermal Science IV	3	2	2½
Engineering 3625, Thermal Science V	4	3	2½
Engineering 3422, Processing of Materials II	3	1	5
Engineering 3322, Mechanical Analysis and Design	5	3	5
Liberal elective	3	Arr.	Arr.
Total	18		
TERM 8 NOT OFFERED UNTIL SPRING, 1965			
Engineering 3323, Design of Machines	3	1	5
Engineering 3324, Vibration and Control of Mechanical Systems	4	3	2½
Engineering 3626, Thermal Systems Engineering	5	3	2½
Engineering elective	3	Arr.	Arr.
Liberal elective	3	Arr.	Arr.
Total	18		

TERM 9 NOT OFFERED UNTIL FALL, 1965	CREDIT HOURS	LECT. REC.	LAB. COMP.
Engineering 3234, Engineering Economic Analysis	3	2	2½
Mechanical engineering project	3	Arr.	Arr.
Mechanical engineering elective	3	Arr.	Arr.
Unrestricted elective	3	Arr.	Arr.
Unrestricted elective	3	Arr.	Arr.
Liberal elective	3	Arr.	Arr.
Total	18		
TERM 10 NOT OFFERED UNTIL SPRING, 1966			
Engineering 3237, Introduction to Industrial Engineering	4	3	2½
Mechanical engineering project	3	Arr.	Arr.
Engineering elective	3	Arr.	Arr.
Unrestricted elective	3	Arr.	Arr.
Liberal elective	3	Arr.	Arr.
Liberal elective	3	Arr.	Arr.
Total	19		
Total for ten terms	175		

INDUSTRIAL COOPERATIVE PROGRAM

See page 5.

GRADUATE STUDY

Specialized programs for a Master of Mechanical Engineering (M.M.E.) degree in the area of machine design are available in the fields of machine dynamics and control, mechanical analysis and development, mechanical design, and vehicles and propulsion; in the area of thermal engineering—in the fields of heat transfer and fluid dynamics, nuclear technology, propulsion engines, thermal environment, and thermal power.

For further information about the programs for the professional Masters' degrees, see p. 6 of this Announcement; for additional information on the Master of Science (M.S.) and the Ph.D. degrees, see p. 6. For each of these graduate programs see also the *Announcement of the Graduate School* and the brochures *Graduate Programs in Mechanical Engineering* and *Graduate Work in Industrial Engineering*, which may be obtained by writing to the School of Mechanical Engineering, Upson Hall.

METALLURGICAL ENGINEERING

OLIN HALL

THE PROGRAM in metallurgical engineering seeks to develop an understanding of the nature and behavior of materials, particularly metallic materials, and their economical processing into useful articles, ranging from transistors and missile nose cones to railroad rails and automobile engines. This understanding is built on a foundation of chemistry, physics, and the engineering sciences.

Metallurgical (or materials) engineers are concerned with the conversion from some raw state (e.g., an ore); refining; alloying and heat treating to develop desired properties; shaping by casting, mechanical deformation, or other means; fabrication into finished or semifinished articles; and joining materials as finished structures. Successful completion of the undergraduate program qualifies the student for work in any phase of the broad subject, in either primary producing industries or in industries which use metals, or for graduate study.

The staff and facilities of metallurgical engineering are currently located in Olin Hall, but a new building to house metallurgical engineering, Bard Hall, is now under construction, and is expected to be ready for occupancy during 1962–1963. Extensive facilities are available, including apparatus for microscopical and X-ray diffraction examinations; a variety of furnaces for melting and heat treating; equipment for casting, working and welding, and for the study of the unit operations of extractive metallurgy, and for physical and mechanical testing. Other more specialized apparatus, such as for electron microscopy, zone refining, levitation melting, and preparation of single crystals, is also available.

ELECTIVE COURSES

The curriculum provides for sixteen elective courses (including the elective of Term 4 in the Division of Basic Studies) for a total of forty-eight credit hours. Of this total, a minimum of twenty-four hours beyond the freshman year must be selected from the humanities and social sciences, within restrictions common to all schools of the College, and described on page 59. Of the remaining elective courses, five must be technical; the remaining courses may be either technical or nontechnical as the student, with the guidance of his adviser, elects.

The student who plans a joint program in law or business and public administration may use the free electives to fulfill a part of the requirements in these programs (see page 7). With careful selection of the elective courses, the student who proposes to work for a professional Master's degree may enroll in the program during his fifth undergraduate year and begin accumulating credits toward the professional degree. The student with still another goal may use the elective hours for a sequence of courses in business administration, law, industrial and labor relations, nuclear technology, materials technology, or the humanities.

For example, if the student wishes to take the nuclear technology option as part of his metallurgical engineering curriculum, he can take his electives in

fields such as nuclear and reactor physics, in nuclear materials, in nuclear measurements, in heat transfer (see below).

If his choice is to gain a more specialized knowledge of particular branches of metallurgical engineering, or if he plans for a broader training in materials science or technology, he may take elective courses in materials science, nuclear materials, high temperature materials, polymeric materials, cast metals engineering, materials processing and engineering physics.

To assure the most effective use of electives, the student is required during his third year to prepare with his adviser a coordinated plan of study for the final two years.

SUGGESTED TECHNICAL ELECTIVE GROUPINGS

	CREDIT HOURS	TERM
MATERIALS SCIENCE		
Mathematics 215, Higher Calculus	3	7
Mathematics 216, Higher Calculus	3	8
Physics 325, Electricity, Magnetism and Light	4	7
Physics 326, Electricity, Magnetism and Light	4	8
Chemistry 481, Advanced Physical Chemistry	4	7
Chemistry 505, Advanced Inorganic Chemistry	4	7
Chemistry 506, Advanced Inorganic Chemistry	4	8
Physics 443, Atomic Physics and Introduction to Quantum Mechanics	4	9
Physics 454, Electronic Properties of Solids and Liquids	4	10
Engineering 6224, Kinetics of Reactions	3	9
Engineering 6681, Advanced Laboratory	3	9
Engineering 6710, Transport Processes	3	10
MATERIALS TECHNOLOGY		
Engineering 3341, Machine Design	3	7, 8
Engineering 3372, Experimental Methods in Machine Design	3	7, 9
Engineering 6651, Physical Metallurgy of Ferrous Materials	2	10
Engineering 6661, Metals at Elevated Temperatures	2	9
Engineering 6872, Nuclear Materials Technology	2	10
Engineering 6620, Advanced Foundry Engineering	3	9
Engineering 6662, Refractory Materials	2	10
POLYMERIC MATERIALS		
Chemistry 357, Introductory Organic Chemistry	5	7
Chemistry 358, Introductory Organic Chemistry	5	8
Engineering 5742, Polymeric Materials	3	9
Engineering 5743, Advanced Polymeric Materials	3	10
Engineering 5752, Polymeric Materials Laboratory	1	10
NUCLEAR TECHNOLOGY		
Engineering 8301, Introduction to Atomic and Nuclear Physics	3	7
Engineering 8311, Nuclear and Reactor Physics	3	8
Engineering 8351, Nuclear Measurements Laboratory	3	8
Engineering 5760, Nuclear and Reactor Engineering	2	9
Engineering 3665, Advanced Heat Transfer	3	9
Engineering 6872, Nuclear Materials Technology	2	10
Engineering 8051, 8052, Project	6	9, 10
PRODUCTION OPERATIONS AND PROCESS CONTROL		
Engineering 3241, Industrial and Engineering Statistics	3	7, 8
Engineering 3242, Statistical Control and Sampling Inspection	3	8, 10
Engineering 3243, Intermediate Industrial and Engineering Statistics	3	10
Engineering 3253, Industrial Accounting and Cost Control	3	7, 9
Engineering 3254, Operations Planning and Control	3	7, 9
or		

	CREDIT HOURS	TERM
Engineering 3281, Computing Equipment and Industrial Applications	3	7, 8
Engineering 5304, Analysis of Unit Operations	3	8
Engineering 5747, Process Control	3	9
Engineering 4934, Principles of Automatic Control	3	8, 10

SCHOLASTIC REQUIREMENTS

A student in the School of Chemical and Metallurgical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average grade of 75, may be placed on probation or dropped.

If, in the opinion of the faculty, a student's general record is unsatisfactory, the student may be refused permission to continue his course even though he has met the minimum requirements of credit hours passed and of grades for those hours. Students who fall behind in their work may be warned, put on probation, or dropped, either from an individual course or from the University, at any time during the term.

CURRICULUM (B.Met.E.)

Course programs for Terms 1, 2, 3 and 4, administered by the Division of Basic Studies, are described on pages 24–25.

		CREDIT HOURS	CONTACT HOURS LECT. REC.	CONTACT HOURS LAB. COMP.
TERM 5	Engineering 211, Mechanics	4	4	0
	Engineering 6331, Materials Science I	3	3	0
	Engineering 6323, Metallurgical Thermodynamics I	3	3	0
	Engineering 242, Electrical Science	3	3	0
	Liberal Elective	3–4		
	Total	16–17		
TERM 6	Engineering 212, Mechanics	4	4	0
	Engineering 6332, Materials Science II	3	3	0
	Engineering 6324, Metallurgical Thermodynamics II	3	3	0
	Engineering 6353, Introductory Metallography	3	1	5
	Liberal Elective	3–4		
	Total	16–17		
TERM 7	Engineering 6401, Chemical Metallurgy I	3	2	2½
	Engineering 6411, Physical Metallurgy I	2	2	0
	Engineering 6451, Experimental Physical Metallurgy	3	2	2½
	Electives *	9–10		
	Total	17–18		
TERM 8	Engineering 6402, Chemical Metallurgy II	3	2	2½
	Engineering 6412, Physical Metallurgy II	2	2	0
	Engineering 6416, Principles of Materials Processing	3	2	2½
	Engineering 6432, Mechanical Metallurgy	3	3	0
	Electives *	6–7		
	Total	17–18		

* A liberal elective must be included in five of the last six terms.

		CREDIT HOURS	CONTACT HOURS LECT. REC.	LAB. COMP.
TERM 9	Engineering 6505, Metallurgical Design	2	2	0
	Engineering 6553, Metallurgical Engineering Project	3	–	9
	Electives *	12–13		
	Total	17–18		
TERM 10	Engineering 6554, Metallurgical Engineering Project	3	–	9
	Engineering, Electrical Engineering	3	2	2½
	Electives *	12		
	Total	18		

RESEARCH AND GRADUATE STUDY

The research program by the staff and students in metallurgical engineering is an integral part of Cornell's interdisciplinary Materials Science Center. Undergraduate students are required to do original research in their fifth year, and in this way project students have an opportunity to work in areas of advanced research with members of the faculty. Areas in which such work is carried out include liquid-solid interfacial reactions; crystalline imperfections, semiconductors, refractory materials, solidification and crystal growth phenomena, recovery and recrystallization, solid solution strengthening; ordering; transformation kinetics; nuclear materials; X-ray diffraction microscopy, optical and electron microscopy, structure of thin films, and physical and mechanical behavior.

Graduate study programs in metallurgical engineering at Cornell are designed to fit the needs of individual students, in the light of their previous training, aptitudes, and interests. Candidates are expected to pursue a program of study that will give them a deeper understanding of the basic and applied sciences, and that will develop initiative and originality. A candidate for a "general" degree, M.S. or Ph.D., is required to take neither a fixed curriculum nor a minimum number of credit hours in his major field. However, the student will ordinarily find it desirable to take advanced courses offered in the Department and to participate in graduate seminars. He will also be urged to pursue advanced courses in mathematics, chemistry, and physics offered in the College of Arts and Sciences. The specific requirements for the degrees M.S. and Ph.D. will be found in the *Announcement of the Graduate School.*

REQUIREMENTS FOR THE DEGREE OF MASTER OF METALLURGICAL ENGINEERING (M.Met.E)

In addition to "general degree" programs (M.S. and Ph.D.), the College of Engineering also offers professional degree programs, as described on page 00 of this Announcement.

The specific requirements for the degree of M.Met.E. are as follows:

* A liberal elective must be included in five of the last six terms.

The successful candidate must complete a minimum of forty-five credit hours of graduate level course work, or its equivalent, as follows:

1. A minimum of eighteen credit hours in the basic physical sciences of chemistry and physics and in mathematics. Normally, six credit hours of mathematics, and three to nine credits in both physics and chemistry should be selected. The courses that may be taken for credit will ordinarily fall within the following list:

Chemistry: courses in inorganic chemistry numbered 421 or higher; in organic chemistry, 465 or higher; in physical chemistry, 380 or higher.
Physics: courses numbered 314 or higher; also courses in engineering physics numbered 8131 or higher.
Mathematics: courses numbered 215 or higher.

2. A minimum of eighteen credit hours in metallurgical engineering (or closely allied subjects) selected from metallurgical engineering courses numbered 6553 or higher (except 6601); also courses 1245, 1260, and 1261.

3. A minimum of nine credit hours of elective courses; courses in the basic physical sciences or in metallurgical engineering in excess of the minimum requirements are considered electives for the purpose of meeting this requirement. All elective courses must be approved by the student's adviser.

All courses to be credited toward the degree must be passed with a minimum grade of 75, or a written statement received from the instructor, attesting that the student's work was of graduate caliber.

DESCRIPTION OF COURSES

THE COURSES listed in the preceding curricula are described in the sections following. Courses are described under the heading of the school or college in which they are offered. Courses in chemistry, English, mathematics, physics, and certain courses in economics are offered by the College of Arts and Sciences.

Courses offered by the Division of Basic Studies in the College of Engineering have three digit numbers. All other courses offered within the College have four digit numbers, the first digit representing the school or department. Descriptions of courses will be found in the section of this Announcement as follows:

1. Engineering Mechanics and Materials
2. Civil Engineering
3. Mechanical Engineering
4. Electrical Engineering
5. Chemical Engineering
6. Metallurgical Engineering
7. Aerospace Engineering
8. Engineering Physics
9. Industrial Engineering

For courses in other colleges not described here, to be taken either as required courses or as electives, see the Announcement of the appropriate college.

DIVISION OF BASIC STUDIES

ENGINEERING PROBLEMS AND METHODS

101. ***ENGINEERING PROBLEMS AND METHODS I.*** Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Lab. Consideration of functions of engineering and major examples of modern engineering to emphasize the nature of engineering and the interrelationships of the several professional fields. Introduction to professional method in solution of engineering problems, graphical representation including sketching, descriptive geometry, and drafting.

102. ***ENGINEERING PROBLEMS AND METHODS II.*** Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Solution of engineering problems; introduction to probability and statistics, introduction to engineering economy, continuation of graphical representation.

MATHEMATICS

113. ***CALCULUS.*** Replaces (163). Either term. Credit 3 hrs. Prereq., 112 (162). Fall: lect. M W 8, 10; T Th 8, 10, plus one hour to be arranged. Spring: M W F 8, 10. Solid analytic geometry and vectors, partial differentiation; linear differential equations; infinite series.

122. ***CALCULUS.*** Replaces (182). Either term. Credit 3 hrs. Prereq., a grade of 80 or better in a lettered section of 111 (161), or 90 or better in a numbered section of 111. Fall: M W F 11, T Th S 9. Spring: M W F 10, 11; T Th S 9, 10. Differentiation and integration of elementary functions; the technique of integration, plane analytic geometry; applications, vector algebra.

[293. ***APPLIED MATHEMATICS.*** Either term. Credit 4 hrs. Prereq., 192. Infinite Series —General, Taylor, Frobenius. First order differential equations and linear equations with constant coefficients—computer. Not given in 1962–1963.]

[294. ***APPLIED MATHEMATICS.*** Either term. Credit 3 hrs. Prereq., 293. Matrices. Complex numbers and linear equations with constant coefficients. Vector calculus. Not given in 1962–1963.]

191. ***CALCULUS FOR ENGINEERS.*** Either term. Credit 4 hrs. M T W Th 8, M W F S 8, M T W Th 9, M W F S 9, M T W Th 11, M W F S 11, M T W Th 12. Plane analytic geometry, differential and integral calculus applications.

192. ***CALCULUS FOR ENGINEERS.*** Spring term. Credit 4 hrs. Prereq., 191. Hours to be arranged. Analytic geometry in the plane and in space, partial differentiation, technique of integration and multiple integrals, applications.

221. ***CALCULUS.*** Replaces (183). Either term. Credit 4 hrs. Prereq., 122 (182). Fall: M W F 8, 10; T Th S 8, 10, plus one hour to be arranged. Spring: M W F 11; T Th S 9. Infinite series, differential equations; vector and matrix algebra.

222. ***CALCULUS.*** Either term. Credit 4 hrs. Prereq., 221, or for fall 1962 only (183). Fall: M W F 10, plus one hour to be arranged. Spring: M W F 8, 10; T Th S 10, plus one hour to be arranged. Differential and integral vector calculus and multiple integrals; applications to physical problems.

1155. ***APPLIED DIFFERENTIAL EQUATIONS.*** For fourth-term engineering students. Credit 3 hrs. Prereq., 113. Hours to be arranged. Theory of first order equations; first and higher order equations, properties of linear differential equations; linear differential equations with constant coefficients; simultaneous linear differential equations; Fourier series and applications; partial differential equations and boundary value problems.

PHYSICS

Physics 121–122 and 223–228 are designed primarily for students in the College of Engineering. The first year's work consists of 121 and 122; the second year's work consists of one of the two-term sequences 223–224, 225–226, or 227–228. The initial assignment to a given sequence in the second year will be made on the basis of the student's previous performance in introductory physics and mathematics courses. Students should see their instructors for section assignments.

121–122. ***INTRODUCTORY ANALYTICAL PHYSICS.*** Throughout the year. Credit 3 hrs. a term. Prereq., calculus or co-registration in Mathematics 191, 192. Course 121 is prerequisite to 122. Primarily for students of engineering. Lect. T 9, 11, or 2. Two discussion periods per week and one 2½-hour lab. period every other week, as assigned. Preliminary examinations will be held at 7:30 p.m. on Oct. 23, Nov. 27, Jan. 8, Mar. 5, Apr. 9, and May 7. The mechanics of particles: kinematics of translation, dynamics, conservation of energy. The properties of the fundamental forces: gravitational, electromagnetic, and nuclear.

Topics for study in the second term: conservation of linear momentum, kinetic-molecular theory of gases, properties of solids and liquids, mechanics of rigid bodies. Harmonic motion and the fundamentals of wave propagation. At the level of *Introductory Analytical Physics* by Newhall. Messrs. NEWHALL, LEVINGER, and staff.

223–224. ***INTRODUCTORY ANALYTICAL PHYSICS.*** Throughout the year. Credit 3 hrs. a term. Prereq., Physics 121, 122 and co-registration in Mathematics 193–194, or equivalent. Course 223 is prerequisite to 224. Lect., Th 9 or 11. Two discussion periods per week, and one 2½-hour laboratory period every other week, as assigned. An introductory survey of the laws of electric and magnetic fields. Electrostatic field. Magnetic fields of steady currents, induced emfs, dielectrics, and magnetic properties of matter. The laboratory work includes experiments in electrical measurements.

Wave motion with emphasis on the properties of electromagnetic waves. Interference, diffraction, dispersion, scattering, and polarization of waves. Selected topics from the fields of atomic, solid state, and nuclear physics dealing with wave-particle experiments, optical and X-ray spectra, radioactivity, and nuclear processes. The laboratory work includes experiments in electrical measurements and in physical electronics and wave optics. At the level of *University Physics,* Vol. II, by Sears and Zemansky, and of *Wave Optics and Atomics* by Tomboulian. Messrs. TOMBOULIAN, PETERSON, and staff.

225–226. ***INTRODUCTORY ANALYTICAL PHYSICS.*** Throughout the year. Credit 3 hrs. a term. Prereq., same as for Physics 223. Lect., T 9 or 11. Two discussion periods per week, and one 2½-hour laboratory period every other week as assigned. The main topics are the same as those listed under Physics 223–224, but their treatment is more analytical and somewhat more intensive. Messrs. TOMBOULIAN, DELVAILLE, WALTON, WOLGA, and staff.

227–228. ***INTRODUCTORY ANALYTICAL PHYSICS.*** Throughout the year. Credit 3 hrs. a term. Prereq., same as for Physics 223–224. Lect., T 9 or 11. Two discussion periods per week, and one 2½-hour laboratory period every other week as assigned. The subject matter of electricity and magnetism listed under Physics 223–224 is covered at a level sufficiently advanced to stimulate students of superior competence and interest. At the level of *Electricity and Optics* by Frank and of *Currents, Fields and Particles* by Bitter. Mr. IRWIN and staff.

CHEMISTRY

105–106. ***GENERAL CHEMISTRY.*** Throughout the year. Credit 3 hrs. a term. Chemistry 105 is prerequisite to Chemistry 106. For those students who will take more chemistry, it serves as a prerequisite to the more advanced courses. Open to those who have had or have not had high school chemistry. May be elected by students who do not intend to take more chemistry. Lectures: fall term, T Th 9, 10, or 12; spring term, T Th 9, 10. Combined discussion-laboratory period, M W F or S 8–11, M T W Th or F 1:40–4:30. The important chemical principles and facts are covered, with considerable attention given to the quantitative aspects and to the techniques which are important for further work in chemistry. Messrs. FAY, PLANE, REYNOLDS, and assistants.

108. ***GENERAL CHEMISTRY AND INORGANIC QUALITATIVE ANALYSIS.*** Spring. Credit 4 hrs. Prereq., superior performance in Chemistry 105. Serves in place of Chemistry 106 plus 205 as prerequisite for advanced courses. Lect. T Th 12. One laboratory period, S 8–11, or M T or Th 1:40–4:30. One discussion hour, T or Th 9 or 10, or W or F 11 or 12. A general study of equilibria and chemical behavior in aqueous solutions as illustrated by the separation and detection of ions of some common elements. Lectures and reading material extend the coverage to a general introduction to inorganic chemistry. Messrs. SIENKO, ZUCKERMAN, and assistants.

276. ***INTRODUCTION TO PHYSICAL CHEMISTRY.*** Replaces (401). Spring. Credit 3 hrs. Prereqs., Chemistry 106 or 108, Mathematics 193, and Physics 223 or 225 or 227. For engineering students. A brief survey of physical chemistry. Mr. WIDOM.

285–286. ***INTRODUCTORY PHYSICAL CHEMISTRY.*** Replaces (405–406). Throughout the year. Credit 5 hrs. a term. Prereqs., Chemistry 108, Mathematics 192, Physics 122, or consent of instructor. For students in engineering. Lectures, M W F 9. Laboratories: fall, M 1:40–4:30 and T 10–12:50 or W Th 1:40–4:30 or S 8–1; spring, M T 1:40–4:30 or W Th 1:40–4:30 or F 1:40–4:30 and either S 8–10:50 or S 10–12:50. The lectures will give a systematic treatment of the fundamental principles of physical chemistry; the laboratory will deal with the experimental aspects of the subject and also develop the needed skills in quantitative chemical analysis. Messrs. ALBRECHT, WUNDERLICH, and assistants.

ENGLISH

111–112. ***INTRODUCTION TO ENGLISH.*** Throughout the year. Credit 3 hrs. a term. English 111 is prerequisite to English 112, M W F 8, 9, 10, 11, 12, 2, 3; T Th S 8, 9, 10, 11, 12. The aim is to increase the student's ability to communicate his own thought and to understand the thought of others. Messrs. SLATOFF, SMITH, and others.

PHYSICAL EDUCATION

All undergraduate students are required by the University to complete four terms of work, three hours a week, in physical education. The requirement must be completed within the first four terms (for further details, see the *Announcement of General Information*). Descriptions of the physical education courses offered will be found in publications made available to entering students by the Department of Physical Education and Athletics.

ELECTRICAL SCIENCE

241. ***ELECTRICAL SCIENCE I.*** Credit 3 hrs. Fall. 2 Lect. 1 (2½ hour) Rec.-Comp. The basic principles of electric and magnetic fields and circuits for steady fields, voltages, and currents. Emphasis is placed on understanding of the physical concepts.

242. ***ELECTRICAL SCIENCE II.*** Credit 3 hrs. Spring. 2 Lect. 1 (2½ hour) Rec.-Comp. Prereq., 241. Extends the treatment of 241 to time-varying fields, voltages, and currents. The relaxation and steady-state behavior of simple systems.

243. ***ELECTRICAL SCIENCE I.*** Credit 3 hrs. Fall. 2 Lect. 1 (2½ hour) Rec.-Comp. The main topics are the same as those in 241, but their treatment is more analytical and more intensive.

244. ***ELECTRICAL SCIENCE II.*** Credit 3 hrs. Spring. 2 Lect. 1 (2½ hour) Rec.-Comp. Prereq., 243. The main topics are the same as those of 242, but their treatment is more analytical and more intensive.

MECHANICS

211. ***MECHANICS OF RIGID AND DEFORMABLE BODIES I.*** Credit 4 hrs. Fall–spring. 1 Lec., 2 Rec., 1 Comp.-Lab. Force systems and equilibrium. Distributed forces, static friction, statically determinate plane structures. Concepts of stress and strain. Shearing force, bending moment, bending and torsion of beams. Analysis of plane stress and strain, combined stress, thermal stress. Theories of failure. Instability of columns.

212. ***MECHANICS OF RIGID AND DEFORMABLE BODIES II.*** Credit 4 hrs. Spring.

1 Lect., 2 Rec., 1 Comp.-Lab. Prereq., 211. Inelastic behavior. Energy methods in mechanics. Principles of particle dynamics. Theory of oscillations. Kinematics of rigid body motion. Dynamics of systems of particles. Kinetics of rigid bodies.

CHEMICAL ENGINEERING

5101. ***MASS AND ENERGY BALANCES.*** Credit 3 hrs. 2 Lect., 1 Comp. period. Parallel, Physical Chemistry 405. Engineering problems involving material and heat balances. Flow-sheet systems and balances. Total energy balances for flow systems. Messrs. WINDING, THORPE, SCHEELE.

5102. ***EQUILIBRIA AND STAGED OPERATIONS.*** Credit 3 hrs. Spring. 2 Lect. 1 Comp. period. Parallel, Physical Chemistry 406. Phase equilibria and phase diagrams. The equilibrium stage, mathematical description of single and multistage operations, analytical and graphical solutions. Messrs. WINDING, THORPE, SCHEELE.

METALLURGICAL ENGINEERING

6211. ***INTRODUCTORY METALLURGICAL ENGINEERING.*** Credit 3 hrs. Fall. 2 Lect., 1 Lab. An introductory course surveying various fundamental principles and applications of metals and allied materials. Centered in the laboratory experiments, with the intention of using the many instruments, furnaces, and varied facilities necessary for the study of the application of the principles of physics and chemistry to metallurgy, and to control and to examine the behavior and utilization of metals and materials. A number of examples, such as batteries, triodes, motors, transistors, engine parts and other manufactured articles, will be studied for their application of metallurgical engineering. Mr. SCALA.

6212. ***MATERIAL AND ENERGY BALANCES.*** Credit 3 hrs. Spring. 3 Lec.-Rec. Engineering problems involving material balances, thermal balances, thermochemistry, and electrochemistry as applied to metals and allied materials engineering. Mr. GREGG.

ENGINEERING MECHANICS AND MATERIALS

1134. ***ADVANCED STRENGTH OF MATERIALS.*** Credit 3 hrs. Fall. 1 Lect. 2 Rec. Prereq., 1153. Strain energy methods, Castigliano's theorem. Reciprocal theorem. Beam deflections. Conjugate beam method. Influence lines. Shear deflection. Curved beams. Arches. Buckling under various end conditions. Eccentric buckling. Strength theories. Fatigue. Impact. High temperatures. Thick tubes. Redundant beams. Limit design. Shear center. Beams on elastic foundation. Plates. Mr. BIJLAARD.

1152. ***ENGINEERING MECHANICS-DYNAMICS.*** Credit 3 hrs. Fall–Spring. 1 Lect. 2 Rec. Prereqs., 1151, 1153, 1155, 1145, 1156 or registration in Engineering 4103. The principles of dynamics of a particle, systems of particles, systems of variable mass, and rigid bodies. Vector kinematics, moving and rotating coordinate systems, plane motion of rigid bodies, gyroscopic motion. Messrs. CRANCH, LUDFORD, and staff.

1153. ***MECHANICS OF MATERIALS.*** Credit 3 hrs. Fall–spring. 1 Lect. 2 Rec. 1 Lab. Prereq., 1151. Stress and strain, tension, compression and shear, generalized plane stress, and Mohr's Circle. Riveted and welded joints. Bending and torsion in elastic and plastic ranges. Deflections of beams. Theories of failure. Columns. Energy methods and Castigliano's theorem. Mr. CONWAY and staff.

1154. ***ADVANCED MECHANICS OF MATERIALS.*** Credit 3 hrs. Fall. 3 Lec. Prereqs., 1153 and 1155. Beam theory including symmetric and unsymmetric bending, beam-columns, shear stresses, continuous beams, plastic bending, curved bars and beams on elastic foundations. Torsion theory of circular and noncircular shafts, plastic design of circular shafts, combined bending and torsion, finite difference methods applied to torsion problems. Bending theory of circular and long rectangular plates, membrane and local bending theory for thin wall pressure vessels. Symmetrical deformation problems including the pressurized thick walled cylinder, shrink fit stresses, rotating discs and thermal stresses in long hollow cylinders. Mr. WATT.

1155 (1145, 1156). ***APPLIED DIFFERENTIAL EQUATIONS.*** Credit 3 hrs. Fall–spring. 1 Lect., 2 Rec. Prereq., Math. 163 or equiv. Formulation and solution of engineering problems which involve the use of ordinary differential equations, Fourier Series, partial differential equations and matrices. In addition to classical analytical methods, numerical methods are introduced. Applications to problems arising in civil, chemical, electrical, and mechanical engineering. Messrs. RUOFF, CRANCH, and staff.

1159. ***EXPERIMENTAL MECHANICS.*** Credit 3 hrs. Spring. 2 Rec. 2 Lab. Prereq., 1154 or

equiv. Primarily for graduate students and qualified undergraduates. Brittle coating method of experimental stress analysis, behavior of stresscoat isocutatics, and isostatic determinations and realistic laboratory examples. Electrical resistance type strain gages, including factors influencing alloy sensitivity, gage construction, gage factors, stress gages. Instrumentation for static and dynamic strain gage work including a brief coverage of amplifiers, galvanometers, recorders, and oscilloscopes. Acceleration, velocity and displacement transducers are analyzed and the various electrical methods employed in making these measurements are compared.

1162. ***THEORY OF VIBRATION.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 1180 or equiv. or consent of instructor. Graduates and qualified undergraduates. Vibration of lumped systems including free and forced vibration, damping, impedance methods, resonance, vibration isolation. Matrix methods. Continuous systems including strings, membranes, torsion and bending of beams, plates. Rayleigh-Ritz Method. Impact and transient response. Applications include vibrations of structures and machine elements. Mr. CRANCH.

1163. ***APPLIED ELASTICITY.*** Credit 3 hrs. Fall. 3 Lect. Graduates and qualified undergraduates. Analysis of thin curved bars. Plane stress and plane strain in the circular cylinder, effects of pressure, rotation, and thermal stress. Small and large deflection theory of plates, classical and approximate methods. Strain energy methods. Symmetrically loaded thin cylindrical shell. Torsion of thin-walled members. A first course in the mechanics of elastic deformable bodies with structural applications. Mr. PAO.

1164. ***THEORY OF ELASTICITY I.*** Credit 3 hrs. Spring. 3 Lect. General analysis of stress and strain. Plane stress and strain, Airey's stress function solutions using Fourier series, Fourier integral, and approximate methods. St. Venant and Michell torsion theory. Simple three-dimensional solutions. Bending of prismatical bars. Axially loaded circular cylinder and half space. Mr. CONWAY.

1165. ***THEORY OF ELASTICITY II.*** Credit 3 hrs. Spring. 3 Lect. Graduate students. Development in tensor form of the basic equations of large deformation elasticity; solution of certain large deformation problems. Linearization to infinitesimal elasticity. Boussinesq-Papkovich potentials and their application to three-dimensional problems; contact problems; plane stress by method of Muskhelishvili; application of conformal mapping; Cauchy integral techniques in elasticity; torsion problems. Mr. MITCHELL.

1166. ***STRESS WAVES IN SOLIDS.*** Credit 3 hrs. Spring. 3 Lect. Prereqs., 1162, 1163 or equiv. Graduate students. General equations of elastodynamics. Waves in extended elastic media. Reflection and refraction of waves. Surface waves and waves in layered media. Vibrations and waves in strings, rods, beams and plates. Dispersion in mechanical waveguides. Transient loads. Scattering of elastic waves and dynamical stress concentration. Waves in visco-elastic media. Mr. PAO.

1167. ***THEORY OF PLATE AND SHELL STRUCTURES.*** Credit 3 hrs. Spring. 3 Lect. Graduate students and qualified undergraduates. Analysis of deformation and stress in plates and flat slabs under transverse loads. Various boundary conditions. Numerical methods. Membrane stresses and displacements in shells under various loading. Bending theory of shells. Applications to shell-type structures such as submarines, aerospace structures, shell roofs, pressure vessels. Mr. BIJLAARD.

1168. ***THEORY OF PLASTICITY.*** Credit 3 hrs. Fall. 3 Lect. Graduate students and qualified undergraduates. Theory of inelastic behavior of materials. Plastic stress-strain laws, yield criteria and flow laws. Flexure and torsion of bars, thick-walled cylinders, metal forming and cutting, stress analysis in metals and soils. Yield hinges. Limit analysis. Shakedown of simple statically indeterminate members. Mr. LANCE.

1169. ***THEORY OF ELASTIC AND INELASTIC STABILITY.*** Credit 3 hrs. Fall. 3 Lect. Graduate students and qualified undergraduates. Buckling of columns, frameworks, arches, plates and shells. Lateral buckling of beams. Inelastic buckling of columns and plates. Postbuckling behavior. Method of split rigidities. Mr. BIJLAARD.

1170. ***ADVANCED DYNAMICS.*** Credit 3 hrs. Fall. 3 Lect. Graduate students and qualified undergraduates. The existence and uniqueness of the solutions of Newton's equations of motion; motion of a system of masses; systems with variable mass, rocket equations; Newton's laws in noninertial frames; variational principles of mechanics, D'Alembert's principle, Lagrange's equations, Hamilton's equations; stability of motion, method of Liapunov; rigid body motion, Euler's equations; tops, gyroscopes, and gyroscopic compass. Special theory of relativity. Mr. MITCHELL.

1171. ***INTRODUCTORY SPACE MECHANICS.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 1170 or equivalent. Potential of earth; two-body problem; Hamilton Jacobi theory; orbit about spherical and nonspherical earth; vector theory of perturbations; drag and solar radiation ef-

fect on orbit; charged satellite in earth's magnetic field; restricted three-body problem; libration points; reflectibility and reversibility of trajectories; attitude control of satellites; satellite libration. Mr. MITCHELL.

1172. ***SELECTED TOPICS IN ENGINEERING MECHANICS.*** Credit as arranged, any term. Qualified students wishing to do work in any field of engineering mechanics should register for this course after consultation with the department. Students work with appropriate members of the staff in the chosen field. Typical areas of work include theory of elastic stability, theory of plates and shells, rocket theory and design, wave propagation, elasticity, vibrations, and experimental mechanics. Staff.

1173. ***RESEARCH IN APPLIED MECHANICS.*** Credit as arranged. Thesis or independent research in a field of applied mechanics. Such research must be under the guidance of a staff member. Staff.

1175. ***OSCILLATIONS IN NONLINEAR SYSTEMS.*** Credit 3 hrs. Spring. 3 Lect. A study of the methods of analysis of nonlinear electrical and mechanical systems. Theory of differential equations, phase plane analysis, stability criteria, comparison between linear and nonlinear methods. Equations of Van der Pol, Duffing, Mathieu, Floquet, Hill. Poincaré Bendixson theorem, orbital stability. Methods of Van der Pol, Poincaré, Kryloff and Bogolioboff, Galerkin, Ritz, harmonic balance, equivalent linearization, graphics, perturbations. Hysteresis. Application of Banach space techniques. Mr. BLOCK.

1180. ***ADVANCED ENGINEERING MATHEMATICS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 1155 or equivalent. Application to engineering problems of elementary differential equations, Laplace and Fourier transforms, series, orthogonal functions, functions of several real variables, vector analysis, partial differential equations. Mr. LAIRD.

1181. ***ADVANCED ENGINEERING MATHEMATICS.*** Credit 3 hrs. 3 Lect. Spring. Prereq., 1180. Applications to engineering problems of calculus of variations, tensor analysis, complex variable, matrices, difference equations, and integral equations. Mr. LAIRD.

1182. ***ADVANCED ENGINEERING MATHEMATICS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 1181 or equivalent. Application of advanced mathematical techniques to engineering problems. Conformal mapping; complex integral calculus; Green's function; integral transforms; asymptotics including steepest descent and stationary phase; Wiener-Hopf technique; general theory of characteristics; perturbation methods; singular perturbations; boundary-layer analysis. Development will be in terms of problems drawn from vibrations and acoustics, fluid mechanics and elasticity, heat transfer, electromagnetics. Mr. LUDFORD.

1183. ***ADVANCED ENGINEERING MATHEMATICS.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 1182 or equivalent. More extensive treatment of 1182 in same spirit. Topics include: advanced methods in partial differential equations, WKB and PLK approximations, Hilbert-Schmidt and Fredholm theories of integral equations, singular integral equations, Hilbert problem, dual integral equations. Mr. LUDFORD.

1184. ***NUMERICAL METHODS IN ENGINEERING.*** Credit 3 hrs. Spring. Prereq., 1181 or equivalent. Methods for obtaining numerical solutions to problems arising in science and engineering, such as boundary value problems, eigenvalue problems, diffusion, conduction, wave propagation, vibrations. Variational and integral equation techniques are developed. Mr. LANCE.

1198, 1199. ***PROJECT.*** Total credit 6 hrs. Work of the ninth and/or tenth terms in the form of projects designed to integrate the student's training in several engineering areas when such work is done principally in the field of engineering mechanics. Staff.

1201. ***ENGINEERING MATERIALS.*** Credit 4 hrs. Fall. 3 Lect. 1 Lab. Prereqs., 1153 and Chem. 402. Emphasizes the application of physics and chemistry to the production of metals and alloys and their subsequent shaping and treatment. The effects of various mechanical and thermal treatments on the microstructures are correlated with the physical and mechanical properties of the materials to provide a basis for their selection, design, treatment, and use in service applications. Laboratory work includes static, dynamic and nondestructive testing of a variety of ferrous and nonferrous alloys, heat treatment, hardenability. Mr. JEFFREY.

1202. ***ADVANCED ENGINEERING MATERIALS.*** Credit 3 hrs. Fall. (*See* Engineering Physics, Course 8252.)

1212. ***ENGINEERING MATERIALS.*** Credit 3 hrs. Fall–spring. 1 Lec. 2 Lab. Prereq., 1241. Should be preceded by or taken concurrently with 2715. Timber, cement, concrete aggregates, concrete, elemental concrete structural members, lime, gypsum. Design of concrete mixes, acceptability of materials, and physicochemical properties of materials. Extensive laboratory testing and report writing.

1217. ***ADVANCED PLAIN CONCRETE.*** Credit 2 hrs. Spring. (Not offered in 1962–1963.) 2 Lect. Prereq., 1212 or the equivalent. Topics in the field of concrete, such as history of cementing materials, air-entrainment, light weight aggregates, petrography, durability, chemical reactions, and properties of aggregates. Relationships between internal structure, physical properties, chemical properties, and the mechanical properties of interest to the design and construction engineer. Mr. SLATE.

1241. ***ENGINEERING MATERIALS.*** Credit 3 hrs. Fall–spring. 3 Lect. Prereqs., 1153 and Chem. 401 and 402. An introductory course in materials science. The crystallography and structure of solids. The packing of atoms in crystals and crystal imperfections. Elastic and plastic deformation of single crystals and polycrystalline aggregates. Phase transformations and equilibrium diagrams. Messrs. RUOFF and JOHNSON.

1242. ***ENGINEERING MATERIALS.*** Credit 3 hrs. Spring. 2 Lect. 1 Rec. Prereq., 1241. A lecture course making a detailed study of the fundamental structure and mechanical properties of metals and alloys and the effects of hot and cold working. Carbon and low alloy steels in the annealed and heat-treated condition. High alloy steels. Mr. MOYNIHAN.

1243. ***ENGINEERING MATERIALS.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 1242. A lecture-laboratory course relating material structure to the electrical, thermal, and magnetic properties of materials. Corrosion. Nonmetallic materials such as plastics, glass, refractories and rubber. Lubricants. Nonferrous and special purpose metals and alloys. Mr. MOYNIHAN.

1260. ***THEORETICAL MATERIALS—CRYSTAL MECHANICS.*** Credit 3 hrs. Fall. Prereq., 1243 or equivalent. Primarily for graduate students. Mechanical and physical characteristics of crystals from a classical viewpoint, including crystallography, symmetry elements, mechanical and physical properties of crystals of differing symmetry, influence of crystal structure upon elastic constants, theories of elastic constants for metals and ionic crystals; crystallography of simple glide and twinning for different crystal structures, double slip, cross slip, deformation bands. Mr. JOHNSON.

1261. ***THEORETICAL MATERIALS — MECHANICAL PROPERTIES.*** Credit 3 hrs. Spring. Prereq., 1243 or equivalent. Primarily for graduate students. A discussion of the structure-sensitive mechanical properties of materials attributable to imperfections in crystals. Includes the role of dislocations, impurities, vacancies, and interstitial atoms and their effect on such properties as plastic flow, fatigue, creep, and fracture. Mr. RUOFF.

1255, 1256. ***MATERIALS OF CONSTRUCTION.*** (See Chemical Engineering 6255, 6256.)

1273. ***RESEARCH IN ENGINEERING MATERIALS.*** Credit as arranged. Fall–spring. Thesis or independent research in a field of materials science. Such research must be under the guidance of a staff member. Staff.

1298, 1299. ***PROJECT.*** Total credit 6 hrs. Work of the ninth and/or tenth terms in the form of projects designed to integrate the student's training in several engineering areas when such work is done principally in the field of engineering materials or physical and mechanical testing. Staff.

CIVIL ENGINEERING

GRAPHICS

Mr. HEWITT and others.

2004. ***ADVANCED GRAPHICS.*** Credit 3 hrs. On demand. Projections and graphical representations are treated in scope beyond that of basic drawing courses, including axonometric projections, perspective, vectors, nomography, illustrations, and the professional drawings.

2005. ***CARTOGRAPHY.*** Credit 3 hrs. Fall. A study of the field of cartography, with particular attention to the principles of map projections, the conventions, scales, and construction of planimetric, topographic, and chorographic maps from survey notes and data from aerial photographs. A first course to combine photogrammetry and topographic surveying into a practical course on map making and interpretation.

2006. ***MAP REPRODUCTION.*** Credit 3 hrs. Spring. The preparation of map manuscripts and models for reproduction by both photographic and mechanical methods of duplication. The selection, evaluation, and organization of cartographic material from ground and aerial surveys into map editions will assure the proper procedure to adopt for local circumstances.

SURVEYING

Messrs. ANDERSON, LYON, STANTON, and others.

2101. *ENGINEERING MEASUREMENTS.* Credit 3 hrs. Fall. 1 Rec. 2 Labs. Study of basic surveying instruments and of linear, angular, and area measuring procedures; data processing and presentation of results of measurement operations; topographic surveys by terrestrial methods; and geometry of circular, transition, and parabolic curves.

2102. *ADVANCED SURVEYING.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 2101. Project planning from topographic maps; photogrammetry; measurement errors and statistics; conditioned measurements; formulation of survey specifications; subsurface surveys; hydrographic surveys; geodesy; field astronomy; and boundary surveys.

2105. *SUMMER SURVEY.* (Topographic, Hydrographic, Route, and Geodetic Survey Camp.) Credit 5 hrs. Field and office work six days a week for five weeks. Date to be announced in spring term. Prereqs., 2101 and 2102. Design and execution of topographic survey and corresponding map with emphasis on transit-stadia and plane table-stadia methods; hydrographic survey and map of Cayuta Lake; and complete route survey including reconnaissance from aerial photographs, preliminary survey, paper location, and staking of the final line. All horizontal and vertical control surveys are executed according to present standards for base-line taping, triangulation with repeating and direction type optical-reading thedolites, subtense and trig traverse, precise leveling, and altimetry. Astronomic observation for azimuth and position are made and results computed.

2115. *ADVANCED ENGINEERING MEASUREMENTS.* Credit 3 hrs. Fall. Prereqs., laboratory work involving physical measurements, Math 163, and permission of the instructor. Measurement systems; analysis of errors and of error propagation; application of the principles of probability to the results of measurements for the purpose of determining the best estimates of measured and deduced quantities, and the best estimate of uncertainty in these quantities; adjustment of conditioned measurements by the method of least squares and other methods; curve fitting; and data processing methods.

2116. *LAND SURVEYING.* Credit 3 hrs. On demand 3 Rec. Prereq., permission of the instructor. Functions and responsibilities of a land surveyor; deeds and land descriptions; land records and land courts. Study of U.S. public land system, metes and bounds, subdivisions, resurveys, cadastral surveys, riparian rights, mineral land surveys, and other land survey systems. Specifications and registration.

2117. *GEODETIC SURVEYING.* Credit 3 hrs. On demand. 3 Rec. Prereq., permission of the instructor. Consideration of special problems in geodetic surveying; base line; triangulation; traverse; precise leveling; deflection of the plumb line; figure of the earth; determination of gravity; isostasy; magnetic properties of the earth. Subject to arrangement to meet the special needs of students.

2119. *MAP PROJECTIONS.* Credit 3 hrs. On demand. The theory of map projections. Construction of projections. Plane coordinate systems.

2120. *VERTICAL CONTROL.* Credit 3 hrs. On demand. Lectures, reading, and field work. Principles of establishing a geodetic sea-level datum; isostasy, the geoid, and reference ellipsoid; barometric, trigonometric, spirit, and electronic leveling; study of precision altimetry; determination of economic relationships of vertical control methods to mapping scale, especially for photogrammetric mapping.

2121. *ELEMENTS OF PHOTOGRAMMETRY.* Credit 3 hrs. Fall. Lectures, recitation, and laboratory work. Principles and practice of terrestrial and aerial photogrammetric mapping, including planning flights, control surveys, uncontrolled mosaics, radial-line control, simple stereoplotting instruments, parallel distortions, graphical tilt determination, trimetrogen charting, and economics. A Balplex projection stereoplotter with three projectors and a Wild A-7 plotter are available for use.

2122. *ADVANCED PHOTOGRAMMETRY.* Credit 3 hrs. Spring. Prereq., 2121. Lectures, reading, and laboratory work. An advanced study of photogrammetric principles including controlled mosaics, rectification, graphical, mechanical, and analytical space orientation. Readings and reports from current technical literature. The principles of many photogrammetric plotters are studied together with the economic relation of these instruments to density of field control, office methods, and personnel. The Balplex plotter and the Wild A-7 Autograph plotter with the attached EK-3 Electric Coordinate Printer are available for study and use.

2123. *SURVEYING AND MAPPING INSTRUMENTATION.* Credit 3 hrs. On demand. Prereq., 2121. Lectures and assigned reading. Independent study of developments in surveying, mapping, and photogrammetric instruments including a brief historical sketch of instrumentation; optical-reading levels and

transits; electronic base line measurement; precision altimeters; sonar equipment; equiangulator, odograph, and stereoscopic plotters. Correlation of the principles of physics and mathematics in new measuring instruments and methods.

2131. ***ELEMENTS OF SURVEYING.*** Credit 1 hr. Fall-spring. 1 Lab. Fundamentals of engineering measurements. Appreciation of observations and errors. Principles of recording data. Use of steel tape, level, and transit. Optical tooling. Problems of particular interest to students in fields other than civil engineering.

2132. ***SURVEYING.*** Credit 3 hrs. Spring. 2 Rec. 1 Lab. Fundamentals of engineering measurements. Appreciation of methods of observations and errors. Principles of recording data. Use of steel tape, level, transit, and plane table. Aerial mapping. Emphasis on problems common in agricultural engineering.

2141. ***PROJECT. GEODETIC OR PHOTOGRAMMETRIC ENGINEERING.*** On demand. Open to specially selected seniors or graduate students. Projects in the various fields of geodesy and photogrammetry may be developed by conference between professors and students. Hours and credit variable.

2142. ***GEODETIC OR PHOTOGRAMMETRIC ENGINEERING RESEARCH.*** On demand. Prerequisites will depend upon the area of studies to be pursued. Special problems in error analysis, geodesy, and photogrammetry as may be arranged.

2143. ***SEMINAR IN GEODESY OR PHOTOGRAMMETRY.*** Credit 1–6 hrs. On demand. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the geodetic or photogrammetric field.

HYDRAULICS AND HYDRAULIC ENGINEERING

Mr. LIGGETT, and staff.

2301. ***FLUID MECHANICS.*** Credit 4 hrs. Fall–spring. 3 Rec. 1 Lab. Prereq., concurrent with 1152. Fluid properties. Pressure and pressure intensity. Hydrostatics. Fluid flow concepts and basic equations. Dimensional analysis. Laminar and turbulent flow. Flow in pipes. Flow in open channels, centrifugal pumps.

2302. ***HYDROLOGY.*** Credit 2 hrs. Fall–spring. 2 Rec. Precipitation, stream flow, unit hydrograph, groundwater, wells, application of hydrologic techniques.

2303. ***ADVANCED HYDRAULICS.*** Credit 3 hrs. Fall. 3 Rec. Prereq., 2301. More detailed and extended theory and application than in the first course. Problems considered include stability of flotation, fluids subject to acceleration, hydraulic similitude, open channel flow, pipe flow, water hammer, and hydraulic models.

2304. ***HYDRAULIC MEASUREMENTS.*** Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 2301. The general flow equation. Volumetric and weight measurements. Measurement of fluid velocity. Rate of flow measurement in pipelines and open channels. Graphical and analytical methods of analyzing data. Error and tolerances.

2306. ***PUMPS AND TURBINES.*** Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq. 2301. Theory and characteristics of the hydraulic ram; reciprocating and centrifugal pumps; impulse, reaction, and propeller type turbines; selection and testing of hydraulic machinery.

2307. ***FREE SURFACE FLOW.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 2315 or permission of instructor. The formulation of the free surface equations and boundary conditions. Shallow water theory and the theory of characteristics. The analogy of gas dynamics to unsteady and two-dimensional flow in open channels. Theory of small amplitude waves.

2311. ***RIVERS AND HARBORS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 2312. Rivers: regimen of flow in natural streams, flood waves, flood control, sedimentation, channel improvement, canalization, tidal effects, and ports. Harbors: gravity waves, shore improvement, harbor improvement, ports, and canals.

2312. ***HYDRAULIC ENGINEERING.*** Credit 3 hrs. Spring. 3 Rec. Prereq., 2302. Introduction to hydraulic engineering problems. Purpose, planning, and component parts of hydraulic projects. Flow measurement, unsteady flow, compressible fluid flow. Flood routing, sedimentation. Reservoirs. Dams, spillways, and river protection works. Flumes and channels. Conduits, tunnels, penstocks. Locks. Hydraulic model studies.

2314. ***WATER POWER.*** Credit 3 hrs. Fall. 2 Lect. 1 Comp. Prereq., 2301 and 2302. Hydrologic and hydraulic investigation of water power sites; selection of turbines, power plant layout, and equipment; economic considerations. Problems cover determinaiton of available power, selection of turbines, use of pondage and storage; and determination of annual power output.

2315. ***ADVANCED FLUID MECHANICS I.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 2301 or

2331. Introduction to vector and tensor notation. The equations of conservation of mass, momentum, and energy. Potential flow including circulation, vorticity, conformal mapping, hodograph methods.

2316. ***ADVANCED FLUID MECHANICS II.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 2315 or equivalent. Exact solutions of the Navier-Stokes equations. The laminar and turbulent boundary layers. Turbulence. Introduction to Non-Newtonian flow. Other topics.

2331. ***FLUID MECHANICS.*** (For electrical engineering students.) Credit 3 hrs. Fall-spring. 3 Rec. Prereq., 1152. Statics, dynamics of fluid flow, law of continuity, energy equation, turbulence, flow of compressible fluids, impulse momentum relations, resistance of submerged bodies, lubrication, and hydraulic machinery.

2342. ***HYDRAULICS RESEARCH.*** Credit 1–6 hrs. On demand. Prereq., 2312 or the equivalent. The subject and scope of the investigations in experimental or theoretical hydraulics should be selected by conference at the beginning of the term if not previously arranged. It is permissible and often desirable for two students to work together on the same investigation.

2343. ***HYDRAULICS SEMINAR.*** Credit 1 hr. Fall-spring. Abstraction and discussion of technical papers and publications in the field of hydraulics and hydraulic engineering.

SANITARY ENGINEERING

Messrs. Behn, Gates, and Lynn.

2501. ***MICROBIOLOGY IN ENGINEERING.*** Credit 3 hrs. Fall-spring. 2 Lect.-Rec. 1 Lab. Prereq., Chem. 106. Introduction to the characteristics and activities of micro-organisms and their effect on man and his environment, with emphasis on their role in the biological oxidation of organic substances, the natural purification of waters receiving organic wastes. Bacteriological measurement of water quality.

2502. ***WATER SUPPLY AND WASTE-WATER SYSTEMS.*** Credit 3 hrs. Fall-spring. 2 Lect.-Rec. 1 Comp. Prereq., 2302. Concepts of water resource development and utilization; water quality control; analysis and design of structures and systems for (1) the collection, transportation, and distribution of water supplies; (2) the collection and transportation of municipal and industrial waste-water and of storm water. Disposal of waste-water.

2503. ***WATER AND WASTE - WATER TREATMENT.*** Credit 3 hrs. Fall-spring. 2 Lect.-Rec. 1 Comp. or Lab. Prereqs., 2501, 2502. Study of processes for the treatment of water supplies and of municipal and industrial waste-water, in terms of the underlying biological, chemical, and physical principles; the application of these principles to the analysis and design of unit treatment processes and to the synthesis of treatment plants.

2506. ***TREATMENT PROCESSES AND SYSTEMS.*** Credit 4 hrs. Fall. Prereq., 2503 or equiv. Analysis and design of processes and systems for the removal of impurities from water supplies and from municipal and industrial waste-water. Theoretical and applied aspects of treatment process design such as reaction kinetics, transfer phenomena, and the mechanics of fine particles.

2507. ***AIR AND WATER RESOURCES.*** Credit 3 hrs. Spring. Prereq., 2502 or equiv. Sources and characteristics of air and water pollutants, including radioactive substances; their reactions in air and in water; their dispersion and fate in the environment. Criteria and methods of disposal. Capacity of air and water resources to assimilate wastes. Air and water control.

2509. ***ENVIRONMENTAL HEALTH ENGINEERING.*** Credit 3 hrs. Spring. Concepts, planning, and control of environmental systems. Epidemiological and engineering aspects of current health problems.

2510. ***SANITARY CHEMISTRY.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 1 year of college chemistry. Primarily intended for graduate students and upperclassmen especially interested in sanitary engineering. Analytical, physical, and organic chemistry specifically applicable to design and control of water and waste treatment processes. Measurement of water quality.

2511. ***SANITARY ENGINEERING LABORATORY.*** Credit 3 hrs. On demand. 1 Lect.-Discuss. 2 Labs. Prereqs., 2510 or parallel registration; 2503. Laboratory studies of water and waste treatment processes, including the application of physical, chemical, and biological principles, methods, and procedures to the treatment of water, sewage, and industrial wastes.

2515. ***ENVIRONMENTAL SYSTEMS ENGINEERING.*** Credit 3 hrs. Fall. Prereq., 3240 or permission of instructor. Intended for graduate students but open to qualified undergraduates. Development of general linear programing problem and special cases such as networks, dyadics, transportation problem. Emphasis placed on application of techniques of operations research, queuing theory, dynamic programing, simulation, game theory, and linear programing to civil and sanitary engineering problems. Mr. Lynn.

2532. ***ENVIRONMENTAL SANITATION.*** For students not in civil engineering. Credit 3 hrs. Fall. Lecture-discussions, reports, and field trips. Concepts of environmental sanitation with emphasis on water resource development, utilization and management; municipal, industrial and individual sewage and solid waste disposal; metropolitan fringe area sanitation; air and water quality control methods and programs; particularly as they relate to environmental planning and control.

2541. ***PROJECT, SANITARY ENGINEERING.*** On demand. Prereqs., 2502 and 2503, or equiv. Students will elect or be assigned individual or group problems or topics dealing with water resource utilization, water quality control, water and waste-water treatment processes, systems and plants, or other problems of special interest.

2542. ***SANITARY ENGINEERING RESEARCH.*** On demand. Prerequisites will depend upon the particular problem to be pursued, but in general they should include a laboratory course and those courses in hydraulics and sanitary engineering pertinent to the field in which the study is to be undertaken. Hours and credit variable.

2543. ***SANITARY ENGINEERING SEMINAR.*** Credit 1–2 hrs. On demand. Open to interested upperclassmen and graduate students. Presentation and discussion of technical papers and publications in the sanitary engineering field.

TRANSPORTATION ENGINEERING

Messrs. BELCHER, LEWIS, and LIANG.

2602. ***TRANSPORTATION.*** Credit 3 hrs. Fall-spring. 3 Rec. Prereq., Economics 103 or permission of the instructor. The historical, economic, regulatory, construction, and operational aspects of transportation. Designed particularly for engineering students. Mr. LEWIS.

2610. ***HIGHWAY ENGINEERING.*** Credit 3 hrs. Fall-spring. 2 Lect. 1 Lab. Prereqs., 2113, and preceded by or taken concurrently with 2725. Highway administration, planning, economics, and finance; reconnaissance and location; geometric design; traffic engineering; drainage; subgrade; base courses; design and construction of flexible and rigid pavements. Mr. LIANG.

2612. ***HIGHWAY LABORATORY — BITUMINOUS.*** Credit 3 hrs. Fall. 2 Lab. 1 Seminar. Prereq., 2610, or may be taken concurrently with 2610. Bituminous materials are tested and aggregates studied for their compatibility with bitumens. Mixes are designed and tested. Condition surveys are made on various classes of bituminous pavements. Laboratory fully equipped for all phases of applied and research studies. Mr. LEWIS.

2613. ***HIGHWAY LABORATORY — SUBGRADE SOILS.*** Credit 3 hrs. Spring. 2 Lab. 1 Seminar. Prereqs., 2725 and 2610, or may be taken concurrently with 2610. Evaluation of current soil engineering practices. Soil surveying and sampling. Correlation of field and laboratory compaction procedures. Tests on soil samples stabilized with bituminous materials. Portland cement and chemicals. Condition surveys are made on stabilized roads. Laboratory fully equipped for all phases of applied and research studies. Mr. LIANG.

2614. ***HIGHWAY DESIGN—STRUCTURAL.*** Credit 3 hrs. Fall. 3 Rec. Prereq., 2610 or permission of the instructor. Part I: Soil index properties and highway soil classification systems; surveying and sampling; subgrade strength evaluation; compaction; drainage and frost action; stabilization; aggregates. Part II: Design and construction of base and surface courses for flexible pavements. Part III: Design and construction of rigid pavements. Mr. LIANG.

2615. ***HIGHWAY DESIGN — GEOMETRIC.*** Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 2610 or permission of the instructor. Route selection; design controls and criteria, including vehicle characteristics and highway capacity; sight distance, and horizontal and vertical control; cross section elements; right-of-way problems and access control; at-grade intersection design, including rotary and channelized intersection; grade separations and interchanges; regional systems of highways, freeways, and parkways. Mr. LEWIS.

2617. ***AIRPORT ENGINEERING.*** Credit 3 hrs. Spring. 2 Rec. and 1 Lab. Prereqs., 2610, 2725. Airport administration, planning, and design. Site selection and evaluation; master plan; grading; drainage; flexible and rigid pavements; terminal facilities; heliports. Mr. LIANG.

LOW-COST ROADS. Primarily for foreign students. Credit 3 hrs. On demand. (See Agricultural Engineering 241, p. 104.)

2619. ***TRAFFIC ENGINEERING — OPERATIONS.*** Credit 3 hrs. On demand. 2 Lab. 1 Seminar. Prereq., preceded by or taken concurrently with 2620. Definition of traffic problems; collection of field data; analysis of field data; findings, conclusions, and recommendations. Traffic surveys. Design of traffic control systems. Mr. LEWIS.

2620. ***TRAFFIC ENGINEERING.*** Credit 3 hrs. Fall-spring. 2 Rec. 1 Lab. Prereq., 2610 or permission of the instructor. City and highway traffic surveys and designs. Accidents, congestion, delay, speed, volume, density, parking, channelization, lighting, traffic control, and routing. Signs, signals, and markings. Urban traffic consideration in city planning. Driver reactions and habit pattern. Traffic engineering organization. Mr. LEWIS.

2621. ***ANALYSES AND INTERPRETATION OF AERIAL PHOTOGRAPHS.*** Preregistration required. Credit 3 hrs. Fall-spring. 2 Lect. 1 Lab. (The student is expected to pay the cost of field trips and aerial photographs for use in a term project, amounting to approximately $15.) A study of the soil and rock areas of the United States and the patterns present in aerial photographs. Fundamental elements of soil patterns are analyzed to permit determination of soil texture, type of bedrock, and drainage properties. Field training in selected test areas. Emphasis is placed on interpretation for engineering, regional planning, and agricultural purposes. Mr. BELCHER.

2622. ***ADVANCED INTERPRETATION OF AERIAL PHOTOGRAPHS.*** Preregistration required. Credit 3 hrs. On demand. Organization of course depends upon fields of interest. Special problems: four each on ground water, engineering projects, agricultural soils mapping, irrigation, and geology. Mr. BELCHER.

2623. ***PHYSICAL ENVIRONMENT EVALUATION.*** Credit 3 hrs. On demand. 2 Lect. 1 Lab. Intended for graduate students or upperclassmen in engineering and planning. Permission of the instructor. A study of physical environment factors affecting engineering and planning decisions and the evaluation methods of these factors. Physical factors include the climate, soil and rock conditions, and water sources in different parts of the world. Evaluation methods include air and ground reconnaissance, interpretation of meteorological, topographic, geological, and soil maps, aerial photography, engineering data, and subsurface exploration records. Mr. LIANG.

2641. ***PROJECT, TRANSPORTATION ENGINEERING.*** Credit 3 hrs. On demand. Projects in the various fields of transportation, advanced aerial photographic studies, traffic engineering, and earth engineering may be developed by conference between professors and students. Projects may involve integrated planning or design drawing upon several fields of interest, or they may concentrate upon special subjects. Adequate facilities, material, and sources of data are necessary to a satisfactory project.

2642. ***TRANSPORTATION ENGINEERING RESEARCH.*** On demand. Students who wish to pursue one particular branch of transportation engineering further than can be done in any of the regular courses may elect work in this field. The work may be in the nature of an investigation of existing methods or systems, theoretical work with a view to simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems. Hours and credit variable.

2643. ***TRANSPORTATION ENGINEERING SEMINAR.*** Credit 1–2 hrs. On demand. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the transportation engineering field.

STRUCTURAL ENGINEERING

Messrs. BRITVEC, MASON, MCGUIRE, NILSON, STEARNS, STURMAN, WHITE, and WINTER.

2701. ***ELEMENTARY STRUCTURAL ANALYSIS.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 1153. A first course in structural theory. Determination of reactions and internal forces and moments in beams, girders, trusses, simple frames, and three-hinged arches due to stationary and moving loads. Simple uses of digital computers in structural analysis. Mr. WINTER.

2702. ***STEEL AND TIMBER STRUCTURES.*** Credit 4 hrs. Spring. 2 Lect. 2 Lab. Prereqs., 2701, 1134. Analysis and design of steel members and connections. Design of welded roof truss. Design of mill-type steel building, including riveted roof trusses, crane girders, crane and building columns, bracing system. Design of thin-walled (light-gage) steel structures. Discussion of fatigue and brittle fracture. Elements of timber design.

2704. ***STATICALLY INDETERMINATE STRUCTURES.*** Credit 4 hrs. Fall. 3 Lect. 1 Lab. Prereq., 2702. Deflections. Classical and modern methods of analysis of statically indeterminate beams, frames, trusses. Influence lines. Plastic design and analysis of steel structures. Mr. BRITVEC.

2706, 2707. ***ADVANCED STEEL DESIGN.*** Credit 3 hrs. per term. Spring-fall. 3 Rec. Prereqs., 2710; 2708 prereq. for 2707. Bridge types and economy. Design of a highway truss bridge. Elastic and plastic designs of a rigid frame building. Partial design of tier building frame including wind and earthquake effects. Other dynamically loaded structures. Design of a steel plate structure. Suspension roof sys-

tems. Continuous composite bridges. Design of light-weight alloy structural elements. Critical review of recent research, current specifications, design, and fabrication procedures throughout. Mr. McGuire.

2708, 2709. ***ADVANCED STRUCTURAL ANALYSIS.*** Credit 3 hrs. a term. Fall-spring. 3 Lect. a week throughout the year. Prereq., 2704 or equivalent. Review of fundamental methods of analyzing indeterminate structures and extension to complex structural systems. Arches, curved beams, out-of-plane loading, suspension structures, trussed and rigid space frames, etc. Mechanical model analysis, numerical methods, matrix solution of structures, use of digital computers in analysis and design. Mr. Fisher.

2710. ***STRENGTH OF STRUCTURES.*** Credit 3 hrs. Fall. 3 Rec. Prereq., 2704; can be taken concurrently. Analysis of two- and three-dimensional stress and strain. Theories of failure of ductile and brittle materials. Strain energy methods applied to bending, shear, and impact. Structural materials under load, strain hardening, residual stresses, hysteresis, stress concentration, brittle fracture, alternating stress. Design for fatigue. Stresses beyond the elastic limit. Inelastic behavior of steel and reinforced concrete structures. Critical discussion of recent research and current design specifications. Mr. Winter.

2711. ***BUCKLING, ELASTIC AND INELASTIC.*** Credit 3 hrs. Spring. Prereqs., 2710 and 1145 or the equivalent. Analysis of elastic and plastic stability. Determination of buckling loads and maximum stresses of columns with and without eccentricity. Solid and open web columns with variable cross-section. Beam columns. Frame buckling. Lateral strength of unbraced beams. Buckling loads and post-buckling strength of plates, shear webs, and cylindrical shells. Critical discussion of current design specification. Mr. Winter.

2715. ***REINFORCED CONCRETE DESIGN.*** Credit 4 hrs. Fall-spring. 2 Lect. 2 Lab. Prereq., 2704. A first course in reinforced concrete. Linear and ultimate strength theory of reinforced concrete applied to rectangular beams, one- and two-way slabs, T-beams, beams reinforced for compression, concentric and eccentric columns. Shear and bond. Design project comprising partial design of concrete building frame. Introduction to prestressed concrete.

2716, 2717. ***CONCRETE STRUCTURES, REINFORCED AND PRESTRESSED.*** Credit 3 hrs. Spring-fall. Prereqs., 2704, 2715, 2708 (for 2717). Review of member design. Ultimate strength theory. Flat-slab and flat-plate design, including bent analysis. Yield line theory. Framing systems in current use. Prestressed concrete. Folded plate construction. Membrane analysis of domes and hyperbolic paraboloids. Critical discussion of current design specifications and recent research. Mr. Nilson.

2720. ***FOUNDATIONS.*** Credit 3 hrs. Fall-spring. 2 Lect. 1 Lab. Prereqs., 2715, 2725. Study of the structural problems encountered in foundation work. Retaining walls, sheet piling, spread footings, piles, piers, abutments, cofferdams, caissons, underpinnings. Design problems.

2725. ***ELEMENTS OF SOILS ENGINEERING.*** Credit 3 hrs. Fall-spring. 2 Lect. 1 Lab. Prereqs., 1153, 2301. Properties of soil and its behavior as an engineering material. Principles of soil identification and classification, terminology and soil characteristics such as gradation, permeability, compressibility, consolidation, and shearing strength with application to simple problems of seepage, settlement, bearing capacity, stability of earth slopes. Lateral earth pressure. Soil exploration. Laboratory tests for experimental determination of above-mentioned soil characteristics, and evaluation and use of data.

2726. ***ENGINEERING PROPERTIES OF SOILS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 2725. Soil structure, adsorbed and free water. Flow of water through soil, flow nets, piezometers, filters, piping, capillary flow, soil suction, and frost action. Uniaxial and triaxial consolidation, volume compressibility and pore pressure coefficients, shrinkage and swelling. Shear strength of saturated and partly saturated, isotropically and anisotropically consolidated soils, true and apparent cohesion and friction resistance, sensitivity and thixotrophy, triaxial, direct shear, penetration and vane tests. Mr. Broms.

2727. ***PRINCIPLES OF SOILS ENGINEERING.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 2725. Failure theories for soils, general and local shear failures, Kötter's equation and boundary conditions. Lateral earth pressures, Rankine, Coulomb, logarithmic spiral, and friction circle methods. Bearing capacity of deep and shallow foundations, eccentric and inclined loading, size and shape effects. Stability of slopes, methods of slices, seepage pressures. Soil pressures, concentrated and distributed loads, influence charts, soil modulus, contact pressures, and pressure cells. Mr. Broms.

2728. ***APPLIED SOILS ENGINEERING.*** Credit 3 hrs. Spring. 3 Lect. Prereqs., 2725 and 2727. Long and short-time strength of soils, numerical methods. Footings and rafts,

design criteria, elastic foundations, construction problems, plate load tests. Piles and caissons, pile tests, pile driving formulas, dynamic and static penetration tests, ultimate strength and settlements of pile groups, stress wave equation, buckling and lateral resistance. Retaining walls, shallow and deep-seated failures, seepage pressures. Bulkheads and bracing, design criteria, behavior of ultimate and working loads. Earth and rock-fill dams, design criteria for core, up-and-down stream slopes, filters, and foundation requirements. Soil exploration, geophysical methods, soundings and borings. Mr. BROMS.

2731. ***ELEMENTS OF STRUCTURAL ENGINEERING I.*** For students not in civil engineering. Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereqs., 1151, 1153. Analysis of statically determinate and simple statically indeterminate structures. Determination, by means of analytical and graphical methods, of reactions and internal forces and moments caused by stationary loads. Influence lines for beams. Mr. MASON.

2732. ***ELEMENTS OF STRUCTURAL ENGINEERING II.*** For students not in civil engineering. Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 2731. Design of simple steel and timber structures. Discussion of design in light gage steel and aluminum. Analysis and design of members and connections, roof trusses, floor systems, and other structures. Mr. MASON.

2735. ***DYNAMICS OF STRUCTURES.*** Credit 3 hrs. Fall or spring. Prereq., Math. 609 or equivalent. For graduate students or qualified undergraduates. Dynamic behavior of structures as caused by blasts, earthquakes, and similar actions. Lumping of masses. Motion of elastic framed structures in the neighborhood of equilibrium positions, caused by arbitrary disturbances. Systems with one degree of freedom. Resonance and stability. Analytical and numerical methods of solution. Energy methods. Hamilton's principle. Lagrange's equations of motion. Natural frequencies and normal modes of vibration of multidegree of freedom systems. Matrix iteration method. The Rayleigh-Ritz method for the approximate determination of natural frequencies of elastic systems. Dynamic response of framed structures in the inelastic range. Free and forced, longitudinal and transverse vibrations of simple and continuous elastic beams. Effect of axial forces on lateral vibrations of beams. Torsional-flexural vibrations of simple beams of open thin-walled sections. Mr. BRITVEC.

2741. ***PROJECT.*** On demand. Prereqs., 2702 2703, and 2715. The student may select a design problem such as an arch bridge, cantilever or rigid frame bridge, a special problem in steel or concrete building design, or the design of any other structure of particular interest to the student provided he has the proper preparation for such design. The work is submitted in the form of reports. Drawings of typical details must accompany reports. Hours and credit variable.

2742. ***STRUCTURAL ENGINEERING RESEARCH.*** On demand. Students wishing to pursue one particular branch of structural engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction, theoretical work with a view of simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems. Hours and credit variable.

2743. ***STRUCTURAL ENGINEERING SEMINAR.*** Credit 1–6 hrs. Spring. Open to specially selected seniors and graduate students. Preparation and presentation of topics of current interest in the field of structures for informal discussion.

2744. ***SPECIAL TOPICS IN STRUCTURAL ENGINEERING.*** On demand. Individually supervised study in one or more of the specialized topics of civil engineering such as tanks and bins, suspension bridges, towers or movable bridges, which are not covered in the regular courses. Independent design or research projects may also be selected. Hours and credit variable.

SPECIAL AND GRADUATE COURSES

2801. ***THESIS.*** The thesis gives the student an opportunity to work out a special problem or to make an engineering investigation, to record the results of his work, and to obtain academic credit for such work. Registration for thesis must be approved by the professor in charge at the beginning of the semester during which the work is to be done.

Individual courses may be arranged to suit the requirements of graduate students. They are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom and working either independently or in conjunction with others taking the same course.

CONSTRUCTION ENGINEERING AND ADMINISTRATION

Messrs. Blessis, Gebhard, Richards and staff.

2901. *CONSTRUCTION METHODS.* Credit 3 hrs. Fall-spring. 3 Rec. Introduction to methods, equipment, and management principles and procedures involved in construction activities; nature of the construction industry and sources of information concerning it; problems and oral reports by students based on current literature; correlation of money, men, materials, machines, and design details to produce economic results. Mr. Richards.

2902. *ENGINEERING LAW.* Credit 3 hrs. Fall-spring. 3 Rec. Basic features of laws and practices relating to contracts, torts, agency, property, water rights, forms of business organizations, sales, insurance, utilities, labor, government regulation of business, sales, negotiable instruments, workmen's compensation, liens, bankruptcy, patents, copyrights, trademarks; work of the expert witness; ethical responsibilities; professional registration; special emphasis on contract documents used in construction work.

2903. *ENGINEERING ECONOMY.* Credit 3 hrs. Fall-spring. 3 Rec. Prereqs., 2901, 3231, or special permission. Principles and techniques for making decisions about the economic aspects of engineering projects: choosing between alternatives; criteria for making decisions; time value of money; economic selection and operation; effect of income taxes; retirement and replacement; economy studies for governmental activities; introduction to estimating costs of construction.

2904. *PUBLIC ADMINISTRATION.* Credit 3 hrs. On demand. 3 Rec. Aspects of federal, state, and local government of interest to engineers, planners, constructors, and administrators: general principles of administration; patterns of government; the engineer's role in government; problems posed by our rapidly growing population and urbanization; regional public works projects; city and regional planning; codes; zoning; planning capital improvements; the city manager; managing and operating the engineering and other functions of municipalities. Mr. Gebhard.

2906. *ADVANCED ENGINEERING LAW.* Credit 3 hrs. On demand. 3 Rec. Prereq., 2902. An extension by the use of case material of the legal principles and practices covered in 2902, particularly those which apply to construction contracts, and employer-employee relationships. Mr. Richards.

2907. *CONSTRUCTION MANAGEMENT.* Credit 3 hrs. On demand. Prereqs., 2901, 2902, 2903, 3231. Planning and operation of construction projects by the civil engineer: coordinated organization and control of men, materials, and machines; scheduling; estimating; purchasing; selection and training of employees; operation and maintenance of equipment; cost control and pay systems; accident prevention; and other topics. Special reports required. Mr. Gebhard.

2941. *PROJECT. CONSTRUCTION ENGINEERING AND ADMINISTRATION.* Credit 3 hrs. On demand. Prereqs., 2901, 2902, 2903, or permission. Development of a public or private engineering project selected by the student, involving economic analysis, planning, design, and construction procedures, with special emphasis on the legal, financial, and management aspects.

2942. *CONSTRUCTION ENGINEERING AND ADMINISTRATION RESEARCH.* Credit 3 hrs. On demand. Prereqs., 2901, 2902, 2903, or permission. Investigation of special problems relating to the economic, legal, financial, and management aspects of public and private engineering operations of interest to the engineer-administrator, consulting engineer, and constructor.

2943. *CONSTRUCTION ENGINEERING AND ADMINISTRATION SEMINAR.* Credit 1–6 hrs. On demand. Prereqs., 2901, 2902, 2903, or permission. Guided study and discussions by small groups of selected students of topics which involve the legal, financial, and management aspects of civil engineering in public and private work, including discussions of current technical papers and publications.

INDUSTRIAL ENGINEERING

(Additional courses offered in industrial engineering topics are shown under the 3200 series of the Sibley School of Mechanical Engineering. These courses will be appropriately listed in the 9000 series in the next edition of the Announcement.)

SERVICE COURSES

9110. *INTRODUCTION TO INDUSTRIAL ENGINEERING.* Credit 4 hrs. Spring term. 3 Rec. 1 Lab.-Comp. Prereqs., 9170 and 9153. An introduction to modern industrial engineering with emphasis on the design activities of industrial engineers in specifying workplace

methods, the integration of many workplaces into integrated man-machine activity in such systems. Queuing theory, line balancing, and introductory concepts of linear programing will be presented as analytical methods to be used in the analysis of plant design problems. Laboratory work and computing problems will be drawn from situations of interest to mechanical and/or electrical engineers.

9153. *ENGINEERING ECONOMIC ANALYSIS.* Credit 3 hrs. Fall term. 2 Rec. 1 Comp. An introduction to underlying economic principles and phenomena associated with engineering projects. Basic accounting and cost control principles and procedures will be presented initially as a frame of reference for a discussion of the more profound problems relating to the engineer's role as consultant on matters of investment and operations. In addition to the necessary accounting, topics will include cost concepts, profit-volume relationships and analysis, make-buy problems, minimum cost models, replacement and renewal models, simple linear programing models, etc.

9170. *INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Fall term. 2 Rec. 1 Comp. Prereq., Math. 112. Applications of probability theory and statistics to industrial and engineering problems; point and confidence interval estimation; statistical testing of hypotheses; properties of binomial, Poisson, and hypergeometric distributions, and applications to sampling inspection problems; large sample theory and the normal distribution, small-sample theory and Student's t and Chi-square distributions; introduction to correlation theory and curve fitting by least squares.

9180. *DIGITAL COMPUTER PROGRAMING.* Credit 1 or 3 hrs. Either term. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., consent of the instructor. Intended to prepare students to use the large-scale digital computer of the Cornell Computing Center. Considers compiling, assembly, and basic machine languages; machine operation and program test procedures; and input-output capabilities, including use of magnetic tape system. (A student can elect to register for 1 hour credit and participate in the first 6 weeks of the course. This consists of programing in a compiling language and should be sufficient for routine mathematical and statistical problems.)

9181. *INTRODUCTION TO MODERN DIGITAL COMPUTATION.* Credit 3 hrs. Either term. 2 Rec. 1 Comp. Required of B.I.E. candidates and elective for upperclass undergraduates and graduate students. Survey of the field of the computer sciences. Development of the modern digital computer, principles and characteristics of current equipment, machine and higher-level information processing languages. Laboratory work involves use of equipment of the Cornell Computing Center, but this is not essentially a course in programing (*see* 9180). Emphasis is placed on the digital computer as a general-purpose device for storing, retrieving, processing, and transmitting information in addition to its role as an arithmetic calculator. Breadth of present and potential application is stressed by considering areas such as artificial intelligence, integrated decision and control systems, Monte Carlo analyses, simulated experimentation, information retrieval, and manufacturing automation.

9310. *INDUSTRIAL ENGINEERING ANALYSIS AND DESIGN I.* Credit 4 hrs. 2 Lec. and 2 Comp. Prereqs., 9350, 9370, 9181. An introduction to industrial engineering. The history and role played by modern industrial engineering activities in manufacturing and commercial organizations. Emphasis will be on those analytical techniques and design situations that are "micro" in character, i.e., of the single station or workplace rather than those of the "macro" or total industrial system. Specific topics covered will include queuing theory applied to machine interference problems, workplace design, sampling problems in the measurement and evaluation of industrial activities, line balancing and its applications in workplace design, problems and methods of measuring human and machine activity and output.

9311. *INDUSTRIAL ENGINEERING ANALYSIS AND DESIGN II.* Credit 4 hrs. 2 Lec. and 2 Comp. Prereqs., 9310, 9351. The "macro" problem in industrial systems as opposed to the "micro" problem in the preceding course. Analytical techniques that are especially useful in these larger-scale problems. Specific topics include flow analysis, facility allocation and assignment methods, machine grouping models, network analysis with mathematical programing, information systems and feedback, and applications of simulation in the design and analysis of complex systems.

9320. *OPERATIONS PLANNING AND ANALYSIS.* Credit 4 hrs. 1 Lec., 2 Rec., and 1 Comp. Prereq., 9311. The operational problems of complex systems. Models that are characteristic of the operational problems in contrast with the problems of design and specification. Specific topics include production planning, loading and scheduling, inventory planning and control, and applications of mathematical programing including linear, dynamic, and quadratic models.

9350. ***PRINCIPLES OF COSTING AND CONTROL.*** Credit 3 hrs. 2 Rec. and 1 Comp. An introduction to problems of cost determination and allocation. Differences between accounting and engineering objectives in cost finding and cost procedures. Cost concepts and characteristics, and the inexactitude of cost figures relative to engineering problems and decisions. Costing techniques and procedures.

9351. ***COST ANALYSIS AND APPLICATION*** Credit 3 hrs. 2 Rec. and 1 Comp. Prereq., 9350. A continuation of the preceding course with emphasis on the analysis, interpretation, and uses of such data in establishing control over operations being judged against cost criteria. Also, the uses of such data for evaluation and prediction of future design and/or operations. The choice of proper cost data for use in economic models of interest to engineers, i.e., replacement and renewal models, linear programing models, make-buy models, etc.

9352. ***ADVANCED ECONOMIC ANALYSIS.*** Credit 3 hrs. 2 Rec. and 1 Comp. Prereqs., 9320 or equivalent and fifth year (or graduate) standing. Study of advanced topics in engineering, economic analysis including economic theory of the firm, problems of forecasting, prediction, and stochastic processes in economic analysis. Use of such processes in developing economic models for decision-making purposes.

9360. ***INTRODUCTION TO PROBABILITY THEORY WITH ENGINEERING APPLICATIONS.*** Credit 3 hrs. 3 Lec.-Rec. Prereq., Math. 112. Definition of probability and basic rules of probability theory. Random variables, probability distributions, and expected values. Important special distributions and relations among them; elementary limit theorems. Introduction to stochastic processes and Markov chains, and their applications in the construction of mathematical models for physical processes.

9370. ***INTRODUCTION TO STATISTICAL THEORY WITH ENGINEERING APPLICATIONS.*** Credit 4 hrs. 3 Lec.-Rec. 1 Comp. Prereq., 9360. The applications of statistical theory to problems associated with the analysis of data and inferences drawn therefrom. Principles of statistical inference: estimating the value of unknown parameters of probability distributions, testing hypotheses concerning these parameters; elements of statistical decision theory. Introduction to correlation theory and curve fitting by least squares.

9398, 9399. ***PROJECT.*** Max. credit 6 hrs. Prereqs., 9311 and concurrent registration in 9320. Project work requires the identification and analysis of both professional and research problems in industrial engineering. The projects emphasize analytic ability and the synthesis of feasible solutions. Projects can be done individually or in groups up to eight. The problem definition and the subsequent analysis and synthesis are the concern of the student with minimal faculty guidance and participation.

ELECTIVE AND GRADUATE COURSES

9510. ***SYSTEMS ENGINEERING.*** Credit 3 hrs. Spring. 2 Rec. 1 Lab. Elective for graduate students and qualified undergraduates not majoring in the Department. Prereq., 9170. Methods of describing, analyzing, and manipulating complex, interrelated, open systems. Graphical and mathematical analysis. Techniques of design of transportation, service and information systems, and appropriate evaluation methods.

9520. ***MATHEMATICAL PROGRAMING.*** Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereq., 9360 or equivalent. Theory, methods, computational techniques, and applications of mathematical programing. Classical constrained maximization and Lagrange multipliers. Linear programing: simplex method and variations; the dual and the dual simplex method; transportation programing. Interger programing. Quadratic and convex programing. Linear and quadratic assignment programing.

9521. ***PRODUCTION PLANNING.*** Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereqs., 9170, 9510, or permission. Scheduling of manufacturing operations—forecasting, leveling, explosion, loading, sequencing. The planning and control of inventories. Emphasis on mathematical and statistical methods of performing these functions, including development of decision rules and reactive control systems.

9560. ***APPLIED STOCHASTIC PROCESSES.*** Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereqs., 9360 and 9370 or permission. An introduction to the theory of stochastic processes, with emphasis on applications to science and engineering. Topics drawn from sequences of random variables; Markovchains; renewal theory; applications to waiting time problems, to counter problems, and to reliability theory; birth and death processes; multiplicative processes; Gaussian processes; stationary processes; correlation and

spectral distribution; applications to communication theory.

9561. *QUEUING THEORY.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended primarily for graduate students. Prereq., 9360 or Math. 371 (711) or permission of the instructor. Definition of a queuing process. Explicit solutions of queuing problems when the arrival and service distributions are exponential or Erlang. A detailed study of the one-server problem for general distributions: the basic Wiener-Hopf equation; existence and uniqueness of stable solutions; approaches to solving the basic equation. Multi-server problems; bulk service; queues in series. Applications to specific engineering problems such as shop scheduling, equipment maintenance, and inventory control.

9570. *INTERMEDIATE INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 9370 or permission. Application of statistical methods to the efficient design, analysis, and interpretation of industrial and engineering experiments; rational choice of sample size for various statistical decision procedures and the operating characteristic curves of these procedures; curve fitting by least squares; simple, partial, and multiple-correlation analysis.

9571. *ADVANCED INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students. Prereq., 9570 or permission. Use and analysis of experimental designs such as randomized blocks and Latin squares; analysis of variance and covariance; factorial experiments; statistical problems associated with finding best operating conditions; response-surface analysis; statistical multiple-decision selection procedures.

9572. *STATISTICAL DECISION THEORY.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students. Prereqs., 9360 and 9570, or equivalent. The general problem of statistical decision theory and its applications. The comparison of decision rules; Bayes, admissible, and minimax decision rules. Problems involving a sequence of decisions over time, including sequential analysis. Use of the sample cumulative distribution function, and other nonparametric methods. Applications to problems in the areas of inventory control, sampling inspection, capital investment, and procurement.

9580. *DIGITAL SYSTEMS SIMULATION.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students and qualified undergraduates. Prereq., 9181 and permission. The use of a symbol manipulation program for a digital computer to simulate the operating characteristics of a complex system in time. Discussion of problems encountered in construction of a simulation program in the design of effective investigations using simulation. Applications of simulation to such areas as production and inventory scheduling and control, design of manufacturing facilities, management control systems, traffic analysis. Applications will include use in design of facilities, design of operating disciplines or decision rules, and use in real time control of an operating system.

9581. *INTEGRATED INFORMATION PROCESSING SYSTEMS.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 9181 and permission. Concerned with the integration of systems for acquiring, recording, coding, transmitting, filing, storing, retrieving, processing, and reporting information. Theoretical basis in such topics as information theory, data communications, information retrieval, queuing theory, character recognition, and adaptive control theory. Also, implementation problems in equipment capability and compatibility, processing languages, and over-all information systems design. Applications in manufacturing—both in accounting and control of operations—merchandising, warehousing, banking, transportation, and military operations.

9582. *SELECTED TOPICS IN INFORMATION PROCESSING.* Credit 3 hours. Spring. 3 Rec. Prereqs., 9181 and permission. Intended for graduate students. Selected topics chosen from such fields as artificial intelligence, automata theory, heuristic programing, theory and construction of computing languages, parallel processing, information retrieval, language translation.

9590. *SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION.* Credit and sessions as arranged. Either term. Elective for qualified undergraduate and graduate students. Offered to qualified students individually or in small groups. Study, under direction, of special problems in the field of industrial and engineering administration.

9591. *INDUSTRIAL AND ENGINEERING ADMINISTRATION GRADUATE SEMINAR.* Credit 1 hr. A weekly 1½ hr. meeting. Intended for graduate students. Discussion and study of assigned topics of importance in the field.

MECHANICAL ENGINEERING

The courses in mechanical engineering are listed under the following headings: General, Drafting and Industrial Design, Industrial and Engineering Administration, Machine Design, Materials Processing, Thermal Engineering.

GENERAL

3041. ***NONRESIDENT LECTURES.*** Terms 9 and 10. Required. Total credit 1 hr. for both terms. Fall and spring. 1 Lect. Given by lecturers invited from industry and from certain other departments of the University for the purpose of assisting students in their approach to employment and in their transition from college to industrial life. Under the direction of Messrs. LOBERG and ALLEN.

3051. ***A.S.M.E. STUDENT BRANCH.*** Credit 1 hr. Students who have completed at least two terms in the School of Mechanical Engineering are urged to become members of the Cornell Student Branch of the American Society of Mechanical Engineers. The meetings of the Society, however, are open to all. Attendance at any fourteen Student Branch meetings entitles the member to one hour elective credit; however, only one elective may be earned in this manner. Application for membership should be made in October of each year at the A.S.M.E. office, or to the Honorary Chairman of the Student Branch, Mr. PIERCE.

3052. ***INDUSTRIAL ACOUSTICS.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. For graduate and qualified fifth year students. Treatment from the engineering point of view. Sources of noise, their measurement, and means for reduction; attenuation of airborne and structure-borne sound; transducers; room acoustics and psychoacoustics; effect of noise on people. Application of ultrasonic waves for testing, control, and processing. Mr. FEHR.

DRAFTING AND INDUSTRIAL DESIGN

Messrs. ABRAHAMS, BAIRD, and SIEGFRIED.

3115. ***CREATIVE SKETCHING.*** Credit 2 hrs. Fall. 2 Lect. The sketch is the graphic tool of creative thought. Exercises to stimulate creative ability follow basic training of eye and hand for form awareness and sketching proficiency. Mr. BAIRD.

3116. ***INTRODUCTION TO INDUSTRIAL DESIGN.*** Credit 3 hrs. Spring. 2 Lab. Prereq., permission. Readings; abstract and applied design problems which investigate and apply the interrelationships existing between form, function, and materials. Mr. BAIRD.

3190. ***SPECIAL INVESTIGATIONS IN DRAFTING OR INDUSTRIAL DESIGN.*** Credit based upon actual hours of work. Lab. as required. Fall or spring. Also may be elected by students who desire the first term only of the Industrial Design Project. Mr. BAIRD.

3198, 3199. ***INDUSTRIAL DESIGN PROJECT.*** Total credit 6 hrs. Ninth and tenth terms. 2 Lab. Prereq., 3116. Project work includes readings and design problems. Readings integrate design with the contemporary social and economic scene. Design problems are directed toward creation of a comprehensive attitude in product development and toward attainment of a measure of design ability. Mr. BAIRD.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

Messrs. ALLDERIGE, ALLEN, BECHHOFER (on leave, 1962–1963), BERNHARD, CONWAY, GOODE, HILLIER (Visiting Assistant Professor, 1962–1963), IGLEHART, KAO, MAXWELL, NEY, SALTZMAN, SAMPSON, SAUNDERS, SCHULTZ (on leave, fall, 1962), WEISS.

3231. ***PRINCIPLES OF COST ACCOUNTING.*** Credit 3 hrs. Fall and spring. 2 Lect. 1 Comp. Basic accounting theory; historical and standard cost system; cost analysis; uses of costs for control and decision purposes. Messrs. ALLEN, BERNHARD, and staff.

3232. ***PERSONNEL MANAGEMENT.*** Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3241 or permission. Techniques of employee selection and evaluation, job evaluation, training, motivation; personnel department organization and interdepartmental relations. Mr. SAMPSON.

3235. ***INDUSTRIAL ORGANIZATION AND MANAGEMENT.*** Credit 3 hrs. Fall. 3 Lect. Management of an industrial enterprise; internal organization; effect of type of product, methods of manufacture, size of enterprise, and personnel involved; types of enterprises; plant location; centralization and decentralization trends; diversification and specialization; growth of industry. Mr. SAMPSON.

3240. ***ANALYTICAL METHODS IN OPERATIONS RESEARCH.*** Credit 3 hrs. Fall. 3 Rec.

Intended for graduate students but open to qualified undergraduates. Prereq., Math. 162. Selected topics of special interest in operations research and industrial engineering including matrix algebra, set theory, convex bodies, linear inequalities, probability theory (including Markoff chains), and applications to selected problems. Messrs. IGLEHART, NEY, WEISS.

3241. ***INDUSTRIAL AND ENGINEERING STATISTICS.*** Credit 3 hrs. Either term. 2 Rec. 1 Comp. Prereq., Math. 162. Applications of probability theory and statistics to industrial and engineering problems; point and confidence interval estimation; statistical testing of hypotheses; properties of binomial, Poisson, and hypergeometric distributions, and applications to sampling inspection problems; large-sample theory and the normal distribution, small-sample theory and Student's t and Chi-square distributions; introduction to correlation theory and curve fitting by least squares. Messrs. KAO, NEY, WEISS.

3242. ***STATISTICAL CONTROL AND SAMPLING INSPECTION.*** Credit 3 hrs. Spring. 2 Rec. 1 Comp. Elective for qualified undergraduate and graduate students. Prereq., 3241 or permission. Underlying theory, assumptions, applications, and limitations of control charts and sampling plans; concept of statistical control, Shewhart control charts, and sampling inspection for attributes and variables; organization, administration, and economic problems, and application of concepts to areas other than quality maintenance. Messrs. GOODE, KAO.

3245. ***SELECTED STATISTICAL TOPICS.*** Credit 3 hrs. Either term. 2 Rec. 1 Comp. Intended for graduate students. Prereq., 3243 or permission. Selected topics chosen from such fields as nonparametric statistical methods, sequential analysis, multivariate analysis. Messrs. IGLEHART, NEY, WEISS.

3246. ***PRINCIPLES OF INDUSTRIAL ACCOUNTING.*** Credit 2 hrs. Fall. 1 Lect. 1 Comp. Basic accounting theory; special journals; controlling accounts and subsidiary records; voucher system; basic manufacturing cost accounting. Messrs. ALLEN, BERNHARD.

3247. ***PRINCIPLES OF COST CONTROL.*** Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 3246 or 3231, or equivalent. Principles of cost accounting for production order and continuous process operations; cost factors related to decision making, control, and profit; budgets and standards; cost analyses. Messrs. ALLEN, BERNHARD, SCHULTZ.

3248. ***STATISTICAL ASPECTS OF RELIABILITY ANALYSIS.*** Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 3243 or permission of the instructor. The role of probability and statistics in reliability analysis; statistical models for failure and fatigue data, with special emphasis on the exponential, Weibull, Gamma, and extreme-value distributions; design, analysis, and interpretation of multifactor reliability experiments; increased-severity testing; improving reliability through redundance and maintenance; applications to component and systems reliability. Messrs. GOODE, KAO.

3253. ***INDUSTRIAL ACCOUNTING AND COST CONTROL.*** Credit 3 hrs. Fall. 2 Lect. 1 Comp. An accelerated course for upperclassmen and graduate students. Basic accounting theory; manufacturing cost accounting and cost analysis; cost factors related to decision making, control and profit; budgets and standards. Messrs. ALLEN, BERNHARD.

3254. ***ANALYTICS OF DECISION AND CONTROL.*** Credit 3 hrs. Fall. 2 Rec. 1 Comp. Elective for graduate students and qualified undergraduates. Prereqs., 3241, 3247, and 3263. Advanced topics in engineering economics. Economic theory of the firm including theories of capital investment and pricing. Economic forecasting. Treatment of risk and uncertainty. Application to engineering problems, e.g., equipment replacement policy. Cost concepts; marginal analysis and linear programing including simplex method. Application to problems in production and sales planning, e.g., "make or buy" decision, statistical sampling and other techniques for cost prediction, analysis, and control. Messrs. BERNHARD, CONWAY.

3262. ***METHODS ENGINEERING.*** Credit 3 hrs. Either term. 1 Lect. 2 Lab. Prereq., 3241 or equivalent. Analysis and design of operations and jobs; factors influencing creation and evaluation of alternative designs; work measurement and other techniques including stop-watch time study, work sampling, queuing, and predetermined motion times as used for evaluation of design, control of operations, wage standards, etc.; introduction to model design concepts. Messrs. ALLDERIGE, SAMPSON.

3263. ***PRODUCTION ENGINEERING.*** Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereqs., 3247 or 3253 and 3262. Basic concepts involved in the design and operation of production systems. Various cost concepts, certain types of cost analysis, and the economics of capital investment decisions. The fundamentals of production and inventory control. Simple linear programing and assignment problems involved

in plant design. Messrs. Goode, Hillier, Saunders.

3264. ***PRODUCTION ENGINEERING.*** Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereq., 3263. The analysis and design of production systems. Emphasis will be placed on analytical methods and procedures. The material will include such topics as the statistical analysis of product designs and specifications, process capability studies, process planning including process automation, plant layout and design, and materials handling. Messrs. Goode, Hillier, Saunders.

3266. ***ADVANCED METHODS ENGINEERING.*** Credit 3 hrs. Fall. 2 Rec. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3262 or permission. Analysis and design or man-micro systems and man-machine micro systems. Advanced statistical treatment of work measurement design, variables measurement, and work sampling; mathematical and statistical treatment of model design, standard data, control, and standards maintenance; study of the micro systems design problem, including emphasis on the behavioral aspects and wage incentives. Mr. Alldferige.

3267. ***ADVANCED PRODUCTION ENGINEERING.*** Credit 3 hrs. Fall. 2 Rec. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3264 or 3261. A continuation of 3264 but with emphasis on the isolation and analysis of production problems concerned with material flow, material handling methods, and plant design. Mr. Saunders.

3280. ***INTRODUCTION TO OPERATIONS RESEARCH.*** Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students and qualified fifth year students. Prereq., 3241 or permission. Model design, methodology, and techniques of operations research including waiting line models, linear programing and assignment, simulation and other specialized techniques; applications to production, cost, inventory, and sales problem. Messrs. Alldderige, Hillier.

3281. ***COMPUTING EQUIPMENT AND INDUSTRIAL APPLICATIONS.*** Credit 3 hrs. Either term. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Principles and characteristics of modern high-speed digital and analog computing equipment. Programing and operation of the digital computer at the Cornell Computing Center. Engineering and scientific computing applications, introduction to numerical analysis, simulation, and Monte Carlo techniques. Data processing applications in accounting, communications and control; problems of integrated systems design. Mr. Maxwell.

3282. ***DIGITAL COMPUTER PROGRAMMING.*** Credit 1 or 3 hrs. Either term. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., consent of the instructor. Intended to prepare students to use the large-scale digital computer of the Cornell Computing Center. Considers compiling, assembly, and basic machine languages; machine operation and program test procedures; and input-output capabilities, including use of magnetic tape system. (A student can elect to register for 1 hour credit and participate in the first 6 weeks of the course. This consists of programing in a compiling language and should be sufficient for routine mathematical and statistical problems.) Mr. Saltzman.

3290. ***SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION.*** Credit and sessions as arranged. Either term. Elective for qualified undergraduate and graduate students. Offered individually or in small groups. Study, under direction, of special problems in the field of industrial and engineering administration. The staff.

3291. ***INDUSTRIAL AND ENGINEERING ADMINISTRATION GRADUATE SEMINAR.*** Credit 1 hr. A weekly 1½ hr. meeting. Intended for graduate students. Discussion and study of assigned topics of importance in the field. The staff.

3298, 3299. ***PROJECT.*** Max. credit 3 hrs. each course. Prereq., 3264. Project work requires the identification and analysis of both professional and research problems in industrial engineering. The projects emphasize analytic ability and the synthesis of feasible solutions. Projects can be done individually or in groups up to eight. The problem definition and the subsequent analysis and synthesis are the concern of the student with minimal faculty guidance and participation. The staff.

MACHINE DESIGN

Messrs. Booker, Burr, DuBois, Fehr, Ocvirk (on leave 1962–1963), Phelan, and Wehe.

[3321. ***KINEMATICS AND DYNAMICS OF MECHANISMS.*** Credit 4 hrs. Fall. 3 Rec. 1 Comp. Prereq., 212. Analysis of displacement, velocity, and acceleration in basic mechanisms for control, transmission, and conversion of motion and force. Cams, gears, and

four-bar linkages. Forces associated with accelerated motion and gyroscopic action. The flywheel as a speed control device. Counterbalancing. Synthesis of mechanisms. Not offered in 1962–1963.]

[3322. ***MECHANICAL ANALYSIS AND DESIGN.*** Credit 5 hrs. Fall. 1 Lec. 2 Rec. 2 Des. Periods. Prereqs., 3321, Materials Science II, 3421, and parallel with 3422. A study of some major components of mechanical equipment such as clutches, brakes, gears, shafts, and bearings, with particular attention to performance characteristics, strength and durability, optimum proportions, choice of materials and treatment, and design for processing and assembly. Theory of lubrication. Stress-concentration, fatigue, residual stresses, and creep. Selected topics from advanced strength of materials, such as curved beams, plates, pressure vessels, rotors, and thermal stress. Layout design of one small but complete machine. Not offered in 1962–1963.]

[3323. ***DESIGN OF MACHINES.*** Credit 3 hrs. Spring. 1 Lec. 2 Des. Periods. Prereq., 3322. Methods for design and the stimulation of ingenuity. Contemporary design of machines in selected fields. Enclosures, assembly, lubrication, controls, and other requirements for a machine as a whole. Feasibility studies and preliminary designs of mechanical systems. A more detailed design of one or more machines in the system. Not offered in 1962–1963.]

[3324. ***VIBRATION AND CONTROL OF MECHANICAL SYSTEMS.*** Credit 4 hrs. Spring. 3 Rec. 1 Lab. Prereqs., 3321, Elec. Engr. II. Free, damped, and forced vibrations. Vibration isolation mounts, absorbers, and dampers. Control systems: the Laplace transform, transient response to specific inputs, transfer functions, frequency response, stability. Analog computer solutions. Laboratory on the vibration of machines and their components, balancing, and hydraulic and pneumatic control circuits. Modern instruments for measuring force and motion. Not offered in 1962–1963.]

[3331. ***KINEMATICS AND COMPONENTS OF MACHINES.*** Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereqs., 212 and Materials Science I, or equivalents. Required of students in industrial engineering and may be elected by other qualified students not in mechanical engineering. Theory and analysis of mechanisms and components based upon considerations of motion, velocity, acceleration, material, strength, and durability. Cams, linkages, couplings, clutches, brakes, belts, chains, gears, bearings, shafts, and springs. Not offered in 1962–1963.]

[3332. ***MECHANICAL SYSTEMS.*** Credit 3 hrs. Fall. 1 Lec. 1 Rec. 1 Lab.-Comp. Prereqs., 3331, 3431, and Materials Science II, or equivalents. Required of students in industrial engineering and may be elected by other qualified students not in mechanical engineering. An introduction to problems associated with the design and experimental investigation of machines and systems of machines. Design considerations for processing and assembly. The synthesis and integration of components into machine systems. A brief treatment of vibration and control theory, followed by laboratory experiments. Use of modern instruments for measuring force and motion. Solution of problems by analog and digital computers. Not offered in 1962–1963.]

3341. ***MACHINE DESIGN.*** Credit 4 hrs. Spring. 3 Rec. 1 Comp. Prereqs., 1153, 1241, 3118, 3402, and 6110, or equivalent. Required of students in agricultural engineering and may be elected by other qualified students not in mechanical engineering. The design of machines and machine members based upon considerations of motion, size, material, strength, durability, and manufacturing processes; selection of cams, linkages, couplings, clutches, brakes, belts, chains, gears, bearings, shafts, springs, and fasteners. Mr. PHELAN.

3351. ***MECHANISM.*** Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereqs., 3112, 1151. An analysis of displacements, linkages, cams, gears, trains of mechanism, and computing linkages; and introduction to synthesis of mechanisms. Mr. J. F. BOOKER.

3352. ***DYNAMICS OF MACHINERY.*** Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereqs., 3351 and 1152. Graphical and analytical studies of velocities and accelerations and of static and inertia forces in mechanism; engine force analysis, flywheel, and balancing; gyroscopic loads; shaft whirl; vibration isolation. Mr. J. F. BOOKER.

3353. ***DESIGN OF MACHINE MEMBERS.*** Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereqs., 3351, 1153, 1241 (prereq. or parallel). Application of mechanics, kinematics, materials, and processes to the design and selection of springs, couplings, clutches, brakes, belts, chains, gears, shafts, bearings, fastenings, and pressure vessels; stress concentration, residual stresses, theory of lubrication. Mr. BURR or Mr. WEHE.

3354. ***DESIGN OF MACHINES.*** Credit 3 hrs. Spring. 1 Lect. 2 Des. Periods. Prereqs., 3353, 3404, 1242 (prereq. or parallel). Feasibility studies and preliminary designs of mechanical systems, including a more detailed design of one or more machines in the system. The

design of castings, weldments, forgings, stampings, housings, and hydraulic systems for machines. Computations, sketches, and layout drawings as required. Mr. DuBois.

3361. *ADVANCED MACHINE ANALYSIS.* Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereqs., 3353, 1155 (prereq. or parallel). Advanced analyses of mechanisms and machinery members such as clutches and brakes; the graphical determination of shaft deflection; problems in impact, creep, thermal stress, residual stress, surface stress, pressure vessels, and rotating disks; and extended treatment of bearing lubrication. Mr. Burr.

[3362. *MECHANICAL DESIGN OF TURBOMACHINERY.* Credit 3 hrs. Spring. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereqs., 1154 or 3361, 3352 or 3367 (prereq. or parallel). Mechanical design of major components of high speed compressors and turbines for structural adequacy and vibration-free operation. Selected topics from among the following: design of rotor components: disks, vanes, blades, shafts, and connections. Design of casing components: cylindrical, conical, torical shells; flat plates and diaphragms. Design of bearings, seals, gaskets, expansion members. Investigation of natural frequencies and critical speeds. Selection of materials. Mr. Ocvirk. Not offered in 1962–1963.]

3366. *ADVANCED KINEMATICS.* Credit 3 hrs. Spring of even years. 2 Rec. 1 Comp. Prereq., 3352. Advanced analytical and graphical treatment of velocities and accelerations. Further treatment of Coriolis' acceleration. Advanced analysis and design of cams, gears, and computing mechanisms. Synthesis of mechanism.

3367. *DESIGN PROBLEMS IN VIBRATIONS AND DYNAMICS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereqs., 1155, 3352. Applications of dynamics and vibration theory to the design of machinery; vibration and shock mounting of machines with single and multidegrees of freedom, properties of isolators, damping devices, critical speeds of shafts and crankshaft systems; analog computer solutions; vibration instruments and experimental investigations. Mr. Phelan or Mr. Burr.

3372. *EXPERIMENTAL METHODS IN MACHINE DESIGN.* Credit 3 hrs. Fall. 1 Rec. 2 Lab. Prereq., 3353 or 3341. Investigation and evaluation of methods used to obtain design and performance data. Techniques of photoelasticity, strain measurement, photography, vibration and sound measurements, balancing methods, and development techniques are studied as applied to machine design problems. Mr. Phelan.

3374. *CREATIVE DESIGN.* Credit 3 hrs. Fall. 2 Lab. Prereq., 3354. Short problems to stimulate ingenuity and originality, emphasizing methods for the development of improved designs. Mr. DuBois.

3375. *AUTOMATIC MACHINERY.* Credit 3 hrs. Fall. 2 Rec. 1 Field trip. Prereq., 3351. A study of automatic and semiautomatic machinery such as dairy, canning, wire-forming, textile, machine-tool, computing, and printing equipment. Mr. Wehe.

3376. *AUTOMATIC CONTROL.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereqs., 1152, 1155, 4933 (prereq. or parallel). Introduction to feed back control theory with emphasis on the applications of hydraulic and pneumatic systems to the automatic control of machines and processes. The Laplace transform; open and closed-loop systems; transfer functions; stability criteria; frequency response; utilization of analog computors in the design of control systems; components of industrial controllers. Mr. Wehe or Mr. Phelan.

3377. *AUTOMOTIVE ENGINEERING.* Credit 3 hrs. Fall of odd years. 3 Rec. Prereq., 3353. Analysis of various designs for the parts of an automotive vehicle, other than the engine, in relation to its performance; stability, weight distribution, traction, steering, driving, braking, riding comfort, power required and available, transmission types, acceleration, and climbing ability. Recommended together with Course 3670 for a study of automotive engineering. Mr. DuBois.

3390. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN.* Permission of department head required. Credit arranged. Either term. Individual work or work in small groups under guidance in the design and development of a complete machine, in the analysis of experimental investigation of a machine or component of a machine, or studies in a special field of machine design. The staff.

3391. *MACHINE DESIGN SEMINAR.* 1 hr. credit at the end of 2 terms. A one-and-a-half-hour meeting approximately every other week. Required of graduate students majoring in machine design. Discussion and study of assigned topics of importance in the field by faculty, graduate students, and outside speakers.

3398, 3399. *PROJECT.* Total credit 6 hrs. Work of the ninth and tenth terms in the form of projects to integrate the training in

mechanical engineering when such work is done principally in the field of machine design. The staff.

MATERIALS PROCESSING

Messrs. Carpenter, Dispenza, Geer, Morgan, and Pentland.

3404. *PRODUCTION MACHINE TOOLS.* Credit 2 hrs. Either term. 1 Lect. 1 Lab. Prereqs., 3406, 3262. Lectures, demonstration studies, and analyses of machine tools for quantity production of goods. Jigs, fixtures, and other tooling accessories. Operation analysis and quality limitations. Mr. Geer.

3405. *GAGE LABORATORY.* Credit 1 hr. Either term. 1 Lab. Demonstration studies of measuring devices and techniques for control of size, form, and alignment of commercial goods to A.S.A. and other standards; laboratory practice in inspection methods; quality control data studies; calibration and gage checking. Mr. Dispenza.

3406. *MACHINE TOOL TECHNOLOGY.* Credit 2 hrs. Spring term. 1 Lect. 1 Lab. Study of chip formation, cutting tools and fluids, speeds and feeds, and their relations to machinability; analyses of general purpose machines and their accessories; machining practice including layouts, set-ups, and use of measuring instruments. Mr. Pentland.

[**3421. *PROCESSING OF MATERIALS I.*** Credit 3 hrs. Spring term. 2 Lect. 1 Lab. Abstract concept of the manufacturing process. Energy, material, environmental, and topological considerations. Physics and mechanics of chip formation, plastic deformation, friction, force relationships, thermal aspects, tool wear. Machinability of materials. Capabilities of single point, multipoint, and abrasive cutting processes. General purpose and production machine tools employed. Transfer machines, automation, numerical control of machine tools. Economics of cutting. Nonchip removal processes; electrical, electrochemical, chemical, ultrasonic, electron beam methods. Basic concepts of metrology and gaging, principles of mechanical, electrical, optical, pneumatic, and radiation measuring instruments. Messrs. Geer and Pentland. Not offered in 1962–1963.]

[**3422. *PROCESSING OF MATERIALS II.*** Credit 3 hrs. Fall term. 1 Lect. 2 Lab. Prereq., 3421 or 3406. Material displacement, addition, and modification processes. Casting of metal and alloys; solidification, heat extraction, shrinkage, and foundry processes. Metal forming theory. Capabilities of shearing, bending, squeezing, drawing, and stretching processes. Welding theory, processes, and effects, and surface coatings. Heat treatment of steel; annealing, hardening, tempering, surface treatments. Processing of nonmetallic materials; plastics molding methods. Gage laboratory and additional cutting process laboratory exercises. Messrs. Geer and Pentland. Not offered in 1962–1963.]

[**3431. *PROCESSES OF MANUFACTURE.*** Credit 3 hrs. Fall term. 1 Lect. 1 Lab. and a second lect. or lab. on alternate weeks. Physics and mechanics of chip formation, force relationships, tool wear, machinability of materials. Machine tool capabilities in single point, multipoint, and abrasive cutting processes. Economics of cutting. Nonchip material removal methods. Basic concepts of metrology and gaging, principles of measuring instruments. Casting of metal and alloys. Metal forming theory and capabilities of shearing, bending, squeezing, drawing, and stretching processes. Welding methods. Heat treatments of steel. Plastics molding. Messrs. Geer and Pentland. Not offered in 1962–1963.]

3490. *SPECIAL INVESTIGATIONS IN MATERIALS PROCESSING.* Credit and hours as arranged. Discussion and study of selected topics on theory of metal cutting and working processes, the technology of manufacture with machine tools, and metrology and production gaging; topics and assigned study to suit individual needs. Messrs. Geer and Pentland.

3498, 3499. *PROJECT.* Total credit 6 hrs. Work of the 9th and 10th terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of materials processing. Messrs. Geer and Pentland.

THERMAL ENGINEERING

Messrs. Barrows, Conta, Dropkin, Erdman, Fairchild (on leave spring, 1963), Gebhart, Mackey, McManus, Pierce, and Shepherd.

3601. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Fall. 1 Lect. 2 Rec. Prereqs., Mathematics 163, Physics 122, Chemistry 106. Laws of thermodynamics; energy equations; thermodynamic properties of state of ideal and real fluids; thermodynamic analysis of processes of ideal and real fluids. Mr. Conta.

3602. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Spring. 1 Lect. 2 Rec. Prereqs., 3601, Chemistry 402. Combustion; thermodynamics of ideal gas reactions; thermodynamic analysis of basic cycles used for power, refrigeration, and air conditioning. Mr. Conta.

3603. *FLUIDS ENGINEERING I.* Credit 3 hrs. Spring. 3 Rec. Prereqs., 3601, 1152. Properties of fluids; hydrostatics; kinematics and dynamics of fluids; two-dimensional ideal flow; viscous flow in ducts, boundary layer, turbulence, velocity distribution; compressible flow with varying area, friction and heat transfer; normal shock. Messrs. SHEPHERD and PIERCE.

3604. *FLUIDS ENGINEERING II.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3603. Dimensional analysis; flow over immersed bodies; boundary layer solutions; lift and drag; oblique shocks; waves in compressible flow; energy transfer between a fluid and a rotor; characteristics of turbomachines for incompressible and compressible flow; reaction and efficiency; cavitation and surging; propulsion analysis; turbojet, ram jet and rocket; hydrodynamic transmissions. Messrs. SHEPHERD and PIERCE.

3605. *HEAT TRANSFER.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereqs., 3603, 1155. Introduction to heat transfer by conduction, convection, and radiation; steady state, transient state; steady periodic state; heat transfer in engineering apparatus; numerical methods; electrical and fluid analogues. Laboratory instruction in temperature measurement, determination of surface coefficients, radiant energy exchange, and experimental use of analogues. Mr. DROPKIN.

3606. *THERMAL ENGINEERING LABORATORY.* Credit 3 hrs. Spring. 1 Lect. 1 Lab. Prereqs., 3602, 3604, 3605. Methods of testing; experimental determination of performance characteristics of engines, turbines, steam generating units, pumps, compressors, fans, refrigerating systems, air conditioning apparatus, auxiliaries and components of complete plants; analysis of experimental data; preparation of engineering reports. Mr. ERDMAN.

3607. *COMBUSTION ENGINES.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to combustion engines with emphasis on application of thermodynamics, fluid dynamics, and heat transfer; reciprocating combustion engines; gas turbines; compound engines; reaction engines. Mr. FAIRCHILD.

3608. *THERMAL POWER PLANTS.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to steam and binary vapor power plants with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; nuclear power. Mr. ERDMAN.

3609. *REFRIGERATION AND AIR CONDITIONING.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to refrigeration and air conditioning with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; compression, absorption, and other systems of refrigeration; control of the physical environment. Mr. MACKEY.

[**3621. *THERMAL SCIENCE I: THERMODYNAMICS.*** Credit 3 hrs. Fall. 1 Lec. 2 Rec. Prereqs., Mathematics 294, Physics 224, Chemistry 276. Concept of temperature. Properties of a pure substance. First law of thermodynamics; quasistatic processes; control volume analysis; steady flow. Second law of thermodynamics; heat engines; heat pumps; Carnot principle; entropy; availability, irreversibility; Gibbs and Helmholtz free energy functions; entropy production and flow; introduction to thermodynamics of irreversible processes and thermoelectricity. Combined first and second laws; Maxwell relations; applications to systems and control volumes. Not offered in 1962–1963.]

[**3622. *THERMAL SCIENCE II: THERMODYNAMICS.*** Credit 3 hrs. Spring. 1 Lec. 2 Rec. Prereq., 3621. Nonreacting gaseous mixtures; Dalton-Gibbs law; Amagat-Leduc law; mixtures including psychrometrics; air-conditioning processes. Nonflow and steady-flow vapor cycles; binary vapor cycles. Heat pump cycles; refrigeration cycles. Air standard nonflow and steady-flow heat engine cycles. Internal combustion engine and gas turbine processes. Thermodynamics of reacting systems; chemical equilibrium; standard state; heats of reaction, formation, and combustion; chemical potential; equilibrium constants; fugacity and activity; combustion processes. Not offered in 1962–1963.]

[**3623. *THERMAL SCIENCE III: FLUID MECHANICS.*** Credit 3 hrs. Spring. 3 Rec. Prereqs., Mechanics 212, 3621. Hydrostatics; kinematics and dynamics of flow including introduction to hydrodynamics; Laplace equation; momentum and energy relations; Euler equations; thermodynamics of flow; wave motion; Mach number; stagnation values. Real flow phenomena; laminar and turbulent motion; pipe flow; universal velocity distribution. Compressible flow with area change; normal shock; nozzle flow. Not offered in 1962–1963.]

[**3624. *THERMAL SCIENCE IV: FLUID MECHANICS.*** Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3623. Continuation of compressible flow, with friction and heating. Hydraulic analogy; flow metering; dimensional analysis. Flow over immersed bodies. Boundary layer: laminar and turbulent; exact and momentum methods of solution. Lift and drag (subsonic and supersonic). Elements of turbomachinery:

Euler turbine equation; reaction; efficiency. Types of turbomachinery and turbomachine characteristics. Propulsion: forces on ducts; propulsive efficiency; elementary characteristics of thermal jets and rockets. Turbomachine components of couplings and torque converters. Not offered in 1962–1963.]

[3625. ***THERMAL SCIENCE V: HEAT TRANSFER.*** Credit 4 hrs. Fall. 1 Lec. 2 Rec. 1 Lab. Prereqs., 3622, 3623. Conduction: steady state; unsteady state with transient and periodic heat flow. Analogue and relaxation methods. Convection: boundary layer fundamentals; natural convection; forced convection inside tubes and ducts; forced convection over various surfaces. Radiation: emission, absorption, reflection, transmission, and exchanges. Radiation combined with conduction and convection. Heat exchangers: over-all heat transfer coefficients; mean temperature difference; effectiveness; design. Not offered in 1962–1963.]

[3626. ***THERMAL SYSTEMS ENGINEERING.*** Credit 5 hrs. Spring. 3 Lec. 1 Lab. Prereqs., 3622, 3624, 3625. Applications of thermodynamics, fluid mechanics, and heat transfer to complete thermal systems rather than to processes. Work-producing, heat-producing, heat-pumping, propulsion, and environmental control systems. Classification, criteria of performance, and economic considerations. Steam power plants, combustion engines, refrigerating systems, air conditioning systems, fuel cells, thermo-electric cooling and power generation. Not offered in 1962–1963.]

3630. ***ENGINEERING THERMODYNAMICS.*** Credit 3 hrs. 3 Rec. Required of students in the Schools of Electrical Engineering and Civil Engineering. Prereqs., Mathematics 163, Physics 122, Chemistry 106. Laws of thermodynamics; energy equations; thermodynamic properties of state of gases and vapors, nonflow and flow processes; gas and vapor cycles; refrigeration; steam turbines. Mr. FAIRCHILD.

[3631. ***ENGINEERING FLUID MECHANICS.*** Credit 3 hrs. 3 Rec. Prereqs., Mechanics 212, 3630. Brief treatment of hydrostatics, kinetics and dynamics of flow; momentum and energy relations. Thermodynamics of flow; wave motion; stagnation properties. Real flow phenomena, laminar and turbulent motion. Pipe flow; compressible flow with area change, normal shock; nozzle flow. Dimensional analysis. Flow metering. Flow over immersed bodies; boundary layer; lift and drag. Elements of turbomachinery; turbomachine characteristics; turbomachine components in couplings and torque converters. Not offered in 1962–1963.]

[3632. ***ENGINEERING HEAT TRANSFER.*** Credit 3 hrs. 3 Rec. Prereqs., 3630, 3631. Steady one-dimensional heat conduction; systems with heat sources; two- and three-dimensional heat conduction; numerical and analogic methods. Unsteady state conduction: periodic heat flow, transient heat flow. Convection: boundary layer fundamentals; dimensional analysis. Natural convection. Forced convection inside tubes and ducts; over exterior surfaces of cylinders and spheres. Heat transfer with change of phase: boiling, condensation. Radiation: fundamentals; heat exchanges. Heat transfer by combined modes. Heat exchangers: over-all coefficients of heat transfer; mean temperature difference; design. Not offered in 1962–1963.]

3642. ***HEAT-POWER.*** Credit 2 hrs. Spring. 2 Lect. Required of students in the School of Civil Engineering. Prereq., 3630. Vapor cycles; heat transfer; the elementary steam power plant; compressors; internal combustion engines; air conditioning. Mr. FAIRCHILD.

3651. ***GRAPHICAL AND NUMERICAL METHODS.*** Credit 3 hrs. Spring. 3 Rec. Intended for undergraduates but open to graduate students. Prereq., 1155. Design of slide rules, network charts, and alignment charts; graphical and numerical methods of solution of problems in thermal engineering; fitting empirical equations to experimental data; analysis of errors. Mr. MACKEY.

3652. ***COMBUSTION THEORY.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 3605. Intended for graduate students and qualified fifth year students. Application of the basic equations of fluid flow and heat and mass transfer to homogeneous and diffusion flames. Ignition, quenching, rate processes, and dissociation effects will be examined. Consideration will be given to flame stabilization and practical systems. Mr. MCMANUS.

3661. ***ADVANCED THERMODYNAMICS.*** Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 3601, 3602, or equivalent. A rigorous and general treatment of the laws of thermodynamics with emphasis on mathematical development and philosophical interpretations; the pure substance; homogeneous and heterogeneous systems; Gibbs and Helmholtz functions; Maxwell relations; availability and irreversibility; equilibrium. Mr. CONTA.

3663. ***ADVANCED TURBOMACHINERY.*** Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereqs., 3602, 3603, 3604, or equivalent. Transfer of energy between a fluid and

a rotor; application of thermodynamics and fluid dynamics to rotating machinery; centrifugal and axial flow pumps, compressors, and turbines. Mr. SHEPHERD.

3664. *ADVANCED FLUID MECHANICS.* Credit 3 hrs. Spring. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3602, 3604. More advanced treatment of some of the topics in 3603 and 3604, with particular reference to two-dimensional ideal flow; laminar and turbulent boundary layer; turbulence and turbulent flow in ducts; compressible flow; method of characteristics. Mr. SHEPHERD.

3665. *ADVANCED HEAT TRANSFER.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3605 or consent of instructor. Basic modes of heat transfer are emphasized. Analytic methods are employed, and results are compared with experimental correlations. Solutions of selected heat conduction problems, a general method of analysis for diffuse radiation, differential similarity, boundary layer convection solutions, heat and momentum similarity theory, phase change processes, and an introduction to numerical methods. Mr. GEBHART.

3666. *ADVANCED AIR CONDITIONING.* Credit 3 hrs. Fall. 3 Rec. Selected studies of air conditioning principles and air conditioning apparatus; solar loads and solar collectors; heat pumps; air conditioning in transportation; thermoelectric refrigeration. Mr. MACKEY.

3667. *TEMPERATURE MEASURING INSTRUMENTS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3605. Theory, construction, calibration, and application of liquid-in-glass thermometers, solid expansion thermometers, pressure-spring thermometers, resistance thermometers, thermoelectric thermometers, optical pyrometers, radiation pyrometers. Mr. DROPKIN.

[**3670. *ADVANCED COMBUSTION ENGINES.*** Credit 3 hrs. Spring. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereqs., 3604, 3607 or equivalent. Advanced study of topics in field of reciprocating engines, both spark-ignition and diesel. Methods of thermodynamic analysis and performance prediction for free-piston power plants and supercharged engines. Relation of engine performance characteristics and performance characteristics of automotive vehicles. Recommended together with Course 3377 for study in automotive engineering. Not offered in 1962–1963.]

3671. *AEROSPACE PROPULSION SYSTEMS.* Credit 3 hrs. Spring. 3 Rec. Prereqs., 3603, 3604, 3607 or equivalent. Intended for graduate students but open to qualified fifth year students. Application of thermodynamics and fluid mechanics to the analysis and design of thermal-jet and rocket engines. Consideration of advanced methods of propulsion. Mr. SHEPHERD.

3672. *ENERGY CONVERSION.* Credit 3 hrs. Spring. 3 Lect. Intended for graduate students but open to qualified fifth year students. Prereqs., 3601, 3602, 3603, 3604, or equivalent. Primarily a classification and thermodynamic analysis of energy conversion devices, but energy sources and the storage of energy are also considered. A study of conventional heat engines and combustion engines; thermo-electric, thermionic, photovoltaic, and magneto-hydrodynamic generators; and fuel cells. Materials, design, and application to conventional and space power requirements are also considered. Mr. CONTA.

3673. *ADVANCED THERMAL ENGINEERING MEASUREMENTS.* Credit 3 hrs. Fall. 2 Lectures. 1 Lab. Intended for graduate students but open to qualified fifth year students. Theory and operation of instruments used in fluid flow investigations; hot wire anemometers; density-sensitive optical systems; transient temperature and pressure measurements; measurements in reacting systems; error analysis and treatment of data. Mr. MCMANUS.

3674. *MICROSCOPIC THERMODYNAMICS.* Credit 3 hrs. Fall. 3 Rec. Prereq., consent of instructor. Intended for graduate and qualified fifth year students. Fundamental equations of kinetic theory, Maxwell-Boltzmann statistics and quantum statistics are derived and used to interpret the phenomenological transport and thermodynamic properties of ideal, inert, and reacting gaseous systems. Consideration given to real gases. Mr. PIERCE.

3680. *ADVANCED CONVECTION HEAT TRANSFER.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3605 or consent of instructor. Processes of transfer of heat, momentum, and mass in fluids considered in detail. Theories of transfer processes and analytic solutions. Analytical and experimental results compared. Transfer differential equations for a fluid, delineation of kinds of processes and differential similarity, natural convection, forced convection at low and high velocities, some techniques of boundary layer solution, similarity theories, effects of turbulence, and experimental results for cases not readily solved by analytical methods. Mr. GEBHART.

3681. *ADVANCED CONDUCTION AND RADIATION HEAT TRANSFER.* Credit 3

hrs. Spring. 3 Rec. Prereq., 3605 or consent of instructor. Theories of conduction mechanisms are reviewed. The conduction of heat in solids for various cases of steady, unsteady, and periodic heat flow with and without internal sources. Mathematical, numerical, and analogue methods of problem solution are presented. The various types of thermal radiation processes in solids and gases. Spatial and specular distributions. Methods of calculation for radiation in the absence and in the presence of absorbing and emitting gases. Mr. GEBHART.

3682. ***SEMINAR IN HEAT TRANSFER.*** Credit 3 hrs. Spring. Two meetings of 2 hours per week to be arranged. Prereq., permission of professor in charge. Discussion of fields of active inquiry and current interest in heat transfer. Considerations of major recent work and several summaries of associated contributions. Mr. GEBHART.

3690. ***SPECIAL INVESTIGATIONS IN THERMAL ENGINEERING.*** Spring. Credit to depend upon hours of actual work. Informal instruction will be given to a limited number of students interested in work to supplement that given in courses in combustion engines, power generation, fluid dynamics, heat transfer, refrigeration, air conditioning, and instruments. Permission of the Department necessary for registration. Mr. MACKEY.

3691. ***THERMAL ENGINEERING SEMINAR.*** No credit. A one-and-a-half-hour meeting approximately every other week. Attendance expected of all graduate students with major subject in the Department of Thermal Engineering. Talks by graduate students, staff members, and invited guests.

3698, 3699. ***PROJECT.*** Total credit 6 hrs. Work of the ninth and tenth terms to integrate the training in mechanical engineering, principally in the fields of thermodynamics, fluid dynamics, heat transfer, combustion engines, energy conversion, power plants, refrigeration, and air conditioning. The staff.

ELECTRICAL ENGINEERING

REQUIRED COURSES

4021. ***TECHNICAL WRITING AND PRESENTATION.*** Credit 3 hrs. Fall. 3 Lect.-Rec. The development of the basic principles of exposition, the knowledge of suitable form, and the appreciation of function that will enable students to write and present reports and communications that meet professional standards.

4041. ***NONRESIDENT LECTURES.*** Credit 1 hr. Fall. 1 Lect. Given by lecturers invited from industry and from certain other departments of the University to assist students in their approach to employment and in their transition from college to industrial life.

4112. ***INTRODUCTION TO LINEAR NETWORK ANALYSIS.*** Credit 3 hrs. Fall 2 Lect. 1 Comp. Prereqs., 4102, 4103. A study of the interconnection of linear elements; elementary network topology and its relationship to the formulation of network equilibrium equations; impedance and admittance concepts; duality; properties of network functions in the complex-frequency plane; natural and forced network behavior; mutual inductance; introduction to Fourier series, with applications to network analysis problems; power and energy relations; detailed analysis of two-port networks, with emphasis on the relationships between driving-point and transfer functions defined on a port basis and those defined on a branch basis; other representations of two-port networks. Mr. KLECKNER and staff.

4113. ***TRANSMISSION LINES AND WAVES.*** Credit 3 hrs. Fall. 2 Lect. 1 Comp. Prereq., 4112. Strip transmission line, one-dimensional electromagnetic waves; mechanical waves; transients, reflections; sinusoidal wave functions, impedance; four-terminal networks, resonators, filters; three-dimensional waves, oblique reflection; rectangular waveguide. Mr. COHEN and staff.

4114. ***MATHEMATICAL ANALYSIS OF LINEAR SYSTEMS II.*** Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 4103. The concept of a transfer function. Synthesis of time-varying vectors by addition of rotating vectors. Contour integration in the complex plane. The Fourier transform. The single and double-ended Laplace transforms. Applications to transient behavior of linear systems.

4116. ***INTRODUCTORY ELECTRICAL LABORATORY.*** Credit 3 hrs. Fall. 1 Lect. 1 Lab. Prereq., 4102. Laboratory experiments on a variety of circuits, circuit elements, and instruments. Some of the subjects considered are the cathode-ray oscilloscope, diodes, rectifiers, transients, audio-transformer, resonance, and the analog computer.

4121. ***INTRODUCTION TO ELECTRONIC ENGINEERING.*** Credit 4 hrs. Spring. 2 Lect. 1 Rec. 1 Lab. Prereqs., 4116 and 4112. Basic study of the conventional electron devices and their immediate electrical circuit environments. Electron flow in vacuum, semiconductor, and ionized gases. The small and large signal characteristics of electron devices. The use of these device characteristics in generating and processing electrical signals. Mr. EASTMAN and staff.

4122. ***ELEMENTS OF SYSTEM THEORY.*** Credit 4 hrs. Fall. 2 Lect. 1 Rec. 1 Lab. Prereqs., 4121 and 4114 or their equivalent. Elementary signals for system analysis; model making of system devices (tubes, transistors, transducers, sensors) with lumped parameters; matrix analysis of interconnected linear models; flow-graphs and analysis by analog simulation; stability; physical realizability and realization techniques; feedback control; system parameter-sensitivity; design methods for compensation; approximations in the frequency and time domains; signal generation; system optimization for deterministic signals. Mr. DECLARIS and staff.

4123. ***ELECTRONICS OF SIGNAL TRANSMISSION.*** Credit 4 hrs. Spring. 2 Lect. 1 Rec. 1 Lab. Prereq., 4122. Information content of messages and the role of band-width and noise in signal transmission; sampling theory; auto-correlation and cross-correlation techniques in signal analysis and detection; modulation theory and techniques; probability theory applied to signals; noise calculations in networks and amplifiers; laboratory work on measurements, wave shaping, modulation circuits, feedback, and oscillation.

4165. ***INTRODUCTION TO ELECTROMAGNETIC THEORY.*** Credit 4 hrs. Spring. 3 Lect. 1 Comp. Prereqs., 2331 and 4113. The foundations of electromagnetic theory and its applications to electrical engineering; vector analysis, including vector calculus; electric, magnetic, and electromagnetic fields, Maxwell's equations; applications include circuits, generators, simple magnetohydrodynamic devices, wave guides, elementary antennas, simple traveling-wave tubes. Mr. BOLGIANO.

4216. ***ELECTRIC AND MAGNETIC CIRCUITS LABORATORY.*** Credit 4 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4116. Experiments on a-c bridges, single-phase and three-phase a-c circuits, d-c and a-c magnetization, and d-c-machinery.

4221. ***ALTERNATING CURRENT MACHINERY.*** Credit 4 hrs. Fall. 1 Conf. 1 Comp. Prereqs., 4112, 4216. Theory, construction, and operating characteristics of transformers, induction motors, synchronous machines, and single-phase motors.

4226. ***ELECTRICAL MACHINERY LABORATORY.*** Credit 4 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4221. Magnetization and circuits with nonsinusoidal voltages. Harmonics in polyphase systems; instrument, constant current, and constant potential transformers; single-phase and polyphase induction motors; synchronous machines.

ELECTIVE AND GRADUATE COURSES

GENERAL

4090. ***SPECIAL TOPICS IN ELECTRICAL ENGINEERING.*** Credit 1 to 3 hrs. Seminar, reading course, or other special arrangement agreed upon between the students and faculty members concerned.

4091 and 4092. ***PROJECT.*** Credit 3 hrs. Fall and spring. Individual study, analysis, and usually experimental tests in connection with a special engineering problem chosen by the student after consultation with the faculty member directing his project; an engineering report on the project is required.

POWER SYSTEMS AND MACHINERY

4321. ***ELECTRICAL MACHINE THEORY.*** Credit 3 hrs. Fall. (Offered only if demand is sufficient.) 1 Conf. 1 Comp. Prereq., 4226. Space harmonics; parasitic torques; two-reaction analysis; transient impedances; symmetrical component impedances; single-phase motor analysis; commutator-type a-c machines.

4326. ***ELECTRICAL MACHINERY LABORATORY.*** Credit 3 hrs. Spring. (Offered only if demand is sufficient.) 1 Lect. 1 Lab. Prereq., 4321. Salient-pole synchronous machines; induction motor loss separation; energy metering; special topics.

4351. ***UNIFIED THEORY OF ELECTROMECHANICAL SYSTEMS.*** Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereqs., 4114, 4221 or equivalent. Electric machines studied as networks of coupled circuits with periodically varying parameters; matrix analysis of networks; forces and torques in electromechanical systems; electromagnetic and electrostatic transducers; single-phase a-c generators; Kron's basic machine with its practical derivatives; the synchronous, induction, and commutator machines, in the transient and steady state; frequency-response methods applied to ma-

chines; laboratory exercises using the generalized machine. Mr. SUDAN.

4352. *ELEMENTS OF POWER-SYSTEM ANALYSIS.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereqs., 4113, 4226 or equivalent. Studies of power systems through the application of equivalent circuits of synchronous machines, transmission lines, transformers and static loads; power-system network theory; power angle equations and circle diagrams; the two-machine system; load flow and voltage regulation of complex systems; symmetrical components; fault analysis of complex systems; introduction to system stability; use of a-c and d-c network analyzers as computing aids. Mr. LINKE.

4353. *TRANSIENT ANALYSIS OF POWER SYSTEMS.* Credit 3 hrs. Spring. 2 Lect.-Rec. 1 Lab.-Comp. Prereqs., 4351, 4352 or equivalent. Study of synchronizing and damping torques for salient-pole and solid-rotor machines; application of constant-flux-linkage theorem to balanced and unbalanced faults; basic assumptions for transient stability studies; voltage regulators and governors; control of system frequency; application of a-c network analyzers and digital computers to transient problems; theory of the electric arc; a-c arc interrupting media; simulated testing of circuit breakers. Mr. SUDAN.

4371. *HIGH-VOLTAGE PHENOMENA.* Credit 3 hrs. Spring. The study of problems of the normal operation of power systems at very high voltages, of the abnormal conditions imposed by lightning, of the methods employed to assure proper operation of power systems and apparatus under high-voltage conditions, and of the devices available for laboratory testing of equipment under actual or simulated conditions. Mr. ZIMMERMAN.

RADIO AND COMMUNICATION

4501. *RADIO AND COMMUNICATION SEMINAR.* Credit 1 to 3 hrs. Fall and spring. Primarily for graduate students. Reading and discussion of technical papers and publications in the field of radio and communication.

4511. *PHYSICAL BASIS OF ELECTRONIC ENGINEERING.* Credit 3 hrs. Fall. 3 Lect. Prereqs., 4113, 4121, Physics 314. The control and use of electrons in modern electronic engineering. The underlying physical phenomena of electronic devices treated in depth, including power exchanges, noise generation, nonlinearity and frequency band-width limitations, conventional, microwave, and quantum electronic principles. Mr. EASTMAN.

4512. *RADIO ENGINEERING.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereqs., 4113, 4123. A study of communication circuits with distributed constants and the production and propagation of electromagnetic radiation; transmission line theory and applications; impedance matching; ultra-high-frequency generation and transmission; electromagnetic theory; propagation phenomena; antenna characteristics and radiation. Mr. MCLEAN.

4516, 4517. *RADIO AND COMMUNICATION LABORATORY.* Credit 3 hrs. each. Fall and spring respectively. Either or both may be taken. (Offered only if demand is sufficient.) 1 Rec. 1 Lab. Prereqs., 4113 and 4123. Choice of three to five different experiments from the field of electronic circuits, networks, transmission lines; wave guides, and antennas. Experiments selected to meet individual needs.

4541. *APPLIED ACOUSTICS.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab. Lab. assignments to meet individual needs. Prereq., 4123. The laws of ideal gases, the thermodynamic properties of air, and the laws of the progagation of compressional waves; the transmission of sound through tubes, horns, and unbounded media; the design of sound sources, microphones, loudspeakers, and wax, lacquer, magnetic, and photographic recorders; reflection, absorption, and reverberation. Mr. INGALLS.

4551. *RADIO AIDS TO NAVIGATION.* Credit 2 hrs. Spring. 2 Lect.-Rec. Prereq., 4123. Long-wave and medium-wave direction finders and radio beacons; atmospheric effects and limitations on accuracy; medium-frequency pulsed transit-time systems and high-frequency return-signal systems, with application to long-range navigation and precision mapping; airport approach systems and traffic control. Mr. MCLEAN.

ELECTRONICS AND MICROWAVES

4521. *MICROWAVE LABORATORY.* Either term. Credit 1–3 hrs. At least 2 lab. for 3 hrs. credit. Prereq., either 4527 or 4561 must precede or be taken concurrently. A wide variety of experiments is available in the area of measurement of active and passive microwave devices, including klystrons, traveling wave tubes, magnetrons, cavities, microwave components, and periodic structures. The experiments are designed to encourage the exploration of the device characteristics while simultaneously developing measurement techniques which range in character from standard techniques to those of considerable sophistication. In addition to performing several of the available experiments the student will

design and execute some laboratory project of interest to him. Stress is laid on independent work by the student.

4526. *ELECTRON DYNAMICS.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereqs., Physics 314, and 4122. Fundamental theory of low-frequency electron devices; emission; conformal mapping; particle dynamics; electrostatic and magnetic lenses; space charge phenomena; limitations at high frequencies; noise; thermoelectric conversion; motion of electrons and holes in metals and semiconductors; junction diodes and transistors. Mr. MacKenzie.

4527. *MICROWAVE ELECTRONICS I.* Credit 3 hrs. Spring. 3 Lect. Coreqs., 4526 and 4565 or consent of the instructor. Study of the theory of the interaction of electron streams and electromagnetic waves in localized and distributed regions; the electron-ballistic and the space-charge-wave approaches; application to planar vacuum tubes and microwave tubes. It is suggested that 4521 be taken concurrently. Mr. MacKenzie.

4528. *MICROWAVE ELECTRONICS II.* Credit 3 hrs. Fall. 3 Lect. Prereqs., 4527 and 4561. Detailed theory of the fields of periodic and slow wave structures; advanced theory of the interaction of electron streams with the fields of microwave structures including both linear and nonlinear interactions; microwave noise in electron streams. Mr. Eastman.

4529. *SEMICONDUCTOR ELECTRONICS I.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereqs., Physics 314, and 4123. Motion of electrons and holes in semiconductors; theory of P-N junctions, metal-semiconductor contacts, and junction triodes; preparation of materials and fabrication of devices; characteristics of diodes and rectifiers, tunnel diodes, solar batteries, transistors, four-layer devices (diodes, controlled rectifiers, and switches), etc.; transistor equivalent circuits; bias-stabilized transistor amplifiers. Mr. Ankrum.

4530. *SEMICONDUCTOR ELECTRONICS II.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4529. A continuation of Semiconductor Electronics I with emphasis on the application of semiconductor devices as active or passive elements in circuits for use as power supplies, power converters, amplifiers, oscillators and multivibrators, pulse circuits, gates and switches, modulators, and other circuits. Mr. Ankrum.

4531. *QUANTUM ELECTRONICS.* Credit 3 hrs. Fall. 3 Lect. Prereqs., Physics 325–326 or 4565 and Physics 314 or 443. A detailed treatment of the physical principles underlying masers and lasers and an analysis of the operation and design of practical devices. Topics will include the interaction of radiation and matter; the coherence properties of spontaneous and stimulated emission of radiation; thermal equilibrium and non-equilibrium in paramagnetic solids; properties of paramagnetic ions in crystals; the gas and solid state masers and lasers; gain-bandwidth product and noise figure of maser amplifiers. Mr. Wolga.

4561. *MICROWAVE THEORY AND TECHNIQUES.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4565 or equivalent. Normal modes in wave guides and cavities; power, energy, perturbation, and transformation relations in confined microwave fields in isotopic media; theory of microwave circuits; introduction to fields and waves in plasmas and ferrites. It is suggested that 4521 be taken concurrently. Mr. Witt.

ELECTROMAGNETIC WAVES AND PROPAGATION

4565. *ELECTROMAGNETIC THEORY.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4113. The foundations of electromagnetic theory required for study of radio wave propagation; reflection and refraction of plane waves; guided waves; simple obstacles in wave guides; angular spectra of plane waves; edge diffraction theory.

4566. *INTRODUCTION TO PLASMA PHYSICS.* Credit 3 hrs. Fall. 3 Lect. Prereqs., 2331 and 4565, or equivalent. Charged particle dynamics; continuum plasma theory; conduction of electricity in gases; magnetohydrodynamics with applications; transverse and longitudinal waves; magneto-ionic theory with applications. Mr. Cohen.

4567. *RADIO WAVE PROPAGATION.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. Influence of the trophosphere on radio wave propagation; dielectric properties of air and distributions of refractive index; propagation in standard and nonstandard atmospheres; diffraction around a spherical earth; inhomogeneities of refractive index; scattering.

4568. *ANTENNAS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. Theory of radiation and reception; directional characteristics; impedance; elementary theory of cylindrical antennas; Huygens' principle; aperture antennas; antenna thermodynamics.

4581. *MAGNETOHYDRODYNAMICAL PROCESSES IN THE SOLAR SYSTEM.* Credit 2 hrs. Fall. 2 Lect. Prereq., 4565 or Physics 325–26. Theories of solar phenomena—

solar flares, prominences, coronal features; the interplanetary plasma—density, velocity, ionization, magnetic fields; cosmic ray effects associated with solar events—production and modulation; theories of magnetic disturbances, magnetic storms, aurorae, Van Allen radiation, and associated ionospheric effects. Mr. GOLD.

SYSTEM THEORY

4115. ***PRINCIPLES OF NONLINEAR SYSTEMS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 4114 or equivalent. First- and second-order nonlinear systems: phase-plane analysis, Poincare-Bendixson Theory, stability, self- and forced-oscillations, theory of van der Pol. Higher order nonlinear problems of automatic control: describing functions, Aizerman's hypothesis, Liapounov's first and second method, theory of Lurie-Letov. Higher order nonlinear problems of communication; parametric excitation and amplification, Mathieu equation, Manley-Rowe relations, nonlinear filters. Determination of optimum nonlinear systems. Mr. DECLARIS.

4563. ***SIGNALS AND NOISE IN COMMUNICATION SYSTEMS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 4123. Analysis of signals in the time and frequency domains; properties of generalized linear systems; the time and frequency response of idealized systems; sampling theory for band-limited signals; probability and noise statistics with applications to signal transmission and signal detection; power spectrum analysis applied to special nonlinear problems of detection; the fundamentals of noise suppression in broad-band systems with particular emphasis on time multiplex communication and data transmission systems. Mr. WAGNER.

4564. ***TRANSMISSION OF INFORMATION.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 4563. Mathematical description of the transmission of information based on statistical models; quantitative measure of information in discrete noise-free systems; discrete transmission in the presence of noise; maximum rate of transmission in a noisy channel; information gain in continuous transmission systems; information capacity of the noisy continuous channel; optimum receivers for the extraction of information from a noisy transmission; applications of information theory to the analysis of transmission rate in practical systems.

4571. ***MODERN NETWORK ANALYSIS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 4122 or equivalent. Network topology and its relation to the analysis of complex systems; energy functions; network functions; general realizability criteria; interrelationship of network functions; Hilbert transforms; flow graphs; generalized coordinates; scattering parameters. Mr. MITRA.

4572. ***MODERN NETWORK SYNTHESIS.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 4571. Real-part sufficiency and related topics; the realization problem of driving-point and transfer functions. Darlington's theory; the Miyata method; Guillemin's zero-shifting technique; iterative and other "classical" procedures; the approximation problem—least square and Tschebyscheff sense—in the frequency domain; time-domain synthesis; correlation between frequency and time domains. Mr. DECLARIS.

4575. ***ADVANCED TOPICS OF SYSTEM THEORY.*** Credit 1 to 3 hrs. Fall and spring. Enrollment by consent of the instructor. Seminar on selected topics which will vary from year to year. Presentation and discussion of current research and recent literature in one or more specific areas such as active networks, signal theory, variable networks, and self-optimizing systems.

ILLUMINATION

4611. ***INTRODUCTORY ILLUMINATION.*** Credit 3 hrs. Fall. 2 Rec. 1 Lab.-Comp. Prereq., Physics 224. Problems commonly encountered in illumination engineering and the methods of solution; sources of light; visual perception; light control, both spectral and directional; measurement of light sources and illumination; general illumination design; production and mixing of colors; architectural objectives.

4612. ***ILLUMINATING ENGINEERING.*** Credit 3 hrs. Spring. (Offered only if demand is sufficient.) 2 Rec. 1 Lab.-Comp. Prereq., 4611. Computation of light-flux distribution and study of difficult lighting problems; emphasis on specialized rather than general lighting problems.

4615. ***ILLUMINATION SEMINAR.*** Credit 2 hrs. Fall. (Offered only if demand is sufficient.) One 2-hour period each week. Must be accompanied or preceded by 4611. Reports on selected topics of current interest in illuminating engineering.

CONTROL SYSTEMS AND COMPUTERS

4711. ***FEEDBACK CONTROL SYSTEMS I.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereqs., 4122, 4216, 4221. Principles of feedback control systems emphasizing analysis of performance from equations and transfer-function

plots; Laplace transformations; error detecting devices; hydraulic devices; factors affecting errors, damping, and speed of response; criteria for stability. Mr. MESERVE and staff.

4712. ***FEEDBACK CONTROL SYSTEMS II.*** Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4711. Synthesis of feedback control systems; prediction of performance from stability criteria and comparison with laboratory performance; relay control systems; consideration of nonlinearity. Mr. MESERVE and staff.

4713. ***FEEDBACK CONTROL SYSTEMS SEMINAR.*** Credit 2 or 3 hrs. One 2-hour period and 1 optional Lab.-Comp. Prereq., 4712. Reports on selected topics in servomechanisms; signal flow diagrams; nonlinear effects on analysis and performance; sampled data systems; statistical considerations; analog computer studies of limiting, backlash, dead zone, and sampled data systems. Mr. TORNG.

4810. ***ANALOG COMPUTATION.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 4121 or 4933. Concepts and principles of analog computation; scaling and programing linear, nonlinear, and time-varying systems of equations; partial differential equations; adjoint computer systems; matrix programing. Laboratory work involves solution of problems on a general-purpose computer and by permission can be devoted in part to special projects to suit the student. Mr. VRANA.

4820. ***SWITCHING SYSTEMS I.*** Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4123 or consent of instructor. Switching algebra; switching devices; logical formulation and realization of combinational switching circuits; minimization aids; number representation and codes; simple memory devices; synchronous sequential circuits; counters; shift registers and arithmetic units in a digital computer. Mr. TORNG.

4821. ***SWITCHING SYSTEMS II.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 4820 or equivalent. Synchronous and asynchronous sequential circuits, formulation and optimization; large-scale memory units, selection and control; further discussion of arithmetic units; integrated study of switching systems including general-purpose digital computer, control switching, and communication switching; introduction to the general theory of learning machines. Mr. TORNG.

COURSES FOR OTHER ENGINEERING CURRICULA

4931. ***ELECTRICAL ENGINEERING.*** Credit 3 hrs. Fall and spring. 2 Lect. 1 Comp. Prereqs., Math. 163, 1132 or 1152. An elementary study of direct-current electric circuits; the concepts of resistance, inductance, and capacitance; magnetic circuits; single-phase and three-phase alternating-current circuits; instruments and techniques appropriate for making measurements in all such circuits.

4932. ***ELECTRICAL ENGINEERING.*** Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4931. D-c generators and motors; motor starters and controllers; transformers; induction motors; synchronous machines; a-c single-phase motors; d-c and a-c selsyn units. Mr. ZIMMERMAN and staff.

4933. ***ELECTRICAL ENGINEERING.*** Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4932. The characteristics and applications of the various commonly used electron tubes; rectifiers; amplifiers; oscillators; electronic control and instrumentation. Mr. MCLEAN and staff.

4991. ***ELECTRONIC CIRCUITS.*** Credit 3 hrs. Fall. (Offered only if demand is sufficient.) 3 Lect. For graduate students majoring in an engineering field other than electrical. Alternating-current circuits; characteristics of high-vacuum tubes and transistors, small-signal and large-signal amplifiers; feedback and oscillators; modulation and demodulation; simple wave-shaping circuits.

CHEMICAL ENGINEERING

5101. ***MASS AND ENERGY BALANCES.*** Credit 3 hrs. Fall. 2 Lect., 1 Comp. Parallel, Physical Chemistry 405. Engineering problems involving material and heat balances. Flow-sheet systems and balances. Total energy balances for flow systems. Messrs. WINDING, THORPE.

5102. ***EQUILIBRIA AND STAGED OPERATIONS.*** Credit 3 hrs. Spring. 2 Lect., 1 Comp. Parallel, Physical Chemistry 406. Phase equilibria and phase diagrams. The equilibrium stage; mathematical description of single and multistage operations; analytical and graphical solutions. Messrs. WINDING, THORPE.

5103, 5104. ***CHEMICAL ENGINEERING THERMODYNAMICS.*** Credit 3 hrs. Fall and spring. 3 Lect. Prereqs., Chemistry 403, 404. A study of the first and second laws with application to batch and flow processes. Physical and thermodynamic properties. Availability;

free energy; chemical equilibrium. Application to gas compression; process steam; power generation; adiabatic reactors; and chemical process development. Mr. Von Berg.

5105. *ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 5104 or equivalent. Primarily for graduate students. Application of the general thermodynamic method to advanced problems in chemical engineering. Evaluation, estimation, and correlation of properties. Chemical and phase equilibria. Mr. Von Berg.

5106. *REACTION KINETICS AND REACTOR DESIGN.* Credit 2 hrs. Fall. 2 Lect. Prereq., 5104. A study of chemical reaction kinetics and principles of reactor design for chemical processes. Mr. Von Berg.

5107. *ADVANCED REACTION KINETICS.* Credit 3 hrs. Spring. 3 Lect. Primarily for graduate students. Theory and applications of chemical reaction kinetics. Mr. Harriott.

5108. *COLLOIDAL AND SURFACE PHENOMENA.* Credit 3 hrs. Fall. Prereq., physical chemistry. Lectures, demonstrations, and problems in the physics and chemistry of small particles and surface films. Topics include sorption, flocculation, colligative properties, electrokinetics, and structural rheology. Applications to detergency, gels, catalysis, behavior of natural products, etc. Mr. Finn.

5203, 5204. *CHEMICAL PROCESSES.* Credit 2 hrs. 2 class periods. An analysis of important chemical processes and industries. Fall term, organic chemical processes; spring term, inorganic chemical processes. Mr. Wiegandt.

5205. *CHEMICAL PROCESS SEMINAR.* Credit 2 hrs. Fall. For graduate students. A discussion of recent advances in chemical processes. Messrs. Hedrick and Wiegandt.

5255, 5256. *MATERIALS OF CONSTRUCTION.* Credit 3 hrs. each term. 3 Lect. Prereqs., or parallel courses. Phys. Chem. 403, 404. An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions. Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed. Messrs. Mason and Rodriguez.

5303. *INTRODUCTION TO RATE PROCESSES.* Credit 3 hrs. Fall. 2 Lect. 1 Rec. Prereqs., 5101 and 5102. An introduction to transport phenomena involving fluid mechanics, heat, and mass transfer. Mr. J. C. Smith.

5304. *ANALYSIS OF UNIT OPERATIONS.* Credit 3 hrs. Spring. 2 Lect. 1 Rec. Prereq., 5303. Analysis of chemical engineering systems involving several components and coupled techniques. Extension of previous studies to transient and feedback aspects of the unit operations. Mr. J. C. Smith.

5353. *UNIT OPERATIONS LABORATORY.* Credit 3 hrs. Fall. Lect., Rec., and Lab. Prereq., 5304. Typical laboratory experiments involving unit operations equipment. Messrs. Harriott and Finn.

5354. *PROJECT LABORATORY.* Credit 3 hrs. Spring. Special laboratory projects involving unit operations equipment. Messrs. Harriott and Finn.

5503, 5504. *CHEMICAL ENGINEERING COMPUTATIONS.* Credit 2 hrs. Fall and spring. Two class periods. Prereqs., or parallels, 5303 and 5304 or equivalent. Lectures and advanced problems in fluid flow and heat transfer; heterogeneous equilibrium; distillation; gas absorption; and extraction. A selected number of the less conventional operations are also considered. Mr. Scheele.

5505. *ADVANCED HEAT TRANSFER.* Credit 3 hrs. Fall. 3 Lect. Prereq., 5303–4 or equivalent. Advanced topics in heat transfer. Heat transfer under unsteady-state conditions; numerical approximation methods; analogies among heat, mass, and momentum transfer; heat transfer to liquid metals; simultaneous heat and mass transfer, etc. Primarily for graduate students. Mr. J. C. Smith.

5506. *DIFFUSIONAL OPERATIONS.* Credit 3 hrs. Spring. 3 Lect. Primarily for graduate students. Advanced topics in diffusional operations. Molecular and turbulent diffusion in binary and multicomponent systems; film, boundary layer, and penetration-theory models of mass transfer; applications to distillation, gas absorption, liquid-liquid extraction, and other industrial operations. Mr. Scheele.

5507. *ADVANCED FLUID DYNAMICS.* Credit 3 hrs. Fall. 3 Lect. Primarily for graduate students. Advanced topics in fluid dynamics. Viscous laminar flow of Newtonian and non-Newtonian fluids; flow stability; turbulent flow; perfect fluid theory; boundary layer theory; analogies among heat, mass, and momentum transfer. Mr. Scheele.

[**5508, 5509. *APPLIED MATHEMATICS IN CHEMICAL ENGINEERING.*** Credit 3 hrs. Fall and spring. 3 Lect. Prereq., 5304. Treatment and interpretation of data. Ordinary differential equations. Series and numerical

solutions. Partial differential equations. Fourier series; Bessel functions; Laplace transforms. Calculus of finite differences. Numerical solutions to partial differential equations. Applications to heat transfer, mass transfer, distillation, gas absorption, reaction kinetics, and catalysis. Mr. York. Not offered in 1962–1963.]

5605, 5606, 5607, 5608. *DESIGN PROJECT.* Credit 2 hrs. Fall and spring. Individual problems in the design of chemical processes and plants. Estimation of costs of construction and operation, variation of costs and profits with production, etc. Staff.

[**5609. *OPERATIONS DESIGN METHODS.*** Credit 2 hrs. Spring. 2 Lect. Description and discussion of chemical process equipment for physical operations, such as mixing diffusional separations, mechanical separations, heat transfer, size reduction, etc. Emphasis is placed on evaluation of alternative methods of achieving a desired objective and on selection and arrangement of equipment for most economical operation. Mr. J. C. Smith. Not offered in 1962–1963.]

5621. *PROCESS AND PLANT DESIGN.* Credit 5 hrs. Fall. Prereqs., 5304, 5104. Techniques and case studies in chemical process design including reactors and separating systems; optimization of piping and equipment; economic balance within process. Cost estimating for process units and plants. Commodity survey and chemical market research. Oral and written presentation. Mr. York.

5622. *PROCESS AND PLANT DESIGN.* Credit 5 hrs. Spring. Continuation of 5621. Plant location, process selection, process design, equipment design and specifications; plant layout. Cost estimates and profitability for a chemical, petroleum, or petrochemical product. Pilot plant operations, research economics, product development, technical service, and related commercial aspects. Oral and written presentation. Mr. York.

5741. *PETROLEUM REFINING.* Credit 3 hrs. Spring. 3 Lect. Prereq., 5304. A critical analysis of the processes employed in petroleum refining. Mr. Wiegandt.

5742. *POLYMERIC MATERIALS.* Credit 3 hrs. Fall. 3 Lect. Polymerization reactions, manufacture and properties of synthetic resins, fibers, plastics, and rubbers. Mr. Rodriguez.

5743. *PROPERTIES OF POLYMERIC MATERIALS.* Credit 3 hrs. Spring. Prereq., 5742. Mechanical, electrical, and optical properties of polymers. Phenomenological aspects and molecular theories of non-Newtonian flow, visco-elasticity and ultimate tensile properties. Mr. Rodriguez.

5745. *ANALYSIS OF POLYMERIC PROCESSES.* Credit 3 hrs. Fall. 3 Lect. Prereq., 5742. Technical and economic evaluations of the principal processes used in manufacture of resins, plastics, and elastomers, including analyses of raw materials, reactor systems, product preparation, and problems in distribution and marketing. Special emphasis on new processes and means of reducing capital and operating costs. Mr. Hedrick.

5746. *CASE STUDIES IN THE COMMERCIAL DEVELOPMENT OF CHEMICAL PRODUCTS.* Credit 3 hrs. Spring. 3 Lect. Prereq. or parallel, 5622. For graduate and selected fifth year students. Detailed analysis of specific cases involving the development of new chemical products. Particular emphasis is given to planning activities, research justification, and market forecasting. Profitability calculations and projections are required. Mr. Hedrick.

5747. *PROCESS CONTROL.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 5304. Frequency response and transient response of process equipment. Brief description of control instruments. Design of processes and selection of controllers for desired dynamic behavior. Mr. Harriott.

5748. *FERMENTATION ENGINEERING.* Credit 2 hrs. Spring. 2 Lect. Prereqs., or parallel courses. Chemistry 404 or 408, and any course in microbiology. An advanced discussion of fermentation as a unit process. Topics include sterilization, aeration, agitation, and continuous fermentation. Mr. Finn.

[**5749. *INDUSTRIAL MICROORGANISMS.*** Credit 1 hr. Fall. 1 Lect. Prereqs., organic chemistry and physical chemistry. A brief introductory course in microbiology for students with a good background in chemistry. Mr. Finn. Not offered in 1962–1963.]

5752. *POLYMERIC MATERIALS LABORATORY.* Credit 2 hrs. Spring. 1 Lab. Prereq., 5742. Experiments in the formation, characterization, fabrication, and testing of polymers. Mr. Rodriguez.

[**5760. *NUCLEAR AND REACTOR ENGINEERING.*** Credit 2 hrs. Spring. 2 Lect. Fuel processing and isotope separation, radioactive waste disposal, fuel cycles, radiation damage, biological effects and hazards, shielding, power reactors. Mr. Von Berg. Not offered in 1962–1963.]

5851. *CHEMICAL MICROSCOPY.* Credit 3 hrs. Either term. 1 Lect. 2 Lab. Prereqs., or

parallel courses, Chemistry 403, 404 or 407, 408 and Physics 123, 124 or special permission. Microscopical examination of chemical and technical materials, processes, and products. Measurements, particle size determination, analyses of mixtures, crystallization, phase changes and colloidal phenomena, lens systems and photomicrography. Mr. MASON.

5853. ***MICROSCOPICAL QUALITATIVE ANALYSIS (INORGANIC).*** Credit 2 hrs. or more. Offered on demand either term. Prereq., 5851. Laboratory periods to be arranged. Laboratory practice in the analysis of inorganic substances containing the more common elements. Mr. MASON.

5859. ***ADVANCED CHEMICAL MICROSCOPY.*** Credit 1 hr. or more. Offered on demand either term. Prereq., 5851 and special permission. Laboratory practice in special methods and special applications of chemical microscopy. Mr. MASON.

5900. ***SEMINAR.*** Credit 1 hr. Fall and spring. General chemical engineering seminar required of all graduate students majoring in the field of chemical engineering. Mr. RODRIGUEZ.

5909. ***RESEARCH SEMINAR.*** Credit 1 hr. Spring. 1 Lect. Required of all students enrolled in the predoctoral honors program. An introduction to the research methods and techniques of chemical engineering. Mr. WINDING.

5952, 5953, 5954. ***RESEARCH PROJECT.*** Credit 3 hrs.; additional credit by special permission. Fall and spring. Prereq., 5304. Research on an original problem in chemical engineering. Staff.

5955, 5956. ***SPECIAL PROJECTS IN CHEMICAL ENGINEERING.*** Credit variable. Either term. Research or studies on special problems in chemical engineering. Staff.

METALLURGICAL ENGINEERING

6112. ***METALS TECHNOLOGY.*** Credit 2 hrs. Spring. 2 Lect. Prereq., 1243. An advanced course for students in mechanical engineering covering the mechanical and metallurgical factors affecting service behavior of metals under static and dynamic loading. Subjects covered include failure criteria, brittle fracture, creep, embrittlement, fatigue, and corrosion. Mr. G. V. SMITH.

6211. ***INTRODUCTORY METALLURGICAL ENGINEERING.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. A survey of various fundamental principles and applications of metals and allied materials, centered in the laboratory experiments. The intention is to use the many instruments, furnaces, and varied facilities necessary for the study of the application of the principles of physics and chemistry to metallurgy and to control and to examine the behavior and utilization of metals and materials. A number of examples, such as batteries, triodes, motors, transistors, engine parts, and other manufactured articles, will be studied for their application to metallurgical engineering. Mr. SCALA.

6212. ***MATERIAL AND ENERGY BALANCES.*** Credit 3 hrs. Spring. 3 Lect.-Rec. Engineering problems involving material balances, thermal balances, thermochemistry, and electrochemistry as applied to metals and allied materials. Mr. GREGG.

6301. ***PRINCIPLES OF METALLURGICAL ENGINEERING.*** Credit 3 hrs. Fall. 3 Lect. Prereq. 6201. *(Not offered after 1962–1963.)* Discussion and calculations concerning fuels, combustion, fluid flow, heat flow, roasting and sintering, gas cleaning, and application of thermochemical data to metallurgical processes. Mr. GREGG.

6323 (Formerly 6403). ***METALLURGICAL THERMODYNAMICS.*** Credit 3 hrs. Fall. 3 Lect. A discussion of thermodynamic equilibria with emphasis upon metallic liquid and solid solutions. Topics considered include binary, ternary, and quaternary phase diagrams; thermodynamic probability and disorder in crystals; partial and integral molar properties of solutions and their applications; experimental methods used in determining thermodynamic parameters. Mr. SPENCER.

6324 (Formerly 6404). ***METALLURGICAL THERMODYNAMICS.*** Credit 3 hrs. Spring. 3 Lect. Topics considered include the equilibrium constant, the partition function, phase field boundaries in heterogeneous systems, chemical stability of ceramic materials, metastable phases, zone purification, vacuum metallurgy, reactive atmospheres, order-disorder phenomena in alloys, surface thermodynamics. Mr. SPENCER.

6331, 6332. ***MATERIALS SCIENCE I AND II.*** Credit 3 hrs. a term. 3 Lect. Fall and spring. Prereqs., 6212, concurrent registration in 6321. *(Offered commencing in 1963–1964.)* Covers those aspects of physics and chemistry that govern the behavior of materials, and the

resultant properties of materials (phase equilibria is taught concurrently in 6321). Topics covered include atomic bonding, structures, structural discontinuities of 1 and 2 dimensions, plastic deformation, radiation damage, fracture, nucleation, crystal growth, diffusion, reaction with environment, physical properties, theory of alloys, recovery, recrystallization and grain growth, solid-state transformations. Mr. WEART.

6353. ***INTRODUCTORY METALLOGRAPHY.*** Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereqs., 6202, 6331, or permission of the instructor. Microstructures of alloys, as related to composition, thermal history, and physical properties. Preparation of specimens; principles and use of metallographic microscopes. Mr. MASON.

6401, 6402. ***CHEMICAL METALLURGY I AND II.*** Credit 3 hrs. a term. Fall and spring. 2 Lect. 1 Lab. (*Offered commencing in 1964–1965*). Application of thermodynamic and kinetic principles to important metallurgical processes, with emphasis on reduction and refining operations. Mr. GREGG.

6411, 6412, ***PHYSICAL METALLURGY I AND II.*** Credit 3 hrs. a term. Fall and spring. 3 Lect. Prereq., 6353. Discussion of the structural basis of behavior of metals. Topics include dislocations, two-dimensional structural discontinuities, plastic deformation, nucleation, solidification, corrosion, diffusion, oxidation, radiation damage, theory of alloys, electrical and magnetic properties, recovery, recrystallization and grain growth, solid state transformations (diffusionless and diffusion-controlled), hardenability. (Commencing in 1964–1965, the content of this course will change to reflect the prerequisite offering in Courses 6331, 6332.) Mr. WEART.

6416. ***PRINCIPLES OF MATERIALS PROCESSING.*** Credit 3 hrs. Spring. 2 Lect. 1 Rec. Prereqs., 6332, 6353. An advanced course relating basic and applied sciences to materials processing and technology. Includes a critical study of selected casting, metal forming and working, welding, and powder metallurgy processes. Emphasis is placed on scientific and engineering principles rather than industrial techniques: alloying, heat transfer, and solidification in foundry operations; criteria for plastic flow in metal working processes; distortion, residual stress and heat effects in welding; compacting and sintering in powder metallurgy; chip formation and tool forces in machining. Mr. BURTON.

6432. ***MECHANICAL METALLURGY.*** Credit 3 hrs. Spring. 3 Lect. Prereqs., 6332, 6353. Elastic, plastic, and fracture phenomena in metallic solids, including yielding, strain hardening, brittle fracture, creep and fatigue. Plastic forming is treated concurrently in Course 6416. Mr. G. V. SMITH.

6451. ***EXPERIMENTAL PHYSICAL METALLURGY.*** Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereqs., 6332, 6353. Theory and applications of X-ray metallography including X-ray diffraction, fluorescent analysis, and microradiography. Lectures and laboratory experiments deal with crystallography and crystal structure determination, lattice dimensions of cubic and noncubic crystals, preferred orientation and pole figures, single crystal orientation, polymorphic transformations, order-disorder transformations, low-temperature and high-temperature diffraction methods, chemical analysis by X-ray fluorescence, microradiographic techniques. Stereographic projection methods and reciprocal lattice concepts are developed and used in the experiments. Additional optical metallographic techniques are considered, including quantitative methods and the use of phase contrast microscopy and polarized light microscopy for opaque materials. Techniques of dilatometry, differential thermal analysis, temperature control, and vacuum technology are included. Mr. BURTON.

6503. ***SERVICE BEHAVIOR OF METALS.*** Credit 3 hrs. Fall. 3 Lect. Prereq., 6412. Metallurgical and mechanical factors governing the selection of metals for various services. Analysis of service requirements, and the selection and fabrication of metals to fulfill such requirements; analysis of service failures of metals and remedies for such failures; and study of the merits and limitations of materials applications in existing products and equipment. Mr. G. V. SMITH.

6504. ***UNIT PROCESSES IN METALLURGY.*** Credit 3 hrs. Fall. 1 Lect. and 1 Lab. with reports. Prereqs., 6201, 6251, 6301. Experimental study of important processes in metallurgy, including generation of furnace atmospheres, furnace design and performance, determination of rates of heating and cooling, and electrochemical operations. Reports based on the experimental data, discussing principles involved in the operations, are important. Mr. GREGG.

6506. ***METALLURGICAL DESIGN.*** Credit 2 hrs. Spring. Prereq., 6503. A seminar course using a modified case-history approach to problems and current developments in metallurgical engineering. Mr. G. V. SMITH.

6553, 6554. ***SENIOR PROJECT.*** Credit 2 hrs. Fall and spring. Research on an original problem in metallurgical engineering. Staff.

6555, 6556. ***ADVANCED PROJECT.*** Credit as arranged. Fall and spring. Staff.

[**6601.** ***METALLURGICAL THEORY AND PRACTICE.*** Credit 4 hrs. Fall. 3 Lect. 1 Lab. Prereqs., thermodynamics, and graduate or senior standing. Prepares students majoring in fields other than metallurgy for graduate courses in metallurgy and familiarizes them with metallurgical laboratory techniques. Topics included are phase equilibrium, thermodynamics of heterogeneous metallurgical systems, imperfections in metals, microstructure, mechanical properties of alloys, and phase transformations. A substantial amount of reading will be incorporated. Mr. SPENCER. Not offered in 1962–1963.]

6620. ***ADVANCED FOUNDRY ENGINEERING.*** Credit 3 hrs. Fall. Prereq., 6416. Offered on demand. Three class periods including special laboratory studies, critical study of foundry technology, and the metallurgical features of cast metals. Laboratory investigation of special foundry process and procedures. Mr. BURTON.

[**6624.** ***KINETICS OF METALLURGICAL REACTIONS.*** Credit 3 hrs. Spring. 3 Lect. Prereq., 6323 or equiv. Designed for advanced undergraduate students in the metallurgy-materials area and for beginning graduate students with limited background in the area. Topics considered include kinetics of gases and partial pressure measurements, empirical treatment of reaction rates and applications, Arrhenius equation, transition state theory, nucleation theory, diffusion, introduction to irreversible processes. Applications include corrosion, recrystallization and grain growth, solidification, and phase transformations. Mr. SPENCER. Not offered in 1962–1963.]

6625. ***THEORY OF REACTION RATES IN SOLIDS.*** Credit 3 hrs. Spring. 3 Lect. Prereqs., 6323, Physics 454. Directed toward graduate students and advanced engineering undergraduates concerned with the application of physical-mathematical concepts to the interpretation of rate processes in metals. The theory of absolute rate processes is presented in detail with reference to the kinetics and thermodynamics of physical and chemical changes primarily in metals. Rates of physical and chemical processes are considered from first principles, utilizing such fundamental properties as atomic configurations, dimensions, and interatomic forces of the reacting molecules. The analytical description is introduced in terms of statistical mechanics, the Arrhenius equation, potential energy surfaces, properties of the activated complex, and the behavior of transition states. Quantitative applications are developed in terms of atomic mechanisms with reference to transport and transformation processes in metals such as diffusion, nucleation and growth, creep, precipitation, and other physical and chemical solid-state processes. Mr. RHODIN.

6651. ***PHYSICAL METALLURGY OF FERROUS MATERIALS.*** Credit 2 hrs. 2 Lect. Prereq., permission of the instructor. Offered on demand. Study of the basic effects of alloying on the structure and properties of steels, and the application of this knowledge to the design of modern high-strength, stainless, or heat-resistant steels and of steels for tools and dies. Mr. G. V. SMITH.

6661. ***METALS AT ELEVATED TEMPERATURES.*** Credit 2 hrs. Fall. 2 Lect. Offered on demand. Prereq., permission of the instructor. Evaluation and application of metals for use at service temperatures. Emphasis is placed on nature of creep flow and fracture at elevated temperatures. Attention is also paid to scaling, metallurgical instability, and various physical properties. Mr. G. V. SMITH.

6662. ***REFRACTORY MATERIALS.*** Credit 2 hrs. Spring. 2 Lect. plus lab. demonstrations and visits. The lectures will review the crystallography, rheology, and engineering characteristics of refractory metals (tungsten, molybdenum, columbium, and tantalum); graphites; refractory oxides (magnesia, alumina, zirconia, yttria, and thoria); and the refractory compounds (carbides, nitrides, borides and beryllides). Laboratory demonstrations will supplement the lectures, illustrating pyrolitic techniques in preparing graphites and compounds, and the melting, joining, and zone refining by electron beam methods necessary for the refractory materials. Research laboratories actively involved in studying these materials will be visited, and key articles in the current literature will be reviewed to augment the lectures. Mr. SCALA.

6671. ***PRINCIPLES OF POWDER METALLURGY.*** Credit 3 hrs. Fall. Offered on demand. 2 Lect. and one 2½-hour lab. each week. Following brief consideration of industrial powder-metallurgy equipment, including dies, presses, and sintering furnaces, and industrial applications such as porous products, permanent magnets, refractory metals, cemented carbides, cermets, etc., the theory of powder metallurgy is treated critically. Emphasis is on the theories of compacting and sintering, diffusional processes, and surface chemistry. The theories, applications, and limitations of hot pressing are examined critically.

Laboratory experimentation is primarily concerned with fundamental investigation of compacting, bonding, sintering, hot pressing, infiltration of porous networks, etc. Laboratory studies of surface chemistry and surface activation are included. Mr. BURTON.

6681. ***ADVANCED EXPERIMENTAL METALLURGY.*** Credit 3 hrs. Fall. Two 2½ hour labs. Experiments using advanced metallurgical laboratory techniques, with discussions of the principles involved and the results of the experiments. Experiments are available in the fields of physical, chemical, and mechanical metallurgy; metallography; materials processing; and materials properties. The student is expected to perform approximately six experiments, selected to meet his individual needs. Independent work by the student is stressed, with emphasis both on the experimental method and the metallurgical phenomena. Messrs. BURTON, NEWKIRK, SCALA.

6710. ***TRANSPORT PROCESSES.*** Credit 3 hrs. Spring. 3 Lect. Prereqs., 6404 and 6624, or consent of instructor. A survey of the transport of matter and energy in condensed systems with emphasis on metallic solids. The phenomenology and theories of diffusion; boundary and surface diffusion. Electrical and thermal conduction. Special cases involving more than one process.

6731. ***X-RAY METALLOGRAPHY I.*** Credit 3 hrs. Fall. Prereqs., principles of light metallography, X-ray diffraction, and crystallography. X-ray theory, scattering, intensity of coherent reflection. Theory and experimental techniques for film and counter methods including powder, Laue, Weissenberg. Stereographic projection, pole figures, analysis of Widmannstatten structure, grain orientation by surface traces, etch pits, X-ray pattern. Reciprocal lattice, oscillating and rotating crystal methods. Diffractometer technology. Lecture, group discussion, and laboratory practice will be included. Mr. NEWKIRK.

6732. ***ADVANCED METALLOGRAPHY.*** Credit 3 hrs. Spring. Prereq., 6731 or equivalent. Structures of metals, substructures in crystals, X-ray fluorescence and absorption analysis, diffuse X-ray scattering effects, quantative metallography, stress measurement by X-rays. Other metallographic techniques including electron microprobe, thermionic emission and field emission microscopy, microradiography, X-ray diffraction microscopy. Applications of modern metallographic methods will be illustrated with metal and ceramic systems undergoing allotropic phase transformations, precipitation, and order-disorder reactions. Mr. NEWKIRK.

6872. ***NUCLEAR MATERIALS TECHNOLOGY.*** Credit 2 hrs. Spring. 2 Lect. Production of fissle, source materials, and other materials used in nuclear reactors. Behavior of materials in nuclear reactors, including deterioration by corrosion and radiation. Problems involved with respect to fuel elements. Fabrication of reactor and reactor components. Mr. GREGG.

6911. ***SEMINAR IN NONCRYSTLLINE MATERIALS.*** Credit 1 hr. Fall. Prereq., consent of instructor. Discussions, guided and supplemented by lectures, of those condensed phases characterized by the absence of long-range order, viz., liquids and glasses. The nature of the liquid and glassy states of atomic, molecular, and polymeric materials is examined via their structure and properties; theories of the liquid state are reviewed to provide a background for a discussion of crystallization vs. glass formation. Mr. WEART.

6961–6962. ***GRADUATE SEMINAR.*** Credit 1 hr. Fall and spring. Objectives are (1) to provide a forum in which subjects at the forefront of metallurgical science and engineering can be effectively discussed; (2) to develop the student's ability to communicate technical ideas effectively through oral presentations; and (3) to give the student practical experience in organizing and conducting efficient technical meetings. Mr. NEWKIRK.

6980. ***RESEARCH IN METALLURGICAL ENGINEERING.*** Fall–spring. Credit as arranged. Thesis research under guidance of a member of the staff. Staff.

AEROSPACE ENGINEERING

7101. ***FUNDAMENTALS OF AERODYNAMICS.*** Credit 3 hrs. Fall. Prereq., engineering mechanics. Properties of gases and fluids. Kinematics of fluid flows. Equations of motion for an incompressible fluid and Bernoulli's equation. Flow around simple bodies, thin airfoils and wings. Basic properties of compressible flow: the energy relations, channel flows. Prandtl-Meyer and shock waves. Small perturbations at subsonic, transonic, super-

sonic, and hypersonic speeds. Introduction to viscous-flow theory, boundary-layer equations and the integral method. Transition between laminar and turbulent flows. Mr. SHEN.

7102. ***FUNDAMENTALS OF ASTRONAUTICS.*** Credit 3 hrs. Spring. Prereq., engineering mechanics and thermodynamics. Performance of chemical- and nuclear-rocket systems, performance in central force fields, optimization of powered trajectories, perturbations of trajectories. Solid- and liquid-propellant rockets, ion and plasma propulsion, photon propulsion, and solar sailing, relativistic rocket mechanics. Mr. TURCOTTE.

7203. ***GASDYNAMICS I.*** Credit 3 hrs. Prereq., engineering thermodynamics. Thermodynamics of gases and gas mixtures; kinetic theory, transport properties; introduction to statistical mechanics, chemical equilibria, and reaction rates; derivation of fundamental equations of gasdynamics; acoustics. Mr. TURCOTTE.

7204. ***GASDYNAMICS II.*** Credit 3 hrs. Prereq., 7203 or 8121. One-dimensional gasdynamics, weak and strong shock limits, shock-tube theory, method of characteristics, blast waves, effects of viscosity and thermal conductivity, one-dimensional gasdynamics of a dissociating gas, one-dimensional gasdynamics of an ionized gas. Mr. TURCOTTE.

7206. ***INTRODUCTION TO MAGNETOHYDRODYNAMICS.*** Credit 3 hrs. Spring. Prereq., 7203. Review of electrodynamics, conduction of electricity in gases, equations of motion of magnetohydrodynamics, solutions for special cases and under various approximations, magnetohydrodynamic waves, phenomena in rarefied gases. Mr. SEARS.

7207. ***DYNAMICS OF RAREFIED GASES.*** Spring. Credit 3 hrs. Review of classical kinetic theory of gases. The Boltzmann equation, the Chapmann-Enskog and Grad solutions for slightly nonuniform flows. The hydrodynamic equation. Studies of flow problems involving gases in the regime where the mean free path becomes comparable to pertinent body dimensions; transition between continuum and free-molecule flow regimes. Mr. SHEN.

7208. ***HYPERSONIC-FLOW THEORY.*** Credit 2 hrs. On demand. Prereqs., 7301, 7303. General features of hypersonic flow; the role played by the ratio of specific heats; normal, oblique and curved shock relations; vorticity and shock curvature; irrotational small-disturbance similitude, the principle of equivalence; blast-wave analogy; Newtonian theory with shock-layer structures; optimum bodies; boundary-layer hypersonic-flow interactions; real-gas effects.

7301. ***THEORETICAL AERODYNAMICS I.*** Credit 3 hrs. Fall. Prereq., differential equations, intermediate mechanics or introduction to theoretical physics. Introduction to theoretical hydrodynamics. Ideal fluids. The boundary-value problems of steady and non-steady two- and three-dimensional potential flows with special attention to flows produced by the motion of solid bodies. Vector methods and complex variable are used extensively. Mr. SEARS.

7302. ***THEORETICAL AERODYNAMICS II.*** Credit 3 hrs. On demand. Prereqs., 7301, 7303. Wing theory; thin-airfoil theory, two-dimensional airfoil theory. Prandtl wing theory, lifting surfaces, general multiple theory, nonstationary wing theory. Correction for compressibility (linearized theory). Wing theory for supersonic speeds; source and sink methods and extensions, conical-flow methods, nonstationary cases.

7303. ***THEORETICAL AERODYNAMICS III.*** Credit 3 hrs. Spring. Prereqs., 7204, 7301. The aerodynamics of compressible fluids; equations of motion, small-perturbation theory (subsonic and supersonic); Janzen-Reyleigh theory, the hodograph methods, the limiting line, the method of characteristics, Prandtl-Meyer flow, hypersonic flow. Mr. SEEBASS.

7304. ***THEORETICAL AERODYNAMICS IV.*** Credit 3 hrs. Fall. Prereq., registration in 7301. The aero-dynamics of viscous fluids; the boundary layer, heat transfer, fundamentals of boundary-layer stability. Turbulence, the fundamentals of isotropic turbulence. Mr. SHEN.

7801. ***RESEARCH IN AEROSPACE ENGINEERING.*** (Credit to be arranged.) Prereq., admission to the Graduate School of Aerospace Engineering and approval of the Director. Independent research in a field of aerospace science. Such research must be under the guidance of a member of the staff and must be of a scientific character.

7901. ***AEROSPACE ENGINEERING COLLOQUIUM.*** Credit 1 hr. Prereq., admission to the Graduate School of Aerospace Engineering. Lectures by staff members, graduate students, personnel of Cornell Aeronautical Laboratory, and visiting scientists on topics of interest in aerospace science, especially in connection with new research.

7902. ***ADVANCED SEMINAR IN AEROSPACE ENGINEERING.*** Credit 2 hrs. Prereq., approval of the Director.

ENGINEERING PHYSICS

8051 and 8052. *PROJECT.* Terms 9 and 10. Credit 3 hrs. Fall and spring. Informal study under direction of a member of the University staff. The objective is to develop self-reliance and initiative, as well as to gain experience with methods of attack and with over-all planning, in the carrying out of a special problem related to the student's field of interest. The choice of a problem is to be made by the student in consultation with members of the staff.

8090. *INFORMAL STUDY IN ENGINEERING PHYSICS.* Fall or spring. Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the staff. Hours to be arranged.

8121–8122. *CLASSICAL THERMODYNAMICS.* Credit 3 hrs. Through the year. 3 Rec. Primarily for candidates for the degree of Bachelor of Engineering Physics. Introduction to classical thermodynamics, kinetic theory of gases, and statistical mechanics. Application to physical and engineering problems. Mr. RESLER.

8131. *MECHANICS OF CONTINUA.* Credit 3 hrs. Spring. 3 Lect. Prereqs., Math. 616, 622 or permission of the instructor. Stress and strain tensors; fundamental equations of motion in continuous media; generalized equation of state; applications to special topics of general and engineering interest in elasticity, wave propagation, vibration, incompressible and compressible fluids, viscous flow, etc. Mr. SEARS.

8252. *SELECTED TOPICS IN PHYSICS OF ENGINEERING MATERIALS.* Credit 3 hrs. Fall term. Primarily for fifth year students in engineering physics; others with consent of instructor. Seminar-type discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semiconductors; radiation damage, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids and their impact on the engineering applications. Current literature is included in the assignments. Staff.

8255. *CRYSTAL DISLOCATION THEORY.* Credit 3 hrs. Spring. 3 Lect. Prereqs., consent of the instructor, equivalents of Math 616 or 1182, and Physics 454. Primarily for graduate students in solid state physics. The theoretical basis for elementary concepts of dislocations, elastic continuum models including continuum field theory, crystallography of line and plane defects, and the dislocation core problem are emphasized. The origin of dislocations and some of their properties such as electron scattering, perturbations of electronic structure, interactions with point defects are discussed. Crystal growth, creep, and plasticity and fracture are considered as applications of dislocation theory. Mr. WEBB.

8262. *PHYSICS OF SOLID SURFACES.* Credit 3 hrs. Spring. (Given in alternate years.) 2 Lect. and 1 Seminar. Primarily for graduate students and seniors in solid state physics and engineering science. An introductory review of recent advances in current theories of surfaces associated with condensed systems. Applications to the interpretation of mechanisms involved in electron emission, phase transformations, friction and wear, oxidation and corrosion. Mr. RHODIN.

8301. *INTRODUCTION TO ATOMIC AND NUCLEAR PHYSICS.* Credit 3 hrs. Fall. 3 Lect. Prereqs., Physics 124 or 126 or 128, and calculus through differential equations. Primarily for students in nuclear engineering. Concepts of atomic structure of matter; fundamentals of quantum theory and applications to structure of atoms, molecules, and nuclei. Concepts of nuclear reactions and their relation to nuclear reactor problems, including the chain reaction. Mr. FISHER.

8311. *NUCLEAR AND REACTOR PHYSICS.* Credit 3 hrs. Spring. 3 Lect. Prereq., Physics 214 or 243. Nuclear particles, nuclear structure, nuclear reactions; characteristics of particle accelerators; properties of neutrons, interactions of neutrons with matter, nuclear fission; elementary reactor theory, types of reactors, reactor design problems; instruments for particle detection and reactor control. Mr. CLARK.

8312. *REACTOR THEORY I.* Credit 3 hrs. Fall. 3 Lect. An enlargement of 8311, with greater emphasis on theoretical aspects of reactor design. Review of neutron interactions, reactor systems, diffusion and slowing down of neutrons, bare reactor criticality. Mr. NELKIN.

8313. *REACTOR THEORY II.* Credit 3 hrs. Spring. 3 Lect. Continuation of 8312. Reflected reactors and group theory, criticality of heterogeneous systems, experimental determination of reactor criticality, time behavior of reactors, reactor control. Mr. NELKIN.

[**8321. *PRINCIPLES OF THERMONUCLEAR POWER.*** Credit 2 hrs. Fall. 2 Lect. Prereq., 8311 or Physics 214 or Physics 244. An introductory course concerned primarily with physi-

cal problems involved in current thermonuclear research. Topics included are cross-sections of fusion reactions; theory of binary reactions; radiation processes; microscopic processes in plasmas; magnetohydrodynamics; problems of plasma confinement; present concepts of thermonuclear power reactors. Not offered in 1962–1963.]

8331. ***NUCLEAR POWER ENGINEERING SEMINAR.*** Credit 3 hrs. Fall. Prereq., background in engineering sciences, and 8312, 8313, or consent of the instructor. Group design project applying the fundamentals of nuclear reactor engineering to nuclear energy systems: power plant thermodynamics; fluid flow, heat transfer, and thermal stresses; radiation protection and shielding; materials; economics of nuclear power and fuel cycles; core design; instrumentation and control. Mr. CADY and Staff.

8341. ***NUCLEAR AND COSMIC CHEMISTRY/PHYSICS.*** Credit 3 hrs. Fall, alternate years. Primarily for graduate students; open to undergraduates by consent of instructor. A discussion of the properties of nuclei; radioactive decay and measurements; nuclear reactions; creation of the elements and nuclide abundances; cosmic rays and their interactions with meteorites; nuclear cosmochronology. Mr. FISHER.

8342. ***READING COURSE IN RADIOCHEMISTRY.*** Credit 2 hrs. Spring. Primarily for graduate students and seniors. Reading assignments in the general field of radiochemistry. Meetings for discussions at the convenience of the group, possibly for two hours every other week. Slanted toward the interests of the students, the course may include such topics as nuclear fission, radiochemistry, nuclear concepts in geochemistry, neutron activation analysis, beta decay studies, radiation chemistry, hot-atom chemistry, biological effects of radiation, cosmic chemistry, nuclear reactions, neutrino searches, elemental abundances, tracer techniques, and applications in various fields. Mr. FISHER.

8351. ***NUCLEAR MEASUREMENTS LABORATORY.*** Credit 3 hrs. Either term. Two 2½ hr. afternoon periods. Pre- or co-req., 8311. Some twenty-five different experiments are available in the fields of nuclear and reactor physics and engineering. Among these are experiments in nuclear radiation detection and absorption; in properties of radiation detectors and specialized electronic circuits used in counting and reactor control; in interactions of neutrons with matter, especially moderation, diffusion, absorption, and scattering; in chemical separations and in casting and metallurgical examination of uranium. Experiments on a subcritical reactor and the TRIGA reactor are included. The student is expected to perform eight to ten experiments, selected to meet his needs. Some stress is laid on independent work by the student. May be elected more than once by students desiring broader or more advanced laboratory experience. Mr. CLARK.

8352. ***ADVANCED NUCLEAR MEASUREMENTS LABORATORY.*** Credit 3 hrs. Either term. Two 2½ hour afternoon periods. Prereq., 8351. A continuation of 8351 for students desiring advanced laboratory experience. Staff.

8512. ***ELECTRON MICROSCOPY.*** Credit 3 hrs. Spring. Prereq., permission of the instructor. Lect. Lab. Hours to be arranged. Basic electron optics, image formation and interpretation, construction and operation of the electron microscope, applications in physics, chemistry, and biology.

8517. ***ELECTRON OPTICS AND ITS APPLICATIONS.*** Credit 3 hrs. Fall. Prereq., Physics 225 (Physics 215 advised but not required). Electron beam formation, Gaussian dioptrics and aberrations of electron lenses, application including cathode ray tube, electron microscope, beta ray spectrometer, mass spectrometer.

AGRICULTURAL ENGINEERING

(For a complete description of the courses in agriculture, see the *Announcement of the College of Agriculture.*)

2. ***INTRODUCTION TO AGRICULTURAL ENGINEERING.*** Credit 2 hrs. Spring. 2 Lect. Limited to students in the five-year agricultural engineering curriculum. The purpose is to introduce the application of engineering principles to problems in agriculture, with a brief history of the development of agricultural engineering in the United States. Problems that are of primary interest to the agricultural engineer are used to provide understanding of the application of principles and to test the students' comprehension of the subject matter. Selected staff.

105. ***ENGINEERING DRAWING.*** Credit 4 hrs. Fall. 2 Lect. 2 Lab. Designed to promote

an understanding of the engineer's universal graphic language. The lectures will deal primarily with spatial relationships involving the problem-solving techniques of descriptive geometry. The laboratories will develop a working knowledge of drawing conventions, drafting techniques, and their application to machine, architectural, and pictorial drawing problems. Graphs and engineering graphics (nomography and graphical calculus) will also be included. Students will accomplish their work with drafting machines as well as the standard T-square and board. Department equipment will be utilized to reproduce selected drawing exercises to illustrate the techniques involved and verify line work quality. The first half-hour of the laboratory will be utilized as an instruction-recitation period. Laboratories will be conducted to promote learning through informal student-teacher contact. Mr. FURRY.

202. ***FARM POWER.*** Credit 3 hrs. Fall. Lect. Lab. Comp. Prereq., Engineering 3601 or the equivalent. Thermodynamic principles applied to internal combustion engines. Application of kinematics and dynamics to tractor design and field use. Elements involved in proper construction, selection, and operation of farm tractors. Emphasis on writing of engineering reports.

203. ***AGRICULTURAL MACHINERY DESIGN.*** Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., Engineering 3341 or the equivalent. The principles of design and development of agricultural machines to meet functional requirements. Emphasis is given to stress analysis, selection of materials of construction, and testing procedures involved in machine and development. Mr. GUNKEL.

220. ***SURVEYING.*** Credit 2 hrs. Spring. 1 Lect. 1 Lab. A study of the principles and practices of surveying measurements. Fundamentals of measurement, sources of errors. Use of steel tape, engineer's level, transit and plane table. Emphasis upon agricultural engineering applications. Mr. LEVINE.

221. ***SOIL AND WATER ENGINEERING.*** Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereqs., Engineering 2132, 2302, and Agronomy 1, or their equivalents. An advanced course in the application of engineering principles to the problems of soil and water control in agriculture. Includes design and construction of drainage systems and farm ponds; and design and operation of sprinkler systems for irrigation. Mr. BLACK.

231. ***FARM STRUCTURES DESIGN.*** Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereqs., Engineering 2732 and 3605 or their equivalents. An advanced course in the application of structural design principles to farm buildings. Includes functional requirements, characteristics of materials, structural design, and the principles of environmental control in farm buildings. Mr. BOYD.

241. ***LOW-COST ROADS.*** Primarily for foreign students. Credit 3 hrs. On demand. Prereq., 2610 or the equivalent. Study of economic importance of routes and selection of roads to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals and bituminous materials; drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construction of low-cost roads. Mr. SPENCER.

251. ***SPECIAL PROBLEMS IN AGRICULTURAL ENGINEERING.*** Credit 1 or more hrs. Fall or spring. Prereqs., adequate ability and training for the work proposed, and permission to register. (Normally reserved for seniors in upper two-fifths of class.) Special work in any branch of agricultural engineering on problems under investigation by the Department or of special interest to the student, provided, in the latter case, that adequate facilities can be obtained. Staff.

253. ***SPECIAL TOPICS IN AGRICULTURAL ENGINEERING.*** Credit 1 hr. Fall and spring. Open only to seniors. Presentation and discussion of the opportunities, qualifications, and responsibilities for positions of service in the various fields of agricultural engineering. Mr. FRENCH.

REQUIRED COURSES IN OTHER DIVISIONS

For detailed information on required courses for undergraduate engineering students, consult the Announcement of the division in which the courses are offered, e.g., the *Announcement of the College of Arts and Sciences.*

FACULTY AND STAFF

DEANE W. MALOTT, A.B., M.B.A., LL.D., D.C.S., President of the University.
DALE RAYMOND CORSON, Ph.D., Dean of the College and Professor of Engineering Physics and Physics.
GORDON P. FISHER, D.Eng., Associate Dean of the College and Professor of Civil Engineering.
JOHN F. McMANUS, C.E., Assistant Dean of the College.
DONALD H. MOYER, B.S., M.A., Director of the Office of Student Personnel.
JEANETTE WOOD, B.S., Librarian.

VICTOR EMANUEL VISITING PROFESSORSHIP

OLAF ERIK HANS RYDBECK, M.Sc., D.Sc., 1957–1958 (fall term).
BALTHASAR VAN DER POL, D.Math. and Physics, Ph.D., 1957–1958 (spring term).
THEODORE VON KÁRMÁN, M.E., Ph.D., 1958–1959 (spring term).
CHAO CHEN WANG, B.S., M.S., D.Sc., 1959–1960 (spring term).

AEROSPACE ENGINEERING

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STANLEY WHITSON WARREN, B.S., Ph.D., Professor of Farm Management.

PROFESSORS

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EMERITUS PROFESSOR

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GEORGE J. WOLGA, B.E.P., Ph.D., Assistant Professor of Electrical Engineering.

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LELAND C. ROBERTS, A.B., B.S.E.E.

RESEARCH ASSOCIATES

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LAWRENCE BYRON SPENCER, E.E., Chief Network Calculator Engineer.

ENGINEERING MECHANICS AND MATERIALS

EDMUND T. CRANCH, B.M.E., Ph.D., Head of the Department and Professor of Mechanics.

EMERITUS PROFESSORS

ERIC V. HOWELL, C.E., Professor of Mechanics, Emeritus.
HAROLD C. PERKINS, M.E., Professor of Mechanics, Emeritus.

PROFESSORS

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HENRY D. BLOCK, B.S., B.C.E., M.S., Ph.D., Professor of Applied Mathematics.

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RICHARD H. LANCE, B.S., M.S., Ph.D., Assistant Professor of Mechanics.

INSTRUCTOR

STANLEY OLSEFSKI.

ENGINEERING PHYSICS

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PROFESSORS

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