CORNELL UNIVERSITY
OFFICIAL PUBLICATION

College of Engineering

THE SCHOOL OF CIVIL ENGINEERING
THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING
THE SCHOOL OF ELECTRICAL ENGINEERING
THE SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING
THE DEPARTMENT OF ENGINEERING PHYSICS
THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

1949-1950

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The College of Engineering

ITS HISTORY AND ORGANIZATION

ENGINEERING has had an important place in the program of Cornell University from the beginning. The Federal Land Grant, or Morrill Act of 1862, which supplied a considerable proportion of the University's original endowment, specified that a leading object of the institution should be to teach "such branches of learning as are related to . . . the mechanic arts"; and this provision was in perfect accord with the ideals of the founder and of the first president. Both Ezra Cornell, the practical man of affairs, who had amassed a fortune in the Western Union Telegraph Company, and Andrew D. White, the brilliant scholar and educator, who had carefully analyzed contemporary higher education in America and in Europe, believed in the equal dignity of scientific and classical studies and determined to put the practical arts, such as engineering, on the same plane with the humanities. This program was considered revolutionary when announced at the University's opening in 1868. That it has since been generally adopted by American universities indicates the soundness of the basic Cornell idea that instruction in engineering should be given on a high professional level. The College of Engineering still adheres firmly to this policy.

Mechanical engineering and civil engineering have been strong divisions of the University since its foundation. The first was originally called the College of Mechanic Arts and later the Sibley College of Mechanical Engineering and Mechanic Arts, in recognition of munificent gifts by Hiram Sibley, founder of the Western Union Telegraph Company, and his son, Hiram W. Sibley. Civil Engineering, originally a separate school in the College of Mathematics and Engineering, and later the College of Civil Engineering, has also retained its identity to the present day.

In 1883 Cornell opened courses in electrical engineering, among the first to be offered anywhere in America; and in 1919, when the Board of Trustees formed the present College of Engineering the School of Electrical Engineering was established as one of the three component units, on a par with the Sibley School of Mechanical Engineering and

the School of Civil Engineering. In 1946 the Graduate School of Aeronautical Engineering was established. Also in 1946 the Department of Engineering Physics was organized with a five-year curriculum leading to the degree of Bachelor of Engineering Physics. All undergraduate curricula have now been extended to five years in order to provide the necessary technical preparation and at the same time to include the very desirable training in nontechnical subjects.

The College of Engineering organized a five-year course in Chemical Engineering in 1931; and seven years later the School of Chemical Engineering was established to supervise the curriculum which leads to the degree of Bachelor of Chemical Engineering. A five-year course in Metallurgical Engineering has now been added and the name of the school has been changed to the School of Chemical and Metallurgical Engineering.

Students in Engineering at Cornell use the facilities of the several Sibley buildings which house the Sibley School of Mechanical Engineering; Lincoln Hall which is devoted to the School of Civil Engineering; Franklin Hall which contains most of the School of Electrical Engineering; Rand Hall, the gift of Mrs. Florence O. R. Lang, in which are located the Machine Shop, Pattern Shop, and senior Electrical Laboratory; the Hydraulic Laboratory on Beebe Lake above Triphammer Falls; and Olin Hall of Chemical Engineering, recently given by Franklin W. Olin to provide most adequately for the School of Chemical Engineering. For various preparatory and elective courses they also use the facilities of the Baker Laboratory of Chemistry, a building given to the University in 1922 by George F. Baker; and those of Rockefeller Hall, erected by John D. Rockefeller for the Department of Physics; and other buildings and equipment available in the College of Arts and Sciences.

Cornell engineers enjoy all the benefits and privileges of an outstanding university community. They associate continually, in fraternities and dormitories, in extracurricular activities, and in general University functions, with students of liberal arts, agriculture, law, veterinary medicine, and architecture. Concerts by world-famous soloists and orchestras, lectures by renowned scholars in widely varying fields, dramatic productions, and art exhibits add to the cultural atmosphere in which Cornell engineers move as undergraduates.

These facts, in addition to the beauty of the Campus and the surrounding Finger Lakes region and the consideration that Ithaca is a small city, removed from the distractions of a metropolitan area but easily accessible by railroad and highway, help to explain the composition of the student population, which each year includes students from every part of the United States and numerous foreign countries.

The College of Engineering now comprises the School of Civil Engi-

neering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering, the School of Chemical and Metallurgical Engineering, the Department of Engineering Physics, and the Graduate School of Aeronautical Engineering. Graduate instruction in engineering is offered by the Engineering Division of the Graduate School of the University.

PURPOSE OF THE INSTRUCTION

Engineering education at Cornell is broadly professional, designed to train men for leadership in public service, business, and industry. In the opinion of the Faculty, confirmed by representatives of concerns employing the bulk of engineering graduates, technical competence in the general field of engineering is essential to success even in the narrower specializations, such as radio, aeronautics, and air-conditioning, and time spent on fundamentals shortens the period of adjustment during which the graduate engineer discovers the specialty he is best fitted to pursue. Hence the College emphasizes instruction in the basic principles and applications of science, and offers specialized options only to a limited extent.

Experience has demonstrated that the secondary school student often lacks the ability to anticipate with accuracy the type of work for which he will ultimately find himself best adapted. Some of the largest industries, which offer the widest variety of opportunity within their own organizations, consider it necessary to observe even the engineering graduate for at least a year before deciding to what division of the company he should be assigned. Their records contain many instances of men who originally desired to become air-conditioning experts or airplane designers but eventually applied their personal aptitudes most successfully in such fields as power-plant management or metallurgical research.

Furthermore, a successful career is a record of competence in a series of situations actually available. No student can be certain that he will be offered precisely the employment that he desires at the time he graduates. Nor, in these times of rapid advances in technology, can he be sure that such a situation, if offered, would be a step along the road to the highest achievement of which he is capable. In electrical engineering, for instance, the full effect of the vacuum tube is as yet unknown, but this invention has already required not only a modification of existing electrical machines, but also an entirely new theoretical approach. Similar developments have taken place and will continue in the flelds of mechanical, civil, and chemical, and metallurgical engineering. Like the village blacksmith, the narrow specialist in engineering may one day find his specialty no longer in demand. Only a broad and intensive training in the fundamental sciences can fit an

engineer to take advantage of new opportunities as progress in industry creates them.

Just as the modern engineer needs broad and deep scientific training, he also must have a working knowledge of the social and economic structure. He can no longer act as an isolated technician; he must become an effective part of the society in which he lives, able to see the results of his efforts in relation to the industrial and social system as a whole. Unemployment, the standard of living, mass prejudices, political programs – all affect him not only as a person but also as an engineer. Such factors have constantly increasing significance in any program of public works or industrial development, and the engineer must understand them in order to solve his professional problems.

These considerations explain certain general features of the courses of study offered by the College. In all the schools, specialization has been postponed until late in the course and is limited both in character and in extent; and opportunities have been made for required and elective courses in such fields as physical science, social studies, and written and spoken English.

Dominant in all the courses of study is instruction designed to teach the fundamental principles, theoretical and practical, that underlie the various branches of engineering. Classroom instruction and laboratory experiment are supplemented by experience with the operation of various kinds of apparatus in the College laboratories and shops and by trips to inspect manufacturing plants, public works, and other places of interest in the industrial centers of the East. The student thus becomes familiar with problems encountered in modern engineering and with practical methods for their solution.

The basic purpose of the entire program is to make adjustment easier for the graduate when he begins actual engineering work, and to fit him for leadership in his profession.

THE FIVE-YEAR CURRICULA

As previously stated, it is intended that the instruction shall be directed towards the development of broad professional competence and leadership. To this end, a common foundation in the basic sciences of mathematics, physics, and chemistry, and in the basic engineering sciences of mechanics, materials of engineering, fluid mechanics, thermodynamics, and basic electrical theory, is constructed for all students in each of the divisions of engineering. Thereafter, each group follows the applications of these fundamentals in its particular areas of interest.

Beyond this, a stem of humanistic studies is carried by all engineering students throughout their programs. Instruction in English, public speaking, economics, psychology, the history of science, business law,

and other subjects, is intended to provide the breadth of intellectual background and viewpoint so essential to a successful career.

In order to provide adequately for this full range of study, the College instituted the Five-Year Undergraduate Curricula for engineering students in the Fall Term 1946. All entering students are now accepted only for the five-year course.

Both the four-year and five-year curricula are outlined in the following sections, the former serving only as reference for the terminal classes in the four-year program which were admitted prior to the Fall Term 1947, and scheduled for graduation not later than June 1950.

THE INDUSTRIAL COOPERATIVE PLAN

During the fourth term of the regular curriculum students in Electrical and Mechanical Engineering who are in good standing may apply for admission to the Industrial Cooperative Plan.

The Cooperative Plan provides three work periods of term length (about 16 weeks each) in one of the industries operating the plan with the University. Industrial periods are scheduled for various times throughout the calendar year. By utilizing the three summer periods after the fourth term (normally vacation periods), Cooperative students are enabled to complete all of the academic work regularly required for the bachelor's degree, and can graduate with their official classes. The program is not viewed as an accelerated program since the industrial periods relieve the continuity of academic work.

Although the student is on the industry payroll during the work periods, the function of the plan is educational rather than to provide part-time employment. The work in industry is coordinated with the student's studies so far as practicable and thus provides an invaluable supplement to engineering training.

Applications for the Cooperative Plan are accepted in the fourth term only. Applicants are subject to approval by both the College and 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.

A publication providing complete information and schedules will be available late in 1948.

DEGREES OFFERED

Cornell University confers the following degrees on the successful completion of undergraduate courses of study in the College of Engineering: Bachelor of Civil Engineering (B.C.E.); Bachelor of Mechanical Engineering (B.M.E.); Bachelor of Electrical Engineering (B.E.E.); Bachelor of Chemical Engineering (B.Chem.E.); Bachelor of Metallurgical Engineering (B.Met.E.); and Bachelor of Engineering Physics.

The corresponding Bachelor of Science degree in certain categories, and in Administrative Engineering, is currently awarded upon completion of certain of the four-year curricular. This degree does not apply to any of the five-year curricula.

The advanced degrees of Master of Chemical Engineering (M.Chem. E.), Master of Civil Engineering (M.C.E.), Master of Electrical Engineering (M.E.E.), Master of Mechanical Engineering (M.M.E.), Master of Metallurgical Engineering (M.Met.E.), Master of Science (M.S.), and Doctor of Philosophy (Ph.D.) are granted by the University on the recommendation of the Faculty of the Graduate School.

The degree Master of Aeronautical Engineering (M. Aero. E.) is granted on the recommendation of the faculty of the Graduate School of Aeronautical Engineering.

THE REQUIREMENTS FOR GRADUATION

Baccalaureate 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 and must have satisfied the University requirements in Military Science and Tactics (or Physical Education), Physical Training, and in the payment of 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.

UNIVERSITY REQUIREMENTS

MILITARY SCIENCE...All physically qualified undergraduate men who are American citizens must take military training during their first four terms. Enrollment in the basic course in Military Science and Tactics is the usual way of meeting this requirement. Regular or Contract students in the Naval ROTC may substitute the first four terms of Naval Science. Students transferring to Cornell from other institutions are exempt from part or all of the requirement, according to the number of terms of residence in college before transfer. Service in the armed forces in World War II will be credited toward the University requirement for military training. Entering students, who have had ROTC training in secondary or military schools, are requested to bring WD AGO Form 131 — Student's Record for presentation to the Military Department at the time of registration. (See also page 127 of this announcement.)

PHYSICAL TRAINING...All undergraduate men, unless officially excused, are required to follow a program of physical training, for the satisfactory completion of which one hour of credit a term will be allowed.

All undergraduate women, unless officially excused, are required to follow a program of physical education during the first four terms of their course of study. For the satisfactory completion of this requirement one hour of credit a term will be allowed.

These requirements are administered by the Dean of the University Faculty, Rockefeller Hall.

REQUIREMENTS CHANGEABLE

The College of Engineering reserves the right to modify its curricula and specific courses of instruction, to alter the requirements for admission or for graduation, and to change the degrees to be awarded, and such changes are applicable to either prospective or matriculated students at any such time as the college may determine.

GRADUATE STUDIES

Graduates of this College or of other colleges of engineering may enter the Graduate School of Cornell University and pursue advanced work in engineering. Such a student may enter either as a candidate for a degree (M.C.E., M.M.E., M.E.E., M.Chem.E., M.Met.E., M.S., or Ph.D.) or without candidacy for a degree, according to the character of his previous training. A prospective graduate student should consult the *Announcement of the Graduate School* and apply to the Dean of the Graduate School. Information concerning graduate scholarships and fellowships, including the John McMullen Graduate Scholarships, can be obtained either from the Dean of the Graduate School or from the Dean of the College of Engineering.

Prospective candidates for the degree M.Aero.E. should apply directly to the Director of the Graduate School of Aeronautical Engineering.

ENGINEERING LIBRARY

This Library maintains working collections in the fields which it serves. Each year the most important new books are added to its stacks, as well as current issues of engineering journals, and transactions and proceedings of many learned societies.

The library of the Schools of Civil, Mechanical, and Electrical Engineering located in Sibley Dome includes, in addition to the regular collection, the following collections and facilities: The Kuichling Memorial Library and the support of the Irving Porter Church Fund

in Civil Engineering. The Diederichs Memorial Library in Mechanical and Electrical Engineering and the James F. Lincoln Arc Welding Foundation Library in Mechanical Engineering. The Alexander Gray Memorial Library in Electrical Engineering.

The School of Chemical and Metallurgical Engineering has the facilities of an unusually complete library in Chemistry, Chemical Engineering, and Metallurgical Engineering located in Olin Hall.

PERSONNEL AND EMPLOYMENT PROGRAM

The College of Engineering maintains a Personnel and Employment Office under the direction of the College Personnel Officer. In cooperation with this office, each school has a personnel adviser to work with the student in an appraisal of his personal characteristics and to assist him in deciding upon the type of work for which he is best suited.

Beginning with the Class of 1928, periodic surveys have been made of all graduates and a detailed record is kept of their activities since graduation. Information thus assembled is used in determining industrial and occupational trends. In cooperation with the University Placement Service, employment information is sent to those graduates who request it.

THE ENGINEERING COLLEGE COUNCIL

The Engineering College Council consists of the President of the University, the Dean of the College, and a group of distinguished engineers, usually alumni, approved by the Board of Trustees of the University. The duties of the Council are to become thoroughly acquainted with the affairs of the College, to advise the administration and the Board of Trustees with regard to policies and programs designed to increase the efficiency of the established operations, to add to the available resources, to improve public and alumni relations, or in any other way to strengthen the College's work.

MISCELLANEOUS INFORMATION

DEAN'S HONOR LIST...Students of the College of Engineering whose weighted average in their studies is 85 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.

STUDENT ACTIVITIES...Students of the College of Engineering find many opportunities of engaging in wholesome activities outside their regular duties, and even outside the College, in company with members of the University generally. Within the College some find

congenial occupation in helping to carry on the student branches of the national engineering societies, in conducting *The Cornell Engineer*, or in membership in national or local honor societies, which include Tau Beta Pi, Phi Kappa Phi, Sigma Xi, Chi Epsilon, Rod and Bob, Pyramid, Atmos, Kappa Tau Chi, and Eta Kappa Nu. In the University at large there are student activities of all sorts, musical, dramatic, journalistic, social, and athletic.

ENGINEERING SOCIETIES...The College of Engineering is closely associated with the Ithaca Sections of the American Society of Civil Engineers, American Society of Mechanical Engineers, and American Institute of Electrical Engineers, many of the meetings of which are held on the campus and are participated in by the members of the College. The College also maintains active student branches of these national societies as well as of the American Institute of Chemical Engineers and the Institute of the Aeronautical Sciences. Their meetings are addressed by engineers of eminence, or are used for the presentation of papers by students, or for discussion, or for contests in public speaking on engineering subjects. The Schools of Mechanical and Electrical Engineering give elective credit hours for activity in the student branches of their respective engineering societies.

The Cornell Engineer, a technical journal published monthly throughout the academic year, is managed and edited by undergraduates in the College of Engineering. Elective credit is given for work on this magazine. (See page 135.)

STUDENT COUNSELORS...In each of the Schools the students have the assistance of a special corps of Class Advisers in the planning and scheduling of their academic work. Also the students are free to consult with the Dean, Directors, Department Heads, and the Instructors not only on matters pertinent to their education and future plans, but also on personal matters. In addition, the University's Dean of Men and his staff may be consulted by men students regarding their non-academic problems. There is also a Dean of Women. Both Deans have offices in the Administration Building.

ASSISTANCE TO FOREIGN STUDENTS...The University maintains on its staff a Counselor to Foreign Students, whose duty is to look after the welfare of all students from other countries. He may be consulted on personal problems, social questions, or any other matter in which he may be helpful. His office is in the Administration Building. It is suggested that all foreign students write him before coming to Ithaca, or call on him immediately upon arrival. He will be glad to meet foreign students at the train, help them find suitable living quarters, either at the Cosmopolitan Club or elsewhere, and introduce them to other University officials, members of the faculty, and other students.

ADMISSION

METHOD OF APPLICATION AND REQUIREMENTS FOR ADMISSION...All correspondence concerning admission to the College of Engineering should be addressed to the Director of Admissions, Cornell University, Ithaca, New York, who will forward the necessary application blanks on request.

Detailed information concerning the requirements for admission and methods of procedure are outlined in the University's *General Information* booklet, which every candidate for admission should read carefully and which can be obtained by application to the Cornell University Official Publication, 336 Administration Building, Ithaca, New York.

Entrance subjects must include English (three units), elementary and intermediate algebra (two units), plane geometry (one unit), and trigonometry (one-half unit). A foreign language (two units) *or* history (two units); advanced algebra (one-half unit) *or* solid geometry (one-half unit); and chemistry (one unit) *or* physics (one unit) must also be offered. It is strongly recommended that at least three of the elective units offered to make up the balance of fifteen be in language or history. Candidates for admission to the School of Chemical Engineering are required to have chemistry (one unit).

Each candidate for admission is required to take the Scholastic Aptitude Tests of the College Entrance Examination Board and to request the Board to report the results to the Director of Admissions, Cornell University. Candidates are urged to take the tests in January of their senior year.

SELECTIVE ADMISSION...The number of applicants admitted to the several schools of the College of Engineering is limited by the facilities available for adequate instruction. The Committee on Admissions in each of the Schools will exercise discretionary power in selecting those to be admitted. Preference will be given to those candidates whose academic preparation and personal character indicate fitness to pursue with success the course of study to be undertaken, who show evidence of professional promise, and who complete the filing of their entrance credentials in ample time for the Admission Committee to give thorough consideration to their qualifications.

PAYMENT TO THE UNIVERSITY

TUITION AND OTHER FEES...For information concerning tuition and other fees payable to the University, see the *General Information* booklet.

FINANCIAL AID

AID FOR NEW STUDENTS...Cornell University's provision of financial help for new students of the College of Engineering consists of certain scholarships which are awarded on the basis of competition, many of them to students entering the freshman class. Prospective freshmen are eligible to compete for twenty-five University Undergraduate Scholarships, 25 National Scholarships, 150 State Cornell Scholarships for residents of the State of New York, and a few others, most of which are restricted to residents of certain localities. The John McMullen Regional Scholarships in Engineering are available for new students coming from outside New York State.

John McMullen Regional Scholarships are awarded annually to thirty or more selected students entering the College of Engineering. Entering male students whose preparatory work was completed at a school outside New York State and those students from New York Schools who are ineligible, at the time they enter, for the Cornell Tuition Scholarships and the State Cash Scholarships offered by the State of New York are eligible to compete. These scholarships have variable stipends up to $300 a term and may be held throughout an undergraduate course of study, provided the recipient maintains the required academic record. They were established by the Board of Trustees from a portion of the income of a munificent gift to the University by the late John McMullen of Norwalk, Connecticut, and are allotted among fifteen districts of the United States. A student is not eligible for both the State and McMullen Regional Scholarships at the same time. An application blank will be sent direct to the candidate upon request to the Committee on Scholarships, College of Engineering. The applications are to be returned to the Chairman, Committee on Scholarships, before March 1. The candidates selected by the Committee for final consideration are requested to take the Scholastic Aptitude Test of the College Entrance Examination Board in April. These candidates are also interviewed by members of an alumni scholarship committee in their respective districts. Final selections are made by the Committee on Scholarships and the Dean, based upon the secondary school record, the aptitude test, and the qualities of character and general ability, as determined by the personal interview. The successful candidates are appointed by the President of the University.

The John McMullen Industrial Scholarships in Engineering are awarded each year to four graduates of secondary schools who have spent some time in industry and have had apprentice training, preferably in a formal course given by an industrial concern. Candidates must be sponsored by responsible officers of the companies by which they

have been employed. Each scholarship has a value of $300 a term and may be held throughout an undergraduate course of study provided the recipient maintains the required academic record. Inquiries should be addressed to the Chairman, Committee on Scholarships, College of Engineering, preferably not later than February, so that formal applications may be filed with the Committee on Scholarships before April 1.

For particulars of all other scholarships that are open to new students, the pamphlet on *Scholarships and Grants-in-Aid* should be consulted. This can be obtained by application to the Cornell University Official Publication, 336 Administration Building.

GRANTS AND OTHER AID

Students who establish superior academic records become eligible for John McMullen Regional Scholarships after one term of residence, regardless of the State in which they reside. Other scholarships, grants, and loans open to undergraduates are reserved for students who have been in residence and good standing at Cornell University for at least two terms.

Any student in the College of Engineering who needs financial aid should immediately consult the Director of his School. Ordinarily a single application is sufficient to assure consideration for all available scholarships and grants. When this is not true, the Director will instruct the student as to the proper procedure for making application. Scholarship applications for the following year received before April 1 will be given primary consideration. Late applications can be considered only for vacancies.

Certain grants are drawn from the income of special funds, the gifts of persons who in many instances have specified to whom in general their benefits are to apply. They are not as a rule available for aid to freshmen.

Much of the financial aid which the University is able to give undergraduate students is in the form of loans from the income of endowments which are administered for the Trustees by the standing Committee on Student Aid, of which the Dean of Men is Chairman. The benefits of these funds are reserved for students who have been in residence and in good standing at Cornell University for at least two terms, and preference is given to applicants of high scholastic standing who are within a year of graduation.

A special fund from which loans may be made to students in the School of Chemical and Metallurgical Engineering has been created by contributions from graduates of that School.

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 students of the University generally. A list of them under the title *Prize Competitions,* will be mailed on request addressed to Cornell University Official Publication, 336 Administration Building. Other prizes are open to competition particularly by students of the College of Engineering, as follows:

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 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, founded by the late Charles H. Baker, a graduate of the School of Civil Engineering of the class of 1886. Three prizes, one of $80, one of $40, and one of $20, are offered annually to members of the junior and senior classes in the Colleges of Engineering and Architecture for proficiency in public speaking.

The Charles Lee Crandall Prizes, founded in 1916 by alumni of the School of Civil Engineering; prizes of $75, $50, $35, and $20. They are awarded each year, by a committee appointed by the Director of the School of Civil Engineering, for the best papers written by seniors or juniors 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 May 1 of each year.

The Sibley Prizes in Mechanic Arts are offered to undergraduates in Mechanical and Electrical Engineering. Under a gift of Hiram Sibley,

made in 1884, the sum of $100 is awarded annually in several prizes to juniors and seniors in the School of Mechanical Engineering and in the School of Electrical Engineering who have received the highest marks in scholarship in at least three full terms of work.

The J. G. White Prize 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.

The Robert Harris Simpson Prize, founded in 1933 by Mrs. Simpson in memory of her late husband, Robert Harris Simpson, C.E. '96. This prize of $25 is awarded annually to that senior in the School of Civil Engineering who submits the best technical description or design of a civic improvement of sufficient substance and merit to justify the award. Papers or designs must be submitted on or before December 15 of each year and are judged by a committee appointed by the Director of the School of Civil Engineering.

Faculty and Staff

EDMUND EZRA DAY, Ph.D., LL.D., President of the University.
SOLOMON CADY HOLLISTER, B.S., C.E., D.Eng., Dean of the College and Professor of Civil Engineering.
WALTER L. CONWELL, C.E., Assistant Dean of the College and Professor of Highway Engineering.
ROBERT FRANKLIN CHAMBERLAIN, M.E., (in E.E.), Assistant Dean of the College and Personnel Officer. Professor of Electrical Engineering.
JOHN F. McMANUS, C.E., Administrative Assistant.
JEANETTE POOR, B.S., Librarian.

SCHOOL OF CIVIL ENGINEERING

NEPHI ALBERT CHRISTENSEN, B.S.C.E., M.S.C.E., Ph.D., Director of the School and Professor of Civil Engineering.

EMERITUS PROFESSORS

FRED ASA BARNES, C.E., M.C.E., Professor of Railroad Engineering, Emeritus.
SAMUEL LATIMER BOOTHROYD, M.S., Professor of Astronomy, Emeritus.
HENRY SYLVESTER JACOBY, C.E., Professor of Bridge Engineering, Emeritus.
JOHN THOMAS PARSON, Professor of Engineering Drawing, Emeritus.
ERNEST WILLIAM SCHODER, B.S., B.S. in Min., Ph.D., World War Memorial Professor of Experimental Hydraulics, Emeritus.
HERBERT HENRY SCOFIELD, M.E., Professor of Testing Materials, Emeritus.
CHARLES LEOPOLD WALKER, C.E., Professor of Sanitary Engineering, Emeritus.

PROFESSORS

DONALD J. BELCHER, B.S.C.E., M.S.E., Professor of Civil Engineering.
HARRY D. CONWAY, B.Sc. (Eng), M.A., Ph.D., Professor of Mechanics.
HOWARD MERRILL GIFFT, B.S., M.S., C.E., Professor of Sanitary Engineering.
DWIGHT FRANCIS GUNDER, B.S., M.S., Ph.D., Professor of Mechanics, Head of the Department of Mechanics, and Acting Head of the Department of Engineering Materials.
ROMEYN Y. THATCHER, C.E., Professor of Civil Engineeering.
PAUL HALLADAY UNDERWOOD, C.E., Professor of Surveying.
GEORGE WINTER, C.E., Ph.D., Professor of Structural Engineering.

ASSOCIATE PROFESSORS

MARVIN BOGEMA, B.S., M.C.E., Associate Professor of Civil Engineering.
EARLE NELSON BURROWS, C.E., M.C.E., Associate Professor of Structural Engineering.

CARL CRANDALL, C.E., Associate Professor of Civil Engineering and Secretary of the Engineering Faculty.
DAVID E. DONLEY, B.S. in C.E., C.E., Associate Professor of Civil Engineering.
BENJAMIN K. HOUGH, JR., B.S., M.S., Associate Professor of Soil Mechanics.
ERIC VAIL HOWELL, C.E., M.C.E., Associate Professor of Mechanics.
HERBERT THEODORE JENKINS, B.S. in C.E., M.S.E., Associate Professor of Civil Engineering.
ROBERT MAINS, B.S. in C.E., M.S. in C.E., Ph.D., Associate Professor of Structural Engineering.
JOHN EDWIN PERRY, B.S. in C.E., Associate Professor of Railroad Engineering and Personnel Officer of the School of Civil Engineering.
MELVILLE STANTON PRIEST, B.S., M.S., Associate Professor of Civil Engineering.
LINCOLN REID, B.S., M.S., Associate Professor of Hydraulics.

ASSISTANT PROFESSORS

RICHARD G. BOND, B.S., M.S., M.P.H., Assistant Professor of Civil Engineering.
GORDON PAGE FISHER, B.S. in C.E., Assistant Professor of Civil Engineering.
CHARLES DONALD GATES, B.A., M.S., Assistant Professor of Civil Engineering.
TAYLOR LEWIS, B.S. in C.E., Assistant Professor of Civil Engineering.
GEORGE B. LYON, B.S. in C.E., M.S., Assistant Professor of Civil Engineering.
FRED W. OCVIRK, B.S., M.S., Assistant Professor of Mechanics.
WALTER J. PURCELL, C.E., M.S. in Eng., Assistant Professor of Engineering Materials.
FRED J. SPRY, C.E., M.C.E., Assistant Professor of Surveying.
MERTON J. WILLIS, B.S. in C.E., M.S.E., Assistant Professor of Civil Engineering.

INSTRUCTORS

THEODORE E. GAZDA, B.S. in C.E., Instructor in Civil Engineering.
WILLIAM L. HEWITT, A.B., B.C.E., Instructor in Drawing.
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BRUCE R. LAVERTY, B.S. in C.E., Instructor in Civil Engineering.
CYRIL J. MORRIS, B.A., B.S., Instructor in Civil Engineering.
THURLOW C. NELSON, B.S. in C.E., Instructor in Civil Engineering.

RESEARCH ASSOCIATES

RAYMOND JOSEPH HODGE, B.C.E., M.C.E., Research Associate in Transportation.
HERMAN C. LADENHEIM, A.B., Research Associate in Transportation.
ROBERT BRUCE McCALLEY, JR., Research Associate in Structures.

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FRED STILLMAN ROGERS, B.S., M.E., Professor of Machine Design.
CLARENCE ELLSWORTH TOWNSEND, M.E., Professor and Head of the Department of Engineering Drawing.

ASSOCIATE PROFESSORS

WILLIAM COOK ANDRAE, M.E., M.M.E., Associate Professor of Mechanical Engineering.
ROY EDWARDS CLARK, M.E., Associate Professor of Heat-Power Engineering.
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ASSISTANT PROFESSORS

THOMAS J. BAIRD, B.Arch., M.R.P., Assistant Professor of Engineering Drawing.

GERALD WAGNER EHRHART, M.E., M.M.E., Assistant Professor of Engineering Materials.

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JOHN ROBERT YOUNG, B.S. in Ch.E., M.S. in Eng., Assistant Professor of Engineering Materials.

INSTRUCTORS

ROBERT NELSON ALLEN, B.S. in A.E., Instructor in Mechanical Engineering,

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HENRY J. GIESELER, B.M.E., Instructor in Engineering Materials.

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VINCENT JEROME HIMROD, B.S. in A.E., Instructor in Mechanical Engineering.
JOHN C. HUSON, Instructor-Technician in Mechanical Engineering.
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NORMAN D. KOUF, Instructor-Technician in Mechanical Engineering.
ROBERT EYNON McGARRAH, B.S. in A.E., M.S. in Eng., Instructor in Mechanical Engineering.
ARTHUR J. MACK, Instructor-Technician in Mechanical Engineering.
ELMER SYLVESTOR MONROE, JR., B.S. in M.E., Instructor in Mechanical Engineering.
W. EVERETT MORGAN, Instructor-Technician in Mechanical Engineering.
RICHARD MAGRUDER PHELAN, B.S. in M.E., Instructor in Mechanical Engineering.
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WILLIAM KERR STAMETS, JR., B.M.E., Instructor in Mechanical Engineering.
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ERNEST S. YAWGER, Instructor-Technician in Mechanical Engineering.
HAROLD CROZIER YOST, B.M.E., Instructor in Mechanical Engineering.

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CHARLES RUSSELL BURROWS, B.S.E. (in E.E.), A.M., E.E., Ph. D., Director of the School of Electrical Engineering and Professor of Electrical Engineering.

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ROBERT FRANKLIN CHAMBERLAIN, M.E. (in E.E.), Professor of Electrical Engineering, and Personnel Officer of the School.
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MALCOLM STRONG McILROY, E.E., Sc.D. in E.E., Professor of Electrical Engineering.
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STANLEY WILLIAM ZIMMERMAN, B.S. in E.E., M.S. in E.E., Professor of Electrical Engineering.

ASSOCIATE PROFESSORS

WALTER WENDELL COTNER, B.S. (in E.E.), E.E., M.E.E., Associate Professor of Electrical Engineering.
CASPER LEHMAN COTTRELL, A.B., Ph.D., Associate Professor of Electrical Engineering.
WILLIAM HARRY ERICKSON, B.S. in E.E., M.S. in E.E., Associate Professor of Electrical Engineering.
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WALTER ROY JONES, E.E., Associate Professor of Electrical Engineering.
ERNEST WILLIAM SUMMERS, B.S.E.E., Associate Professor of Electrical Engineering.

ASSISTANT PROFESSORS

PAUL DENZIL ANKRUM, B.S.E.E., A.B., M.S.E., Assistant Professor of Electrical Engineering.
ALFRED EMERYS DAVIES, B.S. in E.E., M.S. in Ed., Assistant Professor of Electrical Engineering.
MERLE JOHN KELLY, B.S., M.S., Assistant Professor of Electrical Engineering.
ROBERT E. OSBORN, B.S.E.E., Assistant Professor of Electrical Engineering.
STANLEY LEWRY SCHAUSS, E.E., Sc.M., Assistant Professor of Electrical Engineering.
CHARLES LOUIS SEEGER, III, B.E.E., Assistant Professor of Electrical Engineering.
WILLIAM HENDERSON WILDER, B.E.E., M.E.E., Assistant Professor of Electrical Engineering.

INSTRUCTORS

ROGER JOHN AMOROSI, B.E.E., Instructor in Electrical Engineering.
RALPH BOLGIANO, JR., B.S. in E.E., Instructor in Electrical Engineering.
NELSON HOWARD BRYANT, E.E., M.E.E., Instructor in Electrical Engineering.
HARRY GEISEN, B.S. in E.E., Instructor in Electrical Engineering.
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WALTER MILBURN KEENAN, B.E.E., Instructor in Electrical Engineering.
HARRY WILBUR LAWSON, JR., B.S. in E.E., Instructor in Electrical Engineering.
SIMPSON LINKE, B.S. in E.E., M.E.E., Instructor in Electrical Engineering.
JOSEPH CARL LOGUE, B.E.E., M.E.E., Instructor in Electrical Engineering.
HENRY STOCKWELL McGAUGHAN, B.S.E. (in Physics), Instructor in Electrical Engineering.
BENJAMIN NICHOLS, B.E.E., M.E.E., Instructor in Electrical Engineering.
JOSEPH L. ROSSON, B.S. in E.E., Instructor in Electrical Engineering.
WALTER AUGUST SAUTER, B.S. in E.E., Instructor in Electrical Engineering.
EUGENE ROBERT SCATTERGOOD, B.S. in E.E., Instructor in Electrical Engineering.
HENRY J. SMITH, B.S. in E.E., Instructor in Electrical Engineering.
JOHN HAMPTON SMITH, B.S. in M.E., Instructor in Electrical Engineering.
LAWRENCE BYRON SPENCER, E.E., Instructor-Technician in Electrical Engineering.
MARK ALAN STEINHACKER, B.S. in E.E., Instructor in Electrical Engineering.
GEORGE ROBERT UTTING, B.S. in E.E., Instructor in Electrical Engineering.
GORDON JAMES WATT, B.S. in M.E., M.S. in Engineering, Instructor in Electrical Engineering.
RUSSELL WOLFE, B.S. in Engineering, Instructor in Electrical Engineering.

RESEARCH ASSOCIATES

WILLIAM EDWIN GORDON, B.A., M.A., M.S., Research Associate in Electrical Engineering.
CARL HERWALD SUNDELL, Research Associate in Electrical Engineering.
ROBERT DOWNING WILSON, B.E.E., Research Associate in Electrical Engineering.

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CHARLES CALVERT WINDING, B.Chem.E., Ph.D., Professor of Chemical Engineering and Assistant Director for Chemical Engineering.

ASSISTANT PROFESSORS

MALCOLM S. BURTON, B.S. in M.E., S.M. in M.E., Assistant Professor of Metallurgy.
JULIAN C. SMITH, B.Chem., Chem.E., Assistant Professor of Chemical Engineering.
ROBERT L. VON BERG, B.S. in Chem.E., M.S. in Chem.E., Sc.D., Assistant Professor of Chemical Engineering.
HERBERT F. WIEGANDT, B.S. in Chem.E., M.S. in Eng., Ph.D., Assistant Professor of Chemical Engineering.

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MORRIS L. HARPER, Instructor-Technician in Metallurgy.
RALPH W. HODGES, Instructor-Technician in Metallurgy.
DENNIS J. JOYCE, Instructor-Technician in Metallurgy.

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WILLIAM R. SEARS, B.Aero.E., Ph.D., Director of the School, and Professor of Aeronautical Engineering.

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ARTHUR KANTROWITZ, B.S., M.A., Ph.D., Associate Professor of Aeronautical Engineering.
JOHN M. WILD, B.S. in M.E., M.S. in Aero.E., Associate Professor of Aeronautical Engineering.

ASSISTANT PROFESSOR

YUNG-HUAI KUO, B.S., M.A., Ph.D., Assistant Professor of Aeronautical Engineering.

LECTURER

ALEXANDER FLAX, B.Aero.E., Lecturer in Aeronautical Engineering.

RESEARCH ASSOCIATE

EDWIN L. RESLER, JR., B.S. (Aero. E.), Research Associate in Aeronautical Engineering.

DEPARTMENT OF ENGINEERING PHYSICS

LLOYD PRESTON SMITH, Ph.D., Director of the Department and Chairman of the Department of Physics and Professor of Physics.

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CHARLES RUSSELL BURROWS, Ph.D., Director of the School of Electrical Engineering and Professor of Electrical Engineering.
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DWIGHT F. GUNDER, B.S., M.S., Ph.D., Head of the Department, and Professor of Mechanics.

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HARRY D. CONWAY, B.Sc. (Eng.), M.A., Ph.D., Professor of Mechanics.
W. RODNEY CORNELL, B.S., C.E., Professor of Mechanics.

ASSOCIATE PROFESSORS

TREVOR RHYS CUYKENDALL, Ph.D., Associate Professor of Engineering Physics.
ERIC V. HOWELL, C.E., MC.E., Associate Professor of Mechanics.
HAROLD C. PERKINS, M.E., Associate Professor of Mechanics.

ASSISTANT PROFESSORS

CLARENCE B. MANSKY, B.S. in M.E., M.S. in Eng., Assistant Professor of Mechanics.
FRED W. OCVIRK, B.S., M.S., Assistant Professor of Mechanics.

INSTRUCTORS

JOHN D. M. CAMERON, B.M.E., Instructor in Mechanics.
EDWIN S. GALLACHER, B.S., in M.E., Instructor in Mechanics.
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DWIGHT F. GUNDER, B.S., M.S., Ph.D., Acting Head of the Department, and Professor of Mechanics.
JOSEPH O. JEFFREY, M.E., M.M.E., Professor of Engineering Materials.
CLYDE W. MASON, A.B., Ph.D., Professor of Chemical Microscopy and Metallography.
JOHN R. MOYNIHAN, M.E., M.M.E., Professor of Engineering Materials.

ASSOCIATE PROFESSOR

HENRI S. SACK, Sc.D., Associate Professor of Engineering Physics.

ASSISTANT PROFESSORS

GERALD W. EHRHART, M.E., M.M.E., Assistant Professor of Engineering Materials.
WALTER J. PURCELL, C.E., M.S. in Eng., Assistant Professor of Engineering Materials.
HERBERT F. WIEGANDT, B.S. in Chem.E., M.S. in Eng., Ph.D., Assistant Professor of Chemical Engineering.
JOHN R. YOUNG, B.S. in Chem.E., M.S. in Eng., Assistant Professor of Engineering Materials.

INSTRUCTORS

OWEN J. BLACK, JR., B.S. in M.E., Instructor in Engineering Materials.
HENRY J. GIESELER, B.M.E., Instructor in Engineering Materials.
FRANK A. SWINGLE, B.M.E., Instructor in Engineering Materials.

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School of Civil Engineering

THE COURSES OF STUDY

The courses of study offered by the School of Civil Engineering lead to the degree of Bachelor of Civil Engineering. The courses are all planned to provide fundamental instruction for the practice of the profession. In order to meet this objective, the major portion of the curriculum is definitely prescribed, both as to technical content and humanistic studies. Each student, however, is permitted to choose elective courses in various fields which can be planned to intensify the training in a specific area, or to increase the general background of the student.

EQUIPMENT

The principal building occupied by the School of Civil Engineering is Lincoln Hall, containing classrooms, drafting rooms, and laboratories.

The laboratories in Lincoln Hall are as follows: the Testing Laboratory, equipped for a wide variety of tests of cement, concrete, timber, structural steel, and other construction materials used by civil engineers; the Sanitary Laboratory, with facilities for physical, chemical, bacteriological, and biological analyses of water and sewage, and for research in the field of sanitary engineering.

The Soil Mechanics Laboratory is located in a separate building and has available facilities for instruction, standard laboratory work, and specialized research in this field.

The Highway Laboratories are housed in separate buildings and are equipped for making the standard tests and for research in the field of highway engineering. Astronomical equipment in the Fuertes Observatory includes the instruments required for determining time, latitude, longitude, and azimuth.

A large and unusual Hydraulic Laboratory, situated at the outlet of Beebe Lake, is under the jurisdiction of this School. In addition to student instruction and research, this laboratory provides facilities for numerous important hydraulic investigations carried on in cooperation with governmental agencies and private companies.

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to impart knowledge of the fundamental principles of design, construction, and operation of structures and works of the civil engineering type, in addition to providing a liberal opportunity for study of general and cultural subjects. Emphasis is placed upon civil engineering as an applied science rather than as a vocational technique.

Civil Engineering students follow the first year with as thorough a preparation as possible in the following subjects: the survey, design, construction, and operation of buildings, roads, railroads, canals, sewers, and water works; the construction of foundations under water and on land, and of superstructures and tunnels; the survey, improvement, and protection of coasts, and the regulation of rivers, harbors, and lakes; the astronomical determination of geographical coordinates for geodetic and other purposes; the application of mechanics, graphical statics, and descriptive geometry to the construction of the various kinds of arches, girders, roofs, trusses, suspension and cantilever bridges; the drainage of districts, sewerage of towns, and irrigation and reclaiming of land; the applications and tests of hydraulic and electric motors; the preparation of drawings, plans, specifications, and the proper inspection and tests of the materials used in construction. Instruction is given in engineering economy, finance, and jurisprudence. The latter subject deals principally with the fundamental principles of the law of contracts. Opportunity is also given to seniors to specialize to a limited extent, or to broaden their training, by the election of certain courses, some of which may be chosen from approved courses in any department of the University.

The instruction in mathematics, chemistry, physics, geology, economics, psychology, and English is given in the College of Arts and Sciences. All other regular subjects are taught in the School of Civil Engineering, the School of Mechanical Engineering, or the School of Electrical Engineering.

SCHOLASTIC REQUIREMENTS

A student in the School of Civil Engineering who does not receive a passing grade in every course in which he is registered, or fails in any term or summer session to maintain a minimum average of 70 per cent may be dropped from the University or placed on probation.

FIVE-YEAR CURRICULUM (B.C.E.)

REGULAR COURSE

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	3	3
	English 111, Reading and Writing	3	3	0
	Engineering 2001, Drawing	3	0	7½
	Engineering 2101, Elementary Surveying	3	1	5
	Total	18		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	3	3
	English 112, Reading and Writing	3	3	0
	Engineering 2002, Drawing	3	0	7½
	Engineering 2110, Route Surveying	2	2	0
	Total	17		

In addition to these courses, all Freshmen must satisfy the University's requirements in Military Science and Tactics and Physical Training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Economics 107, Introduction to Economics (or Public Speaking 101)	3	3	0
	Geology 113, Engineering Geology (or Advanced Surveying 2102)	3	2	5
	Engineering 1131, Mechanics-Statics	3	3	0
	Total	17		
TERM 4	Physics 118, Physical Electronics and Optics	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Public Speaking 101 (or Economics 107)	3	3	0
	Engineering 2102, Advanced Surveying (or Geology 113)	3	1	5
	Engineering 1132, Mechanics-Dynamics	3	–	–
	Engineering 1133, Strength of Materials	3	–	–
	Total	17		

In addition to these courses, all Sophomores must satisfy the University's requirements in Military Science and Tactics and Physical Training.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
	Engineering 2103, Summer Survey Camp	5	–	–
TERM 5	Engineering 1134, Strength of Materials	3	–	–
	Engineering 1211, Materials (or 2901)	3	2	2½
	Engineering 2301, Fluid Mechanics	3	3	0
	Engineering 2501, Sanitary Science (or Accounting 3231)	3	2	2½
	Engineering 2701, Elementary Structural Analysis	3	2	2½
	Engineering 4921, Electrical Engineering	3	2	3
	Total	18		
TERM 6	Engineering 2901, Construction Methods (or 1211)	3	3	0
	Engineering 2302, Hydraulics	3	2	2½
	Engineering 3231, Accounting (or 2501)	3	2	2½
	Engineering 2702, Elements of Metal and Timber Structures	3	3	0
	Psychology 440, Psychology for Engineers	3	3	0
	Engineering 4922, Electrical Engineering	3	–	–
	Total	18		
TERM 7	Engineering 1212, Materials Laboratory (or 2725)	3	1	5
	Engineering 2401, Applied Hydrology	2	2	0
	Engineering 2502, Water Supply and Treatment (or 2503)	3	2	2½
	Engineering 2715, Reinforced Concrete Design (or 2703)	3	0	6
	Engineering 2902, Engineering Law (or 2610)	3	2	2½
	Engineering 3541, Heat Power I	3	2	2
	History 165, Science in Western Civilization	3	3	0
	Total	20		
TERM 8	Engineering 2725, Soil Mechanics (or 1212)	3	2	2½
	Engineering 2402, Hydraulic Engineering	2	2	0
	Engineering 2503, Sewerage and Sewage Treatment (or 2502)	3	2	2½
	Engineering 2703, Steel and Timber Design (or 2715)	3	0	7½
	Engineering 2610, Highway Engineering (or 2902)	3	2	2½
	Engineering 3542, Heat Power II	2	2	0
	History 166, Science in Western Civilization	3	3	0
	Engineering 2850, Inspection Trip	Required		
	Total	19		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 9	Engineering 1145, Applied Mathematics (or 2602)	3	3	0
	Engineering 2704, Statically Indeterminate Structures (or 2720)	3	2	2½
	Engineering 2903, Economics of Engineering (or 2904)	3	3	0
	Economics 401, Labor Conditions and Problems (or 201)	3	3	0
	Electives (Free)	6		
	Total	18		
TERM 10	Engineering 2602, Transportation (or 1145)	3	3	0
	Engineering 2720, Foundations (or 2704)	3	2	2½
	Engineering 2904, Public Administration (or 2903)	3	3	0
	Economics 201, Money and Banking (or 401)	3	3	0
	Electives (Free)	6		
	Total	18		

Grand total for ten terms—185 credit hours including Summer Survey Camp, but not including Military Science and Tactics, or Physical Training.

FOUR-YEAR CURRICULUM (B.C.E.)

(See page 6)

TERM 1	Mathematics 155, Analytic Geometry and Calculus	5	5	0
	Physics 107, Mechanics, Sound, and Heat	4	4	2½
	Chemistry 101 or 105, General Inorganic Chemistry	3	3	3
	Engineering 2001, Drawing	3	0	7½
	Engineering 2101, Surveying	3	1	5
	Total	18		
TERM 2	Mathematics 156, Analytic Geometry and Calculus	5	5	0
	Physics 108, Electricity and Light	4	4	2½
	Chemistry 102 or 106, General Inorganic Chemistry	3	3	3
	Engineering 2051, Drawing	3	0	7½
	Engineering 2151, Surveying	3	3	0
	Total	18		

In addition to taking the above courses, all Freshmen must satisfy the University's requirements in Physical Training and in Military Science and Tactics.

TERM 3	Public Speaking 101	3	3	0
	Geology 113, Engineering Geology	3	2	5
	Engineering 2002, Drawing	3	0	6
	Engineering 1136, 1137, Mechanics	6	5	2½
	Engineering 2601, Route Surveying	3	1	5
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 4	English 111, Reading and Writing	3	3	0
	Astronomy 182, Field Astronomy	2	2	0
	Engineering 2052, Drawing	2	0	5
	Engineering 1138, 1139, Mechanics	5	4	2½
	Engineering 2901, Construction Methods	3	3	0
	Economics 107, Introduction to Economics	3	3	0
	Total	18		

In addition to these courses, all Sophomores must satisfy the University's requirements in Military Science and Tactics and Physical Training.

TERM 5	Engineering 2103, Summer Survey Camp	5		
	Engineering 1225, Materials	3	3	0
	Engineering 1226, Materials Laboratory	3	0	5
	Engineering 2351, Hydraulics	4	3	2½
	Engineering 2751, Structural Analysis	4	3	2½
	Total	19		
TERM 6	Engineering 2702, Structural Design	3	0	7½
	Engineering 2725, Soil Mechanics	3	2	2½
	Engineering 2502, Treatment of Water	3	2	2½
	Engineering 2503, Sewerage and Sewage Treatment	3	2	2½
	Engineering 2715, Concrete Construction	3	0	6
	Elective	3		
	Total	18		
TERM 7	Engineering 4920, Electrical Equipment	3	2	2½
	Engineering 2903, Engineering Management	3	3	0
	Engineering 2610, Highway Engineering	3	2	2½
	Engineering 2902, Engineering Law	3	3	0
	Electives	6		
	Total	18		
TERM 8	Engineering 3543, Heat-Power Engineering	3	2	2½
	Engineering 2401, Applied Hydrology	2	2	0
	Engineering 2720, Foundations	3	3	0
	Engineering 2752, Engineering Problems	2	0	5
	Electives	6		
	Total	16		

Grand total for eight terms ..... 143 academic hours
(not including Military Science and Tactics and Physical Training)

Sibley School of Mechanical Engineering

EQUIPMENT

The Sibley School of Mechanical Engineering, named in recognition of important gifts made by Hiram Sibley and his son, Hiram W. Sibley, occupies a group of buildings at the north end of the campus. In addition to the Sibley Buildings, this group includes Rand Hall, which was added through the generosity of Mrs. Florence O. R. Lang as a memorial to Jasper R. Rand, Addison C. Rand, and Jasper R. Rand, jr. The school is provided with a central working library in Sibley Dome and many of the departments also maintain special working and reference libraries.

Numerous laboratories and shops are available for carrying on the many activities of the School of Mechanical Engineering, as follows: the Materials Testing Laboratory, Heat Treatment Laboratory, and Metallography Laboratory, for determination of the physical properties of engineering materials under various conditions; the Photo-elasticity Laboratory, for instruction and research in photoelastic work; the Steam Laboratory, for instruction and research involving steam power; the Internal-Combustion Engine Laboratory, for work with this type of power equipment; the M. E. Hydraulics Laboratory, a pump-operated laboratory for hydraulic problems; the Lubrication Laboratory, for determination of the physical properties of lubricants; the Refrigeration Laboratory, for the study of refrigeration; the Fuel Testing Laboratory, for determination of the composition and calorific value of all types of fuel; the Foundry Sand Laboratory for determining the properties of various mixtures of sands and binders under the temperatures and pressures existing in foundry molds; the Micro-Motion Laboratory, for motion and time study; the Constant-Temperature Room, and the Heat Transfer, Heating, Ventilating, Air Conditioning Laboratories; a series of Research Laboratories; the Materials Processing Laboratories – the Woodworking and Pattern Shop, the Machine Shop and Gage Laboratory; the Laboratory Boiler House; and the University Heating Plant and Power House.

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to lay as broad and substantial a foundation of general and technical knowledge and provide as much training in engineering practice in the fields of Mechanical Engineering and Engineering Administration as can well be imparted in a school.

Students of Mechanical Engineering are instructed primarily in the utilization of nature's sources of energy and materials for the benefit of mankind, through the development and application of prime movers, machinery, and processes of manufacture; thus, they have to do mainly with things dynamic. The province of the mechanical engineer includes the design, construction, operation, and testing of steam engines, steam turbines, steam generating apparatus, and power plant auxiliaries, internal combustion engines, hydraulic machines, pumping engines, railway equipment, compressed-air machines, ice making and refrigerating machinery, equipment for heating and ventilating and air conditioning, machine tools, mill equipment, and transmission machinery. The work of the mechanical engineer further includes the planning of power plants and factories, the selection and installation of their equipment, the development of systems of operation and manufacturing processes, and the organization and administration of plants and industries. In addition the mechanical engineer may engage in scientific research in the innumerable branches of this field.

During the earlier terms, fundamental instruction is given in mathematics, physics, chemistry, drawing, materials processing, mechanics of engineering, strength of materials, materials of construction, mechanism, applied mathematics, economics, industrial organization and management, English, public speaking, and psychology. This fundamental training is followed during the last three years with instruction in the fields of thermodynamics, heat transfer, fluid mechanics, machine design, cost control, electrical engineering, testing of materials, steam power-plant engineering, combustion engineering, refrigeration and air conditioning, mechanical engineering, laboratory practice, advanced mechanics and strength of materials, advanced work in materials processing, industrial history, business law, and industrial engineering.

PROJECT AND ELECTIVES

During the last two years, provision is made for the choice of elective courses and a senior project in the student's major field of study. His project may be an individual one or a group project in a technical, managerial or related field for the purpose of applying to one or more basic problems the fundamental concepts he has been taught in the preceding years and for the purpose of developing in him the ability to do work of an original nature.

The project may be in any one of many branches, such as, management, industrial engineering, heat-power engineering, internal combustion engines, heat engineering, heating, ventilating and air conditioning, refrigeration engineering, automotive engineering, aeronautical engineering, mechanical design, advanced mechanics and strength of materials, metallurgical engineering, engineering materials, experimental engineering, materials processing, tool engineering, welding engineering, structural engineering, physics, electrical engineering, and other fields related to mechanical engineering.

OPTIONS

The curriculum in Mechanical Engineering is fixed for all students through the first two years. At the start of the third year, each student is required to elect either of two options, A or B. Option B requires somewhat less work in the fields of heat-power engineering and electrical engineering than does Option A. It provides for fewer free electives and slightly less work related to the project than does Option A. The time thus made available is devoted to courses which provide additional training in the field of Industrial Engineering and Management for those students who prefer specific work in this field rather than in the more technical fields. Training is provided in the fields of industrial statistics, methods engineering, production engineering, industrial marketing, and cost accounting.

Both options lead to the B.M.E. degree.

(See also pp. 7 for note on Industrial Cooperative Plan).

EMPLOYMENT AFTER GRADUATION

Graduates in Mechanical Engineering find employment in the design, construction, testing, and operation of prime movers and other machinery, and of complete plants in their own and related fields, and in sales engineering and industrial research and development. They serve also as planners of new projects and processes, and as aeronautical engineers, air-conditioning engineers, industrial engineers, power-plant engineers, refrigeration engineers, research engineers, and teachers of engineering—to mention only a few of the many special fields open to them. With the instruction in liberal subjects and those related to administration and management coupled with the technical training, they have special qualifications to develop into leaders in their chosen field.

SCHOLASTIC REQUIREMENTS

A student in the School of Mechanical Engineering who does not receive a passing grade in every course in which he is registered, or fails in any term or summer session to maintain a minimum average of 70 per cent may be dropped from the University or placed on probation.

FIVE-YEAR CURRICULUM (B.M.E.)

		HOURS CREDIT	CONTACT HOURS REC. LEC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	3	3
	English 111, Reading and Writing	3	3	0
	Engineering 3111, Drawing and Descriptive Geometry	3	1	5
	Engineering 3001, Introductory Lectures	0	1	0
	Engineering 6110, Casting, Working, and Welding of Metals (or Pattern Shop 3401 and Machine Tools 3403)	2	1	2
		17		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	3	3
	English 112, Reading and Writing	3	3	0
	Engineering, 3112, Mechanical Drafting	3	1	5
	Engineering, 3401, Pattern Shop } or Engineering 6110	1	0	2½
	Engineering, 3403, Fundamentals of Machine Tools } or Engineering 6110	1	0	2½
		17		

In addition to taking the previously mentioned courses, all freshmen must satisfy the University requirements in Physical Training and in Military Science and Tactics.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Introduction to Organic Chemistry	2	2	0
	Engineering 1151, Mechanics of Engineering, Statics	3	3	0
	Economics 107, Introduction to Economics (or Corporate and Industrial Organization, 3235)	3	3	0
	Psychology 440 (or Production Machine Tools, 3404)	3	3	0
	Public Speaking 105 (or Gage Laboratory, 3405)	2	2	0
		19		
TERM 4	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Introduction to Physical Chemistry	2	2	0
	Engineering 1152, Mechanics of En'g, Dynamics	3	3	0
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 3235, Corporate and Industrial Organization (or Introduction to Economics, 107)	3	3	0
	Engineering 3404, Production Machine Tools (or Psychology 440)	2	0	5
	Engineering 3405, Gage Laboratory (or Public Speaking 105)	1	0	2½
		17		

In addition, all sophomores must satisfy the University requirements in Physical Training and in Military Science and Tactics.

OPTION A

		HOURS CREDIT	CONTACT HOURS REC. LEC.	LAB. COMP.
TERM 5	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3250, Industrial Accounting and Cost Control	4	2	5
	Engineering 3351, Mechanism	3	2	2½
	Engineering 3501, Engineering Thermodynamics	4	3	2½
	Engineering 3502, Heat-Power Laboratory	2	0	5
	Engineering 1155, Applied Mathematics (or Fluid Mechanics, 2331)	3	3	0
		19		
TERM 6	Engineering 1154, Advanced Strength of Materials	3	3	0
	Engineering 1222, Engineering Materials	3	3	0
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 3503, Heat Transfer and Thermal Measurements	3	2	2½
	Engineering 2331, Fluid Mechanics (or Applied Mathematics 1155)	3	3	0
		18		
TERM 7	Engineering 1232, Engineering Materials Laboratory	3	1	2½
	Engineering 3353, Design of Machine Members	3	2	2½
	Engineering 3504, Fuels and Combustion	2	2	0
	Engineering 3505, Refrigeration and Air Conditioning	3	2	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 6113, Casting, Working, and Welding of Metals	3	2	2
		17		
TERM 8	Engineering 3261, Industrial Engineering	3	1	5
	Engineering 3354, Design of Machines	3	1	5
	Engineering 3506, Steam Power	3	2	2½
	Engineering 3507, Combustion Engines	4	3	2½
	Engineering 4932, Electrical Engineering	3	2	3
	Electives	3		
		19		
TERM 9	Engineering 4933, Electrical Engineering	3	2	3
	History 165, Science in Western Civilization	3	3	0
	Project	3		
	Courses related to project	3		
	Electives	3		
	Law	3	3	0
		18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 10	Engineering 4934, Electrical Engineering	3	2	3
	History 166, Science in Western Civilization	3	3	0
	Project	3		
	Courses related to project	3		
	Electives	6		
	Engineering 3041, Non-Resident Lectures	1	1	0
		19		
	Total for ten terms	180		

OPTION B

TERM 5	Engineering 1155, Applied Mathematics	3	3	0
	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3241, Industrial Statistics	3	2	2½
	Engineering 3250, Industrial Accounting and Cost Control	4	2	5
	Engineering 3351, Mechanism	3	2	2½
	Engineering 2331, Fluid Mechanics (or Methods Engineering, 3262)	3	3	0
		19		
TERM 6	Engineering 1154, Advanced Strength of Materials	3	3	0
	Engineering 1222, Engineering Materials	3	3	0
	Engineering 1231, Engineering Materials Lab	3	1	2½
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 3501, Engineering Thermodynamics	4	3	2½
	Engineering 3262, Methods Engineering (or Fluid Mechanics, 2331)	3	1	5
		19		
TERM 7	Engineering 1232, Engineering Materials Lab	3	1	2½
	Engineering 3263, Production Engineering	3	1	5
	Engineering 3353, Design of Machine Members	3	2	2½
	Engineering 3502, Heat-Power Lab	2	0	5
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 6113, Casting, Working, and Welding of Metals	3	2	2
		17		
TERM 8	Engineering 3264, Production Engineering	3	1	5
	Engineering 3270, Industrial Marketing	3	3	0
	Engineering 3356, Design of Machines	3	1	5
	Engineering 3503, Heat Transfer and Thermal Measurements	3	2	2½
	Engineering 3504, Fuels and Combustion	2	2	0
	Engineering 4932, Electrical Engineering	3	2	3
	Electives	2		
		19		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 9	Engineering 3254, Standard Costs	3	1	5
	Engineering 3508, Heat Power	3	2	2½
	Engineering 4933, Electrical Engineering	3	2	3
	History 165, Science in Western Civilization	3	3	0
	Project	3		
	Courses related to project	3		
		18		
TERM 10	Engineering 3509, Heat Power	3	2	2½
	History 166, Science in Western Civilization	3	3	0
	Law	3	3	0
	Project	3		
	Electives	5		
	Engineering 3041, Non-Resident Lectures	1	1	0
		18		
	Total for ten terms	180		

FOUR-YEAR CURRICULUM (B.M.E.)

(See page 6)

TERM 1	Same as Term 1 of the 5-year curriculum (page 36)			
TERM 2	Same as Term 2 of the 5-year curriculum (page 36)			
TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Introduction to Organic Chemistry	2	2	0
	Engineering 3235, Corporate and Industrial Organization	3	3	0
	Public Speaking 105 (either term)	2	2	0
	Economics 107, Introduction to Economics (either term)	3	3	0
	Psychology 440, Psychology for Engineering Students (either term)	3	3	0
	Total	19		
TERM 4	Engineering 1151, Mechanics of Engineering, Statics	3	3	0
	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Introduction to Physical Chemistry	2	2	0
	Engineering 3351, Mechanics	3	2	2½
	Engineering 3250, Cost Accounting	4	2	5
	Engineering 3404, Production Machine Tools	2	0	5
	Engineering 3405, Gage Laboratory	1	0	2½
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Engineering 1152, Mechanics of Engineering, Dynamics	3	3	0
	Engineering 3535, Heat-Power Engineering	3	3	0
	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 2331, Fluid Mechanics (either term)	3	3	0
	Total	18		
TERM 6	Engineering 1153, Strength of Materials	3	3	0
	Engineering 3536, Heat-Power Engineering	3	3	0
	Engineering 1222, Engineering Materials	3	3	0
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Engineering 4932, Electrical Engineering	3	2	3
	Engineering 1155, Applied Mathematics (either term)	3	3	0
	Total	18		
TERM 7	Engineering 1154, Advanced Strength of Materials	3	3	0
	Engineering 3353, Design of Machine Members	3	2	2½
	Engineering 1232, Engineering Materials Laboratory	3	1	2½
	Engineering 3581, Internal Combustion Engines	3	3	0
	Engineering 3601, Mechanical Engineering Laboratory	3	0	5
	Engineering 4933, Electrical Engineering	3	2	3
	Total	18		
TERM 8	Engineering 3354, Design of Machines	3	1	5
	Engineering 3582, Steam-Power Plants	3	3	0
	Engineering 3602, Mechanical Engineering Laboratory	3	0	5
	Engineering 3261, Industrial Engineering	3	1	5
	Engineering 6113, Casting, Working, and Welding of Metals	3	2	2
	Engineering 4934, Electrical Engineering	3	2	3
	Total	18		
	Grand total for eight terms	143		

School of Electrical Engineering

EQUIPMENT

The School of Electrical Engineering occupies the greater portion of Franklin Hall, and the second floor of Rand Hall. Some of its facilities are located in the studios and the transmitter of the University Broadcasting Station WHCU.

The School's library, which was established through a generous gift of the McGraw-Hill Book Company in memory of the first director of the School, is known as the Alexander Gray Memorial Library. The library is housed in Sibley Dome, as a unit of the combined Mechanical, Electrical, and Civil Engineering Library.

The School's lecture and laboratory facilities have been expanded and modernized through the acquisition of equipment which has become available since the end of the war.

Laboratory facilities include the Electrical Machinery Laboratories, with a great variety of both direct- and alternating-current machinery; the Electrical Measurements and Standardization Laboratory, equipped for instruction in the checking of meters and secondary standards, and in the precise measurement of electrical and magnetic quantities; the Radio and Communication Laboratory, well provided with modern electrical-communication apparatus; the Industrial Electronics Laboratory, for the study of electronic power and control devices; the Electronics Apparatus and Project Laboratory, for the construction of electronic apparatus by students according to their own designs; the High-Vacuum and Tube-Construction Laboratory, for the construction of special electron tubes, and for general instruction in the appropriate glass techniques; and the Servomechanism Laboratory, containing "servo" or "follow-up" systems of recent design.

THE CURRICULUM

The curriculum, which leads to the degree of Bachelor of Electrical Engineering, provides a solid foundation of basic study with considerable breadth and depth, and sufficient specialization to exercise special interests. Beginning with the eighth term, more selection of study is provided by a choice of one of several technical options. This provision permits the student in the last three terms to choose from among

several broad branches of the profession that one in which he will continue his fundamental study. Within these options are found the various specialties such as radar, television, radio, servo-mechanisms, and lightning phenomena. The several programs also include studies in the fields of administration and the humanities.

OPTIONS

The curriculum in Electrical Engineering provides specifically for six options: Power Utilization, Power Generation and Transmission, Industrial Electronics, Illumination, Radio and Communication, and Physics.

The Power Utilization option concerns motors, their characteristics, control and application; servomechanisms; the electrical aspects of transportation by land, water, and air; and the use of electrical energy in industry, commerce, and the home.

The Power Generation and Transmission option deals with electric power-station equipment, transmission and distribution systems, protective equipment, and high voltage practice.

The Industrial Electronics option deals with the theory and application of equipment utilizing the principles of electron emission, of control of electron flow in vacuum, and of ion and electron flow in gases. It concerns electronic control and instrumentation with both low- and high-frequency equipment.

The Illumination option provides for the study of the generation and utilization of light. This field offers unique opportunties for the student with considerable breadth of interest. The option is adapted to those with interest and ability in art, dramatics, and the physiology and psychology of vision, as well as in the rigorous engineering and economic aspects of the field.

The Radio and Communication option concerns the transmission of information by means of electricity. It includes the study of telephone and telegraph equipment, telemetering, television, sound recording and reproducing, radio transmission and equipment, as well as a study of the more recent high-frequency developments, such as radar.

The Physics option emphasizes, even more than do the other options, basic physical principles rather than engineering applications. It is intended to prepare students for research and advanced development in electrical engineering. This option includes such subjects as electrostatic and electromagnetic fields, electromagnetic waves, and atomic and nuclear physics. It is open only to students who demonstrate unquestionable ability in science.

Before a student completes his seventh term, he should, in consultation with his Class Adviser, elect one of the six options.

(See also p. 7 for note on Industrial Cooperative Plan).

PROJECT AND ELECTIVES

The Electrical Engineering curriculum provides for a considerable number of elective hours. Some of these are unrestricted, some are confined to non-technical or managerial courses, and others are confined to a technical group in the chosen option. Each option has a specified number of hours designated as "Project." The project in any option is chosen by the student according to his particular interests. It usually will comprise a problem in one of the option subjects although other subjects related to electrical engineering may be exploited, and any proportioning of theoretical and experimental work suited to the project is permissible.

Within the curriculum leading to the B.E.E. degree it is possible for the student to exercise considerable latitude of selection according to his interests. The new curriculum provides elective hours for other than technical study. Opportunity for contact with the broader phases of education afforded by the University has far-reaching potentiality in shaping the future life interests of the student.

THE FRESHMAN YEAR

The curriculum of the Freshman year in Electrical Engineeering is essentially the same as that in Mechanical Engineering and Engineering Physics so that transfer of a student between these three curricula may occur before the third term without loss of time. The Freshman curricula in Civil and in Chemical and Metallurgical Engineering differ to such an extent from that in Electrical Engineering that a transfer is almost certain to require a lengthening of the student's program.

CLASS ADVISERS

An experienced member of the faculty is appointed as Class Adviser to each class that enters the School of Electrical Engineering. He continues with the class, usually until graduation, to counsel each student in regard to curriculum, registration, scholarship, and other matters of the academic program. In addition, he tries to be helpful in the solution of personal problems which are brought to him, no matter how unrelated to the student's scholastic success those problems may appear to be.

Because responsibility for the registration of each student is vested in the Class Adviser, it is especially important that no cancellation of courses or other changes in program be initiated without the adviser's knowledge and approval. Should the Class Adviser in his judgment be unable to authorize a registration or change in program desired by the student, the latter may appeal his case by petition to the Faculty of the School of Electrical Engineering.

SCHOLASTIC REQUIREMENTS

A student in the School of Electrical 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 at least 70 per cent may be dropped or placed on probation.

FIVE-YEAR CURRICULUM (B.E.E.)

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	3
	Chemistry 105, General Chemistry	3	2	3
	Engineering 3111, Descriptive Geometry	3	1	6
	Engineering 6110, Casting, Working, and Welding of Metals	2	1	2
	English 111, Introductory Course	3	3	0
	Total	17		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	3
	Chemistry 106, General Chemistry	3	2	3
	Engineering 3112, Mechanical Drafting	3	1	6
	Engineering 3402, Machine Tool Processes	2	0	6
	English 112, Introductory Course	3	3	0
	Total	17		

In addition to the above courses, freshmen are required to take Military Science and Tactics and Physical Training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	3
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 2131, Surveying	1	0	3
	Engineering 3327, Kinematics	2	2	0
	Public Speaking 101, Public Speaking	3	3	0
	Economics 107, Introduction to Economics	3	3	0
	Total	17		
TERM 4	Mathematics 607, Applied Mathematics for Electrical Engineers	3	3	0
	Physics 118, Electricity, Magnetism, and Light	3	3	3
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1151, Mechanics	3	3	0
	Engineering 3231, Accounting	3	2	3
	Engineering 4111, Basic Electrical Engineering	4	3	3
	Total	18		

In addition to the above courses, sophomores are required to take Military Science and Tactics and Physical Training.

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 5	Engineering 1223, Engineering Materials	3	3	0
	Engineering 1152, Mechanics	3	3	0
	Engineering 4112, Alternating-Current Circuits	4	3	3
	Engineering 4116, Electric-Circuit Laboratory	3	1	3
	Engineering 4211, Direct-Current Machinery	3	2	3
	Psychology 440, Psychology	3	3	0
	Total	19		
TERM 6	Engineering 1153, Mechanics of Materials	3	3	0
	Engineering 2331, Fluid Mechanics	3	3	0
	Engineering 4121, Electron Tubes and Circuits	3	3	0
	Engineering 4126, Electronics Laboratory	2	0	6
	Engineering 4128, Electronic-Equipment Shop	1	0	3
	Engineering 4216, Electrical-Machinery Laboratory	4	2	3
	Engineering 4221, Alternating-Current Machinery	3	2	3
	Total	19		
TERM 7	Mathematics 608, Differential Equations for Electrical Engineering	3	3	0
	Engineering 3530, Thermodynamics	3	3	0
	Engineering 4122, Electronic Circuit Elements	4	2	6
	Engineering 4131, Basic Communication Systems	2	1	3
	Engineering 4226, Electrical-Machinery Laboratory	4	2	3
	History 165,* Modern Economic History	3	3	0
	Total	19		

*Students admitted to the Physics Option will take Physics 123 in Term 7, and will defer History 165 to Term 9.

POWER UTILIZATION OPTION

TERM 8	Engineering 3531, Heat-Power Engineering	2	2	0
	Engineering 3532, Heat-Power Engineering	1	0	3
	Engineering 4311, Advanced Circuit Analysis	3	2	3
	Engineering 4321, Machine Theory	2	2	0
	Engineering 4351, Low-Frequency Heating, and Industrial Distribution Systems	3	2	3
	Physics, Modern Physics	3	3	0
	History 166, Modern Economic History	3	3	0
	Total	17		
TERM 9	Engineering 4021, Composition of Technical Reports	3	3	0
	Engineering 4326, Power Laboratory	2	1	3
	Engineering 4331, Electrical Design Economics	3	2	3
	Engineering 4341, Motor Control	2	2	0
	Engineering 4391, Project	2		
	Electives (See page 49)	6		
	Total	18		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 10	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4342, Application of Motors	3	2	3
	Engineering 4392, Project	4		
	Electives (See page 49)	9		
	Total	19		

Grand total for 10 terms . . . . . 180 hours
(not including Military Science and Tactics and Physical Training)

POWER GENERATION AND DISTRIBUTION OPTION

TERM 8	Engineering 3531, Heat-Power Engineering	2	2	0
	Engineering 3532, Heat-Power Engineering	1	0	3
	Engineering 4311, Advanced Circuit Analysis	3	2	3
	Engineering 4321, Machine Theory	2	2	0
	Engineering 4361, Power Systems	3	2	3
	Physics, Modern Physics	3	3	0
	History 166, Modern Economic History	3	3	0
	Total	17		
TERM 9	Engineering 4021, Composition of Technical Reports	3	3	0
	Engineering 4326, Power Laboratory	2	1	3
	Engineering 4341, Motor Control	2	2	0
	Engineering 4362, Transmission of Electric Energy	3	2	3
	Engineering 4391, Project	2		
	Electives (See page 49)	6		
	Total	18		
TERM 10	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4371, High-Voltage Phenomena	3	2	3
	Engineering 4392, Project	4		
	Electives (See page 49)	9		
	Total	19		

Grand total for 10 terms . . . . . 180 hours
(not including Military Science and Tactics and Physical Training)

INDUSTRIAL ELECTRONICS OPTION

TERM 8	Engineering 3531, Heat Power Engineering	2	2	0
	Engineering 3532, Heat Power Engineering	1	0	3
	Engineering 4311, Advanced Circuit Analysis	3	2	3
	Engineering 4321, Machine Theory	2	2	0
	Engineering 4411, Electronic Control Equipment	3	2	3
	Physics, Modern Physics	3	3	0
	History 166, Modern Economic History	3	3	0
	Total	17		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 9	Engineering 4021, Composition of Technical Reports	3	3	0
	Engineering 4326, Power Laboratory	2	1	3
	Engineering 4341, Motor Control	2	2	0
	Engineering 4421, Electronic Power Converters	3	2	3
	Engineering 4491, Project	2		
	Electives (See page 49)	6		
	Total	18		
TERM 10	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4492, Project	4		
	Option Electives (See page 49)	3		
	Electives (See page 49)	9		
	Total	19		

Grand total for 10 terms . . . . . 180 hours
(not including Military Science and Tactics and Physical Training)

RADIO AND COMMUNICATION OPTION

TERM 8	Engineering 3531, Heat-Power Engineering	2	2	0
	Engineering 3532, Heat-Power Engineering	1	0	3
	Engineering 4511, Radio and Communication Theory	3	2	3
	Engineering 4513, Communication Networks	3	3	0
	Engineering 4516, Radio and Communication Laboratory	3	1	3
	Physics, Modern Physics	3	3	0
	History 166, Modern Economic History	3	3	0
	Total	18		
TERM 9	Engineering 4021, Composition of Technical Reports	3	3	0
	Engineering 4512, Radio and Communication Theory	3	2	3
	Engineering 4517, Radio and Communication Laboratory	3	1	3
	Engineering 4591, Project	3		
	Electives (See page 49)	6		
	Total	18		
TERM 10	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4592, Project	3		
	Option Electives (See page 49)	3		
	Electives (See page 49)	9		
	Total	18		

Grand total for 10 terms . . . . . 180 hours
(not including Military Science and Tactics and Physical Training)

ILLUMINATION OPTION

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Engineering 3531, Heat-Power Engineering	2	2	0
	Engineering 3532, Heat-Power Engineering	1	0	3
	Engineering 4311, Advanced Circuit Analysis	3	2	3
	Engineering 4321, Machine Theory	2	2	0
	Engineering 4611, Introductory Illumination	4	2	6
	Physics, Modern Physics	3	3	0
	History 166, Modern Economic History	3	3	0
	Total	18		
TERM 9	Engineering 4021, Composition of Technical Reports	3	3	0
	Engineering 4326, Power Laboratory	2	1	3
	Engineering 4341, Motor Control	2	2	0
	Engineering 4612, Illuminating Engineering	3	2	3
	Engineering 4691, Project	2		
	Electives (See page 49)	6		
	Total	18		
TERM 10	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4615, Illumination Seminar	2	2	0
	Engineering 4692, Project	4		
	Electives (See page 49)	9		
	Total	18		

Grand total for 10 terms ..... 180 hours
(not including Military Science and Tactics and Physical Training)

PHYSICS OPTION

TERM 8	Engineering 3531, Heat-Power Engineering	2	2	0
	Engineering 3532, Heat-Power Engineering	1	0	3
	Physics 210, Advanced Physics Laboratory	3	1	6
	Option Electives (See page 49)	3		
	Electives (See page 49)	9		
	Total	18		
TERM 9	Engineering 4021, Composition of Technical Reports	3	3	0
	Physics 243, Atomic Theory of Properties of Matter	3	3	0
	History 165, Modern Economic History	3	3	0
	Option Electives (See page 49)	6		
	Electives (See page 49)	3		
	Total	18		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 10	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Physics 254, Electronic Theory of Properties of Matter; Physics of Solids and Liquids	5	3	6
	History 166, Modern Economic History	3	3	0
	Option Electives (See page 49)	4		
	Electives (See page 49)	3		
	Total	18		

Grand total for 10 terms . . . . . 180 hours
(not including Military Science and Tactics and Physical Training)

ELECTIVE COURSES

Credit hours earned in Advanced Military Science and Tactics may be counted, to the extent of six, toward meeting the requirements of the baccalaureate degree. The hours so credited will be considered to lie within the free-elective area of the curriculum.

The following list of subjects defines an extensive area from which nine of the elective hours of the ninth and tenth terms of the five-year curriculum are to be selected. (See the Announcement of the other divisions of the University for descriptions of the courses offered.)

Elective hours without special designation and in excess of these nine may be chosen from this list, from any of the option electives for which prerequisites are satisfied, or from any other courses in the University which are available to the student.

LIST OF SUBJECTS

Archaeology	Economics	History	Ornithology
Architecture	English	Language	Philosophy
Astronomy	Fine Arts	Landscape Architecture	Psychology
Biology	Floriculture	Meteorology	Sociology
Botany	Geology	Music	Speech
Dramatics	Government		Zoology

OPTION ELECTIVES

Some of the curricula provide, in the later "Option" terms, hours for "Option Electives." These are elective hours restricted to courses given within the field of the chosen option. Except for the Physics option, these option electives are described on pages 103–118. In the Physics option, nine of the thirteen total hours of option electives

must be chosen from the upperclass courses in Electrical Engineering, preferably distributed as three hours in each of the last three terms. The other four of the thirteen hours may also be chosen in Electrical Engineering, or from the upperclass courses in Physics or Mathematics.

WAR SERVICE EXPERIENCE AND COURSES

Provision is made for veterans to obtain toward the Baccalaureate Degree some credit for war service experience or courses. The student should consult with his Class Adviser.

OPTIONS IN SCIENCE

A student who has completed the first three terms of the four-year course with a satisfactory record and with excellent grades in Mathematics, Physics, and Mechanics may, if his class adviser approves, substitute a group of courses in Physics, Chemistry, or Mathematics for certain courses normally required, namely:

Engineering 2731	Structures
Engineering 3231	Accounting
Engineering 3327	Kinematics
Engineering 3337	Machine Design

Permission to continue in any of these science options may be withdrawn at any time if the student's work is not satisfactory.

A student of the School of Electrical Engineering may elect courses of instruction offered by the School of Electrical Engineering or by other schools or departments of the University, provided he has a sufficient number of elective hours available, has the necessary prerequisites, and secures the approval of his class adviser.

FOUR-YEAR CURRICULUM

(See page 6)

A student who is following the four-year curriculum should select one of the following options before the beginning of his seventh term:

1. Electric Power Generation and Utilization
2. Electric Communication
3. Administrative, Power
4. Administrative, Communication

FOUR-YEAR CURRICULUM (B.E.E.)

(See page 6)

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	3
	Chemistry 101 or 105, General Chemistry	3	2	3
	Engineering 2131, Surveying	1	0	3
	Engineering 3111, Descriptive Geometry	3	1	6
	Engineering 3401, Pattern Making	1	0	3
	Engineering 6111, Metal Working	1	0	3
	English 111, Introductory Course	3	3	0
	Total	18		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	3
	Chemistry 102 or 106, General Chemistry	3	2	3
	Engineering 3112, Mechanical Drafting	3	1	6
	Engineering 3403, Fundamentals of Machine Tools	1	0	3
	Engineering 6112, Casting Processes	1	0	3
	English 112, Introductory Course	3	3	0
	Total	17		
TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	3
	Engineering 1111, Mechanics	5	5	0
	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3404, Production Machine Tools	2	0	6
	Economics 107, Introduction to Economics	3	3	0
	Total	19		
TERM 4	Mathematics 607, Applied Mathematics for Electrical Engineers	3	3	0
	Physics 118, Electricity, Magnetism, and Light	3	3	3
	Engineering 1112, Strength of Materials	3	3	0
	Engineering 3231, Accounting	3	2	3
	Engineering 3327, Kinematics	2	2	0
	Engineering 4111, Basic Electrical Engineering	4	3	3
	Total	18		

Terms 1, 2, 3, and 4 are listed as a matter of record only, inasmuch as students are no longer being accepted in the four-year curriculum at these levels.

TERM 5	Mathematics 608, Differential Equations for Electrical Engineers	3	3	0
	Engineering 1231, Engineering Materials Laboratory	3	1	3
	Engineering 3530, Thermodynamics	3	3	0
	Engineering 4112, Alternating-Current Circuits	4	3	3
	Engineering 4116, Electric-Circuit Laboratory	3	1	3
	Engineering 4211, Direct-Current Machinery	3	2	3
	Total	19		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 6	Engineering 2331, Fluid Mechanics	3	3	0
	Engineering 3337, Machine Design	3	3	0
	Engineering 4121, Electron Tubes and Circuits	3	3	0
	Engineering 4126, Electronics Laboratory	2	0	6
	Engineering 4216, Electrical-Machinery Laboratory	4	2	3
	Engineering 4221, Alternating-Current Machinery	3	2	3
	Total	18		

POWER OPTION

TERM 7	Engineering 3531, Heat-Power Engineering*	2	2	0
	Engineering 3532, Heat-Power Engineering*	1	0	3
	Engineering 4131, Basic Communication Systems	2	1	3
	Engineering 4226, Electrical-Machinery Laboratory	4	2	3
	Engineering 4311, Advanced Circuit Analysis	3	2	3
	Engineering 4321, Machine Theory	2	2	0
	Engineering 4361, Power Systems	3	2	3
	Electives	2		
	Total	19		

*Heat-Power Engineering may be deferred to the eighth term to permit the inclusion of an elective.

TERM 8	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4326, Power Laboratory	2	1	3
	Engineering 4362, Transmission of Electrical Energy	3	2	3
	Option Electives (See page 49)	3		
	Electives	7		
	Total	18		

Grand total for 8 terms . . . . . 146 hours
(not including Military Science and Tactics and Physical Training)

The electives in this option may be chosen, with the approval of the Class Adviser, from any courses in the University which are available to the student.

COMMUNICATION OPTION

TERM 7	Engineering 3531, Heat-Power Engineering*	2	2	0
	Engineering 3532, Heat-Power Engineering*	1	0	3
	Engineering 4122, Electronic Circuit Elements	4	2	6
	Engineering 4128, Electronic Equipment Shop	1	0	3
	Engineering 4131, Basic Communication Systems	2	1	3
	Engineering 4226, Electrical-Machinery Laboratory	4	2	3
	Engineering 4513, Communication Networks	3	3	0
	Electives	2		
	Total	19		

*Heat-Power Engineering may be deferred to the eighth term to permit the inclusion of an elective.

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4511, Radio and Communication Theory	3	2	3
	Engineering 4512, Radio and Communication Theory	3	2	3
	Engineering 4516, Radio and Communication Laboratory	3	1	3
	Electives	6		
	Total	18		

Grand total for 8 terms . . . . . 146 hours
(not including Military Science and Tactics and Physical Training)

The electives in this option may be chosen, with the approval of the Class Adviser, from any of the courses in the University which are available to the student.

ADMINISTRATIVE POWER OPTION

TERM 7	Engineering 3531, Heat-Power Engineering	2	2	0
	Engineering 3532, Heat-Power Engineering	1	0	3
	Engineering 4131, Basic Communication Systems	2	1	3
	Engineering 4226, Electrical-Machinery Laboratory	4	2	3
	Engineering 4361, Power Systems	3	2	3
	Electives (Administrative)	7		
	Total	19		
TERM 8	Engineering 2731, Structures	2	1	3
	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4362, Transmission of Electrical Energy	3	2	3
	Electives (Administrative)	12		
	Total	18		

Grand total for 8 terms . . . . . 146 hours
(not including Military Science and Tactics and Physical Training)

ADMINISTRATIVE COMMUNICATION OPTION

TERM 7	Engineering 2731, Structures	2	1	3
	Engineering 4122, Electronic Circuit Elements	4	2	6
	Engineering 4128, Electronic Equipment Shop	1	0	3
	Engineering 4131, Basic Communication Systems	2	1	3
	Engineering 4226, Electrical-Machinery Laboratory	4	2	3
	Electives (Administrative)	6		
	Total	19		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Engineering 4041, Non-Resident Lectures	1	1	0
	Engineering 4511, Radio and Communication Theory	3	2	3
	Engineering 4512, Radio and Communication Theory	3	2	3
	Engineering 4516, Radio and Communication Laboratory	3	1	3
	Electives (Administrative)	8		
	Total	18		

Grand total for 8 terms . . . . . 146 hours
(not including Military Science and Tactics and Physical Training)

School of Chemical and Metallurgical Engineering

EQUIPMENT

The specialized training in Chemical and Metallurgical Engineering is given in Olin Hall of Chemical Engineering, and in the laboratories for foundry practice and metal working. The courses in chemistry are given in Baker Laboratory of Chemistry.

Olin Hall of Chemical Engineering was provided through the generosity of Franklin W. Olin as a memorial to his son Franklin W. Olin, Jr. This modern and well-equipped building, with about 105,000 square feet of available floor space, provides lecture-room, recitation-room, and laboratory facilities for the instruction in chemical and metallurgical engineering. The unit operations laboratory, which is about one hundred feet long and fifty feet wide, extends through three floors, and houses semi-plant scale equipment for both instruction and research. It is served by a traveling crane, and by its own shops and analytical laboratory. A considerable part of the building is subdivided into unit laboratories for advanced and graduate students.

OUTLINE OF THE INSTRUCTION

The purpose of the instruction in this School is to provide a broad foundation of training in the fundamental subjects of mathematics, chemistry, and physics, and in the essential principles and methods of engineering, and professional training in the specific fields of chemical and metallurgical engineering. In the required curriculum a certain amount of work in cultural subjects is included. By providing elective work in the later years, the curriculum makes it possible for the student to take additional courses either in subjects outside the field of his major interest or in special and advanced technical subjects within that field.

The first four terms provide thorough training in chemistry, mathematics, and physics, and the other basic subjects on which the specific professional training is based. The later terms include more strictly technical and more advanced courses in engineering and in chemistry, and the fundamental courses in the specific fields of chemical and metallurgical engineering. The last two terms include the more advanced

work in engineering and in the specialized fields. (For an outline of the course of study see below.)

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 per cent may be dropped or placed on probation.

If in the opinion of the Faculty of the School concerned, 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 in respect to the number of hours of work passed and the grades in 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.

EMPLOYMENT AFTER GRADUATION

Graduates in Chemical Engineering find employment in the design, development, operation, and administration of chemical engineeering plants. There is also some demand for men with chemical engineering training for technical sales work in the chemical industries, and for editorial work on technical publications. Some graduates in chemical engineering continue their specialized training as graduate students in chemistry or chemical engineering to prepare for positions as research chemists or research engineers.

Graduates in Metallurgical Engineering are employed in the various industries engaged in the winning and refining of metals, in the foundry industry, and in industries in which the heat-treatment, welding, and forming of metals are important.

FIVE-YEAR CURRICULUM (B.Chem.E.)

		CREDIT HOURS	CONTACT HOURS LEC. & REC.	LAB. & COMP.
TERM 1	Chemistry 111, Introductory Inorganic Chemistry	3	3	0
	Chemistry 115, Inorganic Chemistry Laboratory	3	1	5
	Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, English Literature and Composition	3	3	0
	Engineering 3114, Drawing and Descriptive Geometry	2	1	2½
		17		

		CREDIT HOURS	CONTACT HOURS LEC. & REC.	LAB. & COMP.
TERM 2	Chemistry 112, Introductory Inorganic Chemistry	2	2	0
	Chemistry 212, Qualitative Analysis	5	2	7½
	Physics 116, Wave Motion, Sound, and Heat	3	3	3
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, English Literature and Composition	3	3	0
	Engineering 3115, Drawing and Descriptive Geometry	2	1	2½
		18		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in Physical Training and Military Science and Tactics.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Chemistry 307, Introductory Organic Chemistry	3	3	0
	Chemistry 311, Organic Chemistry Laboratory	3	0	7
	Chemistry 220, Introductory Quantitative Analysis	3	3	0
	Chemistry 222, Quantitative Analysis Laboratory	3	0	7
	Physics 117, Electricity and Magnetism	3	2	3
		18		
TERM 4	Engineering 1156, Applied Mathematics	3	3	0
	Chemistry 308, Introductory Organic Chemistry	3	3	0
	Chemistry 312, Organic Chemistry Laboratory	3	0	7
	Engineering 5501, Chem. Eng. Stoichiometry	2	2	0
	Engineering 1151, Mechanics	3	3	0
	Physics 118, Physical Electronics and Optics	3	2	3
	Public Speaking 101	3	3	0
	or			
	Psychology 440, Psychology for Engineering Students	(3)	(3)	(0)
		20		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in Physical Training and Military Science and Tactics.

TERM 5	Chemistry 403, Introductory Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	3	1	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 5203, Chem. Eng. Technology	2	2	0
	Engineering 1255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3	1	5
	or			
	Chemistry 240, Special Methods of Chemical Analysis	(3)	(1)	(5)
	History 165, Science in Western Civilization	3	3	0
	or			
	Electives	(3)	–	–
		20		

		CREDIT HOURS	CONTACT HOURS LEC. & REC.	LAB. & COMP.
TERM 6	Chemistry 404, Introductory Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	3	1	5
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 5204, Chem. Eng. Technology	2	2	0
	Engineering 1256, Materials of Construction	3	3	0
	Chemistry 240, Special Methods of Chemical Analysis	3	1	5
	or			
	Engineering 5851, Chemical Microscopy	(3)	(1)	(5)
	History 166, Science in Western Civilization	3	3	0
	or			
	Electives	(3)	–	–
		20		
TERM 7	Engineering 5303, Unit Operations of Chemical Engineering	3	3	0
	Engineering 5353, Unit Operations Laboratory	3	2	3
	Engineering 3535, Heat Power	3	3	0
	Engineering 1233, Materials Testing Laboratory	3	1	3
	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Electives	3	–	–
	or			
	History 165, Science in Western Civilization	(3)	(3)	(0)
		18		
TERM 8	Engineering 5304, Unit Operations of Chemical Engineering	3	3	0
	Engineering 5354, Unit Operations Laboratory	3	2	3
	Engineering 3536, Heat Power	3	3	0
	Engineering 5104, Chemical Engineering Thermodynamics	2	2	0
	Engineering 5711, Library Use	1	1	0
	Engineering 5701, Plant Inspections	1	–	–
	Electives	3	–	–
	or			
	History 166, Science in Western Civilization	(3)	(3)	(0)
		19		
TERM 9	Engineering 4951, Electrical	4	3	3
	Engineering 5603, Chemical Equipment	2	2	0
	Engineering 5605, Chemical Plant Design	2	1	3
	Engineering 5503, Chemical Engineering Computations	2	2	0
	Engineering 5953, Senior Project	3	0	9
	Engineering 3253, Chemical Engineering Economics	3	2	3
	or			
	Electives	(3)	–	–
	Electives	4	–	–
		20		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 10	Engineering 4952, Electrical	4	3	3
	Engineering 5504, Chemical Engineering Computations	2	2	0
	Engineering 5604, Chemical Equipment	2	2	0
	Engineering 5606, Chemical Plant Design	2	1	3
	Engineering 5954, Senior Project	3	0	9
	Electives	3	–	–
	or			
	Engineering 3253, Chemical Engineering Economics	(3)	(2)	(3)
	Electives	4	–	–
		20		

Elective courses may be taken in any college of the University. The selection must be approved by the student's adviser.

METALLURGICAL ENGINEERING FIVE-YEAR CURRICULUM (B.Met.E.)

TERM 1	Chemistry 111, Introductory Inorganic Chemistry	3	3	0
	Chemistry 115, Inorganic Chemistry Laboratory	3	1	5
	General Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, English Literature and Composition	3	3	0
	Engineering 3114, Drawing and Descriptive Geometry	2	1	2½
	Engineering 6111, Introductory Metallurgy	2	1	2
		19		
TERM 2	Chemistry 112, Introductory Inorganic Chemistry	2	2	0
	Chemistry 212, Qualitative Analysis	5	2	7½
	General Physics 116, Wave Motion, Sound, and Heat	3	3	3
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, English Literature and Composition	3	3	0
	Engineering 3115, Drawings and Descriptive Geometry	2	1	2½
		18		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in Physical Training and Military Science and Tactics.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Chemistry 301, Engineering Chemistry (Organic)	2	2	0
	Engineering 3403, Fundamentals of Machine Tools	1	0	2½
	History 165, Science in Western Civilization	3	3	0
	Economics 107, Introduction to Economics	3	3	0
	Public Speaking 101	3	3	0
	General Physics 117, Electricity and Magnetism	3	2	3
		18		

		CREDIT HOURS	CONTACT HOURS LEC. & REC.	LAB. & COMP.
TERM 4	Engineering 1156, Applied Mathematics	3	3	0
	General Physics 118, Physical Electronics and Optics	3	2	3
	Engineering 1151, Mechanics	3	3	0
	History 166, Science in Western Civilization	3	3	0
	Geology 712, Metallurgical Raw Materials	2	2	0
	Chemistry 220, Introductory Quantitative Analysis	3	3	0
	Chemistry 222, Quantitative Analysis Laboratory	3	0	7
		20		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in Physical Training and Military Science and Tactics.

TERM 5	Chemistry 403, Introductory Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	3	1	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 1255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3	1	5
	Engineering 6501, Metallurgical Calculations	2	2	0
	Psychology 440, Psychology for Engineering Students	3	3	0
		20		

TERM 6	Chemistry 404, Introductory Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	3	1	5
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 6811, Introductory Metallography	3	1	5
	Engineering 1233, Engineering Materials Laboratory	3	1	2½
	Engineering 1256, Materials of Construction	3	3	0
		18		

TERM 7	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Engineering 6311, Physical Metallurgy	3	3	0
	Engineering 6351, Physical Metallurgy Laboratory	3	1	5
	Engineering 6253, Unit Processes in Metallurgy	3	1	2½
	Engineering 6203, Smelting and Refining	3	3	0
	Engineering 5711, Library Use and Patents	1	1	0
	Electives (Technical or Non-Technical)	3	–	–
		19		

		CREDIT HOURS	CONTACT HOURS LEC. & REC.	LAB. & COMP.
TERM 8	Engineering 5104, Chemical Engineering Thermodynamics	2	2	0
	Engineering 6114, Casting, Working, and Welding of Metals	3	2	2
	Engineering 6254, Unit Processes in Metallurgy	2	1	2½
	Engineering 3235, Corporate and Industrial Organization	3	3	0
	Engineering 3255, Elements of Industrial Accounting	3	1	5
	Engineering 3241, Elementary Industrial Statistics	3	3	0
	Electives (Technical or Non-Technical)	3	–	–
	Engineering 6701, Plant Inspections	1	0	0
		20		
TERM 9	Engineering 6323, Advanced Ferrous Metallurgy	3	3	0
	Engineering 6953, Senior Project	3	0	7½
	Engineering 3242, Statistical Quality Control	3	3	0
	Engineering 4951, Electrical Engineering	4	3	3
	Electives (Technical or Non-Technical)	3	–	–
	Electives (Non-Technical)	3	–	–
		19		
TERM 10	Engineering 6324, Advanced Non-Ferrous Metallurgy	3	3	0
	Engineering 6954, Senior Project	3	0	7½
	Engineering 4952, Electrical Engineering	4	3	3
	Electives (Technical or Non-Technical)	6	–	–
	Engineering 6602, Metallurgical Design	3	3	0
		19		

Elective courses may be taken in any college of the University. The selection must be approved by the student's adviser.

OPTIONS IN CHEMICAL AND METALLURGICAL ENGINEERING

A student in Chemical Engineering or in Metallurgical Engineering may select his elective courses in any one of several optional fields to provide somewhat more extensive training than is afforded by the required courses in the curriculum. The student may also, if he so desires, arrange his elective work to provide a cultural background broader than that given by the required courses. The selection of electives must be approved by the class adviser.

The Graduate School of Aeronautical Engineering

The primary objective of this School is the training of selected engineering and science graduates in the scientific aspects of aeronautics. This training is intended especially to prepare the students to carry out intensive research and development engineering in the aeronautical and related industries, and in aeronautical scientific institutions.

To this end, students are admitted to this School who have demonstrated, in their undergraduate careers, more-than-average abilities in analytical subjects, and who have shown adequate promise of carrying on graduate study successfully.

In the Aeronautical Engineering program, considerable emphasis is placed upon original research, both theoretical and experimental. Through the academic year, close contact is maintained between the Graduate School at the University and the Cornell Aeronautical Laboratory in Buffalo, New York. In addition, certain periods of employment at the Laboratory are offered to Aeronautical Engineering students – usually during their summer vacations. Students are urged to take advantage of such employment, if it is available. It is also possible that certain experimental equipment of the Laboratory will occasionally be available to graduate students in connection with their original research.

The Graduate School of Aeronautical Engineering is equipped with a fluid-mechanics laboratory, on the campus in Ithaca, for fundamental scientific research in fluid mechanics and aerodynamics.

ADMISSION

Application for admission to the Graduate School of Aeronautical Engineering as a candidate for the degree M.Aero.E. should be made directly to the Director of the Graduate School of Aeronautical Engineering, College of Engineering, Cornell University. A special application blank for this purpose can be obtained from the office of the Director. It should be sent directly to the Director of the Graduate School of Aeronautical Engineering.

Students who desire to work for the degree Ph.D. with Aeronautical Engineering as their Major Subject must be admitted to the Graduate School of the University in the usual manner. They should make application to the Dean of the Graduate School, using the application blank for admission to the Graduate School.

The degree M.Aero.E. is awarded under the jurisdiction of the College of Engineering, and candidates for this degree are not necessarily admitted to the Graduate School of the University. The degree is awarded upon satisfactory completion of a required curriculum of studies and an acceptable thesis. Candidates for this degree do not have Special Committees and do not select a Minor Subject.

CURRICULUM

The Aeronautical Engineering Curriculum is planned to accomplish the broad objectives stated above. Courses of study are provided leading to the degree Master of Aeronautical Engineering and to the degree Doctor of Philosophy with Aeronautical Engineering as the Major Subject.

A. Course of Study Leading to the Degree M.Aero.E.

It is anticipated that two years' study will ordinarily be required for the degree M.Aero.E. It should be noted, however, that only one year's residence is required, so that students entering the School with credit for a sufficient number of the required courses may be able to qualify for the degree in one year. Credit for courses completed at other universities is awarded on the basis of examination only. Upon request, the Director will schedule such examinations prior to Registration Day each term.

In the recommended program outlined below, the courses required for the M.Aero.E. degree have been supplemented by additional Aeronautical Engineering courses and electives, so as to result in a balanced program of approximately 16 credit-hours a term. Required courses are indicated by an asterisk (*).

The program covered in the first year of graduate study is applicable to much of the standard engineering work in the aeronautical industry. Beyond that the course is planned to increase the student's facility in the use of the basic sciences in aeronautical engineering, and to stimulate growth in the performance of independent research and development work. Because the progress in this field is so extremely 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.

FIRST YEAR OF GRADUATE STUDY

		CREDIT HOURS
TERM 1	Mathematics 611, Higher Calculus for Engineers and Physicists	3
	*or	
	Engineering 1170, Advanced Mechanics	(3)
	Engineering 7101, Mechanics of Airplanes*	4
	Engineering 7203, Aerodynamics of Power Plants	3
	Engineering 7401, Airplane Structures*	3
	Engineering 7403, Airplane Design*	1
	Engineering 7901, Aeronautical Engineering Colloquium	1
		15
TERM 2	Mathematics 612, Higher Calculus for Engineers and Physicists	3
	*or	
	Engineering 1171, Advanced Mechanics	(3)
	Engineering 7102, Mechanics of Airplanes	4
	*or	
	Engineering 7103, Propeller Theory	(3)
	or	
	Engineering 7104, Mechanics of Rotary-Wing Aircraft	(3)
	Engineering 7204, Gasdynamics*	4
	Engineering 7402, Airplane Structures*	3
	Engineering 7404, Airplane Design*	1
	Engineering 7901, Aeronautical Engineering Colloquium	1
		16

*Required for the degree M.Aero.E.

SECOND YEAR OF GRADUATE STUDY

		CREDIT HOURS
TERM 3	Engineering 7301, Theoretical Aerodynamics I*	3
	Engineering 7801, Research in Aeronautical Engineering*	3†
	Engineering 7901, Aeronautical Engineering Colloquium	1
	Electives chosen from List A below*	6
	Electives	3
		16
TERM 4	Engineering 7801, Research in Aeronautical Engineering*	6†
	Engineering 7901, Aeronautical Engineering Colloquium	1
	Electives chosen from List A below*	6
	Electives	3
		16

*Required for the degree M.Aero.E.

†A total of at least six (6) credit hours in Research in Aero.E. will be required for the degree M.Aero.E.

ELECTIVES: LIST A

Engineering 7205, Kinetic 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 7405, Aero-Elastic Problems	3
Engineering 1162, Mechanics of Vibration	3
or	
Engineering 1170, Advanced Mechanics	3
Engineering 1171, Advanced Mechanics	3
Engineering 1165, Theory of Elastic Stability	3
Engineering 1181, Current Literature in Applied Mechanics	3
Mathematics 621, Mathematical Methods in Physics	3
Mathematics 622, Mathematical Methods in Physics	3
Physics 242, Analytical Mechanics	3
Physics 090, Special Laboratory Work	(arranged)

B. Courses Leading to the Degree Ph.D.

Students wil be admitted to candidacy for the degree Ph.D. as set forth in the current Announcement of the Graduate School. General requirements such as Residence, Major and Minor Subjects, Requirements in Foreign Languages, Qualifying Examinations, and Thesis are also explained there. Each candidate is required to complete a schedule of courses acceptable to his Special Committee, as explained in the Announcement.

PREPARATION FOR GRADUATE STUDY

The Graduate School of Aeronautical Engineering will admit students holding a baccalaureate degree in any branch of engineering, physics, or mathematics, providing that their undergraduate scholastic records are such as to indicate ability to handle graduate study. The course of study in Engineering Physics is especially recommended to students who expect to enter this School after graduation.

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. The following courses are recommended for this purpose:

Engineering 7101,	7102	Mechanics of Airplanes
Mathematics 611,	612	Higher Calculus for Engineers and Physicists
	or	
Mathematics 621,	622	Mathematical Methods in Physics
Engineering 7204		Gasdynamics

Engineering	7401, 7402	Airplane Structures
Engineering	7403, 7404	Airplane Design
Engineering	1170, 1171	Advanced Mechanics
Engineering	1162	Mechanics of Vibration
Engineering	1165	Theory of Elastic Stability.
Physics	242	Analytical Mechanics.

To be admitted to any of the graduate courses listed above, an undergraduate student must

(1) be a regularly enrolled student in at least the seventh term of one of the engineering, physics, or mathematics curricula at Cornell University,

(2) show promise, by his previous scholastic record or otherwise, of ability satisfactorily to pursue advanced study and research, and

(3) have his admission to the courses recommended by the Director of the Graduate School of Aeronautical Engineering (or the Chairman of the department concerned) and approved by the Dean of the College of Engineering

It is further recommended that all students who expect to enter the Graduate School of Aeronautical Engineering include in their programs the following courses, or their equivalents:

Mathematics	201	Differential Equations
Engineering	1111	Engineering Mechanics
Engineering	1155	Intermediate Mechanics
Engineering	1151, 1152, 1153	Mechanics and Strength of Materials
Engineering	3530	Thermodynamics

Department of Engineering Physics

OBJECTIVE

The Department of Engineering Physics is a new department constituted so as to provide a type of education and training which will effectively bridge the gap between that of the basic sciences and engineering. The general aim is to prepare students for a prospective career in technical research and advanced engineering development. As a result of the expanding technological activities in the country, the industrial research laboratories and engineering development laboratories are in urgent need of graduates with the vigorous and exacting course of study which the curriculum of this department provides.

FACULTY

The administrative arrangement of the department is such that the Faculty of the Department includes members of the Science Departments of the College of Arts and Sciences, and members of the several Schools of Engineering in the College of Engineering, who are particularly interested in the objectives of the Department.

CURRICULUM

The curriculum leading to the degree of Bachelor of Engineering Physics covers intensive study over a five-year period. The course of study is designed to combine the broad, basic scientific and analytical training of the physicist with the knowledge of the properties of materials and the technological principles of the engineer. The subject matter falls into three main categories: fundamental science, namely, mathematics, physics, and chemistry; the properties and treatment of materials; and engineering practice.

For training in research, the student terminates the course by carrying out a semi-research project in a special field of his own choice, under the direction of a faculty member who is an authority in the selected field. There are a great variety of these special fields in physics and engineering. These fields include topics in electron physics, atomic physics, optics, x-rays and crystal structure, spectroscopy, nuclear phys-

ics, engineering electronics, communications, electrical machinery, ultra high frequency generation and propagation, circuit analysis, elasticity and stress analyses, properties of materials, engineering mechanics, aerodynamics, physical metallurgy, etc.

ELECTIVES AND LIBERAL COURSES

Considerable flexibility in the technical courses is provided in the last few terms of the curriculum to allow the student to follow some technical fields somewhat more intensively as his interest in certain fields develops. To permit this, 20 hours are provided to cover the semi-research project and technical electives which may be selected, with the permission of student's adviser, from the following subjects: Physics, Mathematics, Chemistry, Physical Metallurgy, Advanced Mechanics and Elasticity, Fluid Mechanics, Aerodynamics, Ultra-high frequency. The choice will depend largely on the student's particular ability or interest.

The Curriculum provides for approximately 30 hours of liberal courses. Of these, there are 12 hours required and 18 hours to be elected. These electives may be chosen from the following subjects: History of Science, History, Psychology, Economics, Public Speaking, Business Law, Corporate and Industrial Organization, Industrial and Labor Relations or other similar subjects on permission of the student's adviser.

CLASS ADVISERS

Members of each entering class in the Engineering Physics Curriculum are assigned to an adviser who will counsel and supervise each student in matters connected with choice of curriculum, registration, scholarship and other matters of importance encountered during the student's entire college career. The personal relationship between the adviser and the student and the adviser's intimate knowledge of the student's academic performance can be of great help to the student in obtaining the best results from his university training.

SCHOLASTIC REQUIREMENTS

A student enrolled in the Engineering Physics Curriculum is expected to maintain the following minimum academic scholastic requirements:

(1) Receive a passing grade in every course for which he is registered,
(3) Maintain an overall weighted average of 75 per cent.
(3) Exhibit natural aptitude and competence in the basic subject matter of the curriculum,

A student failing to satisfy these requirements may be put on Probation or asked to transfer out of this curriculum.

DEPARTMENT OF ENGINEERING PHYSICS
FIVE-YEAR CURRICULUM

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105	3	3	2½
	English 111	3	3	0
	Drawing and Descriptive Geometry 3117	2	0	5
	Liberal Elective	3	3	0
		17		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound and Heat	3	3	2½
	Chemistry 106	3	3	2½
	English 112	3	3	0
	Drawing and Descriptive Geometry 3118	2	0	5
	Fundamentals of Machine Tools 3403	1	0	2½
	Liberal Elective	3	3	0
		18		
TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301	2	2	0
	Engineering Mechanics 1121	3	3	0
	*Language (elective)	6	2	6
	Engineering 6110, Casting, Working, and Welding of Metals	2	1	2½
		19		

*(See note page 70)

TERM 4	Mathematics 201, Elementary Differential Equations	3	3	0
	Physics 118, Electricity, Magnetism, and Light	3	3	2½
	Physical Chemistry	3	3	0
	Strength of Materials 1122	3	3	0
	Physics 208, Physical Mechanics and Properties of Matter	3	2	2½
	Electric and Magnetic Circuits, (Modified) 4981	3	3	2½
		18		

In addition to these courses, students must satisfy the University's requirements in Military Science and Tactics and Physical Training for the first 4 terms.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Physics 225, Electricity and Magnetism	3	3	0
	Mathematics 611, Higher Calculus	3	3	0
	Thermodynamics and Kinetic Theory, 8121	3	3	0
	Alternating-Current Circuits, 4982	3	2	2½
	Electric-Circuit Laboratory 4116	3	2	3
	Liberal Elective	3		
		18		
TERM 6	Physics 242, Analytical Mechanics	3	3	0
	Mathematics 612, Higher Calculus	3	3	0
	Thermodynamics and Kinetic Theory 8122	3	3	0
	Electron Tubes and Circuits 4121	3	3	0
	Electronics Laboratory	2	1	2½
	Liberal Elective	3		
		17		
TERM 7	Physics 243, Atomic and Molecular Theory	3	3	0
	Mathematics 621, Mathematical Methods in Physics	3	3	0
	Engineering Materials	3	3	0
	Electrical Machinery	3		
	Technical Elective	3		
	Liberal Elective	3		
		18		
TERM 8	Physics 254, Electronic Properties of Matter	5	3	5
	Mathematics 622, Mathematical Methods in Physics	3	3	0
	Engineering Materials Laboratory 1231	3	1	2½
	Technical Elective	3		
	Liberal Elective	3		
		17		
TERMS 9 and 10	Mechanics of Continuum	3	0	0
	Advanced Physics Lab	3	1	6
	Advanced Engineering Materials	6		
	Project and Technical Electives	20		
	Liberal Electives	6		
		38		

*Students who pass the proficiency examination of the Department of Modern Languages may substitute six hours of Liberal Arts electives in place of the language requirement.

Description of Courses

THE COURSES listed in the preceding curricula are described in the following sections of this Announcement. Courses are described under the heading of the school or college in which the course is offered. Courses in Chemistry, English, Mathematics, Physics, and certain courses in Economics, are offered by the College of Arts and Sciences. Courses in Military Science and Tactics and Physical Training, under the direct supervision of the University as a whole, are listed in a general section.

The courses designated by four digit numbers are offered by the College of Engineering. The first digit represents 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. Aeronautical Engineering
8. Engineering Physics

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

Engineering Mechanics and Materials

Courses described in this section are given by the Department of Mechanics and the Department of Engineering Materials. They constitute a major part of the stem of basic engineering science prescribed

for all engineering students and are directed towards the development of fundamental background for application to all phases of engineering work.

Advanced and graduate courses in these fields are also included in this section.

MECHANICS OF ENGINEERING

Messrs: CAMERON, CONWAY, CORNELL, CUYKENDALL, ECKMAN, GALLACHER, GUNDER, HOWELL, LANSING, MANSKY, OCVIRK, PERKINS, and UNDERWOOD.

1121. *STATICS AND STRENGTH OF MATERIALS.* Fall term. Credit three hours. Three recitations a week. Prerequisities, Mathematics 162, Physics 116. The principles of statics applied to the calculation of forces in mechanisms and structures. Stress, strain; strength and elastic behavior in tension, compression, and shearing; torsion of shafts; springs; shearing forces, bending moments and deflections of simple beams; special beams.

1122. *STATICS AND STRENGTH OF MATERIALS.* Spring term. Credit three hours. Three recitations a week. Prerequisites, 1121 and Physics 117. (A continuation of 1121.) Eccentric thrust in bars; buckling; continuous beams; combined stresses; principal stresses; theories of failure; thick-walled cylinders; curved bars; unsymmetrical bending; strain energy; Castigiano's theorem.

1131, 1151. *MECHANICS OF ENGINEERING — STATICS.* Credit three hours. Prerequisites Physics 115 and parallel registration in Mathematics 163. The principles of statics of particles, chains, and rigid bodies. Equilibrium, friction, centroids, moments and products of inertia, virtual displacements, graphical methods, three dimensional trusses and frames. 1131 will be taken by civil engineers and 1151 by all others.

1132, 1152. *MECHANICS OF ENGINEERING — DYNAMICS.* Credit three hours. Prerequisites 1151 and Mathemetics 163. The principles of dynamics of particles and rigid bodies. Rectilinear, curvilinear, rotational, and general plane motion of rigid bodies. Impulse-momentum, work-energy, virtual work. 1132 will be taken by civil engineers and 1152 by all others.

1133, 1153. *MECHANICS OF MATERIALS.* Credit three hours. Prerequisites 1151 and parallel registration in 1132 or 1152. Stress and strain, tension, compression, and shear, riveted and welded joints, elementary beam theory, combined stresses, columns, strain energy, beams on several supports. 1133 will be taken by civil engineers, and 1153 by all others.

1134. *MECHANICS OF ENGINEERING — STRENGTH OF MATERIALS.* Required of all Civil Engineering students in the five-year curriculum. Credit three hours. Two recitations and one computing period a week. A continuation of course 1133. Elastic curves, safe loads, columns, flexure of beams. Problems showing the application of Engineering Design.

1140. *ADVANCED MECHANICS.* Elective. Seniors and graduates. Any term. Credit three hours. Three recitations a week. Prerequisites, courses 1136 and 1138. Following a brief general review of fundamental topics in Mechanics of Materials, this course covers induced stresses, torsion, unsymmetrical bending; torsion of prisms of non-circular section; hoops; flat plates; localized stresses; theory of least work; internal work and its derivations. For civil engineering students.

1145. *APPLIED ENGINEERING MATHEMATICS.* Credit three hours. Three recitations a week. Prerequisites, Mathematics 163 and Mechanics 1134. Elementary

differential equations and their applications to engineering problems in the civil engineering fields. Analysis of numerical data and their graphical representation.

1154. *ADVANCED STRENGTH OF MATERIALS.* Credit three hours. Three recitations a week. Prerequisite, course 1155. Strength, stiffness and stability of machine parts, disks, plates, shells, thick cylinders, straight and curved beams; principal stresses in two and three dimensions; fatigue and theories of failure.

1155. *APPLIED MATHEMATICS.* Credit three hours. Three recitations a week. Prerequisites, 1152 and 1153. The formulation and solution of problems in mechanics involving elementary types of ordinary differential equations. The gyroscope, the pendulum, three dimensional dynamics. Emphasis is placed on numerical as well as analytical methods of solution of equations. Required of Mechanical Engineers.

1156. *APPLIED MATHEMATICS.* Credit three hours. Three recitations a week. Prerequisite, Mathematics 163. The formulation and solution of problems in chemical engineering involving ordinary and partial differential equations, graphical and numerical methods and special functions.

1162. *MECHANICS OF VIBRATION.* Prerequisite 1155 or equivalent. Elective for graduates and qualified undergraduates. Credit three hours. Three recitations a week. The characteristic phenomena of mechanical vibrations encountered in engineering, and their quantitative investigation, illustrated by a group of typical vibrating systems. Representation of simple harmonic motion; combination of several simultaneous motions; simple cases of free and forced vibrations, with damping; resonance; principles of transmission and isolation of vibration; systems of variable mass and variable elasticity; systems with several degrees of freedom; vibrations of taut wires, bars, beams, rings, membranes, and plates; relation of vibration and noise; self-excited vibration; detection and measuring instruments; examples of diagnosis and preventive measures.

1163, 1164. *APPLIED ELASTICITY.* Credit three hours each term. Three recitations a week. Spring and fall terms respectively. Prerequisite for 1163, permission of the instructor for 1164, 1163 and 1170 or a basic knowledge of Fourier's series. Elective for graduates and qualified undergraduates. Continuing two terms. General analysis of stress and strain, Airey's stress functions in cartesian and polar co-ordinates, trigonometric and strain energy methods; torsion of bars of arbitrary section, the membrane analogy, the Griffith-Taylor graphical method, effects of grooves, torsion of thin tubes, stress in thick cylinders and disks due to pressure, heating and rotation; beams on elastic foundations; revision of Castigliano's theorem and virtual displacements, application to frameworks and rings, closed rings under hydrostatic pressure.

1165. *THEORY OF ELASTIC STABILITY.* Credit three hours. Three recitations a week. Elective for graduates and qualified undergraduates. Mathematical analysis of the conditions under which columns, beams, rings, tubes, thin plates, and thin curved shells may fail by general or local buckling. Applications to mechanical, civil, naval, and aeronautical structures.

1167. *THEORY OF PLATES AND SHELLS.* Spring term. Credit three hours. Three recitations a week. Prerequisite, 1155 or a knowledge of elementary differential equations and permission of the instructor. Historical introduction; differential equations for the deflection of a plate in cartesian and polar co-ordinates; methods of solution for cases of uniform and non-uniform thickness; Navier and Levy solutions for simply supported rectangular plate, rectangular plate with clamped edges; temperature stresses; the membrane method of Marcus and applications; strain energy of a bent and stretched plate, application to large deflection theory, Föppls methods. Symmetrical deformation of cylindrical shells, temperature stresses, pressure

vessels; buckling under radial pressure and end thrust; deformation of shells without bending, conical, ellipsoidal, and toroidal shells.

1168. *ANALOGIES IN THE SOLUTION OF BOUNDARY VALUE PROBLEMS OF ENGINEERING.* Spring term. Credit two hours. One recitation, one laboratory a week. Elementary theory of photoelasticity. The membrane, electrical potential and hydrodynamic analogies; X-ray diffraction and other methods of stress evaluation.

1170. *ADVANCED MECHANICS.* Spring term. Credit three hours. Three recitations a week. Prerequisite 1155. The formulation and solution of problems in engineering mechanics by vector methods, Lagrange's equations, generalized coordinates, Fourier's series. Conservative systems.

1171. *ADVANCED MECHANICS.* Fall term. Credit three hours. Three recitations a week. Continuation of 1170. Non-conservative systems, energy methods, impact loads, operational methods.

1172. *SELECTED TOPICS IN ADVANCED MECHANICS.* Offered as required. Credit as arranged. Special studies in selected topics.

1181. *ANALYSIS OF CURRENT LITERATURE IN APPLIED MECHANICS.* Fall term. Credit three hours. Three recitations a week. Open to graduate students only. Registration by permission of instructor only. Special training in the critical analysis and interpretation of technical papers currently appearing in the field of applied mechanics. Evaluation of assumptions, procedures, and conclusions of such papers. The preparation of critical discussions.

ENGINEERING MATERIALS

Messrs: BLACK, EHRHART, GIESELER, GUNDER, JEFFREY, MASON, MOYNIHAN, PURCELL, SACK, SWINGLE, WIEGANDT, and YOUNG.

1211. *MATERIALS OF CONSTRUCTION.* Credit three hours. Two recitations and one laboratory period a week. Prerequisite, Mechanics 1133 or 1153. A study of the basic chemical and physical properties of various engineering materials including cast iron, wrought iron, steel, aluminum, magnesium, stone, brick, tile, and other building materials. Laboratory testing of these materials so conducted as to emphasize both the techniques of testing and the evaluation of fundamental material properties. Behavior of the material both as an isolated element and as a structural component. Tensile, compressive, torsional, shearing, and flexure tests. Required of civil engineers in the five-year curriculum.

1212. *MATERIALS OF CONSTRUCTION.* Credit three hours. One recitation and two laboratory periods a week. Prerequisites, Mechanics 1134 and Materials 1211. Should be preceded by or taken concurrently with course 2715. A continuation of course 1211 with special emphasis on timber, cement, concrete, and elemental concrete structural members. Emphasis is placed upon the laboratory studies of the fundamental characteristics and behavior of the materials. Required of civil engineers in the five-year curriculum.

1214. *ENGINEERING MATERIALS RESEARCH.* Either term. Credit one hour for forty hours of actual work. A project may be started during the junior year for completion in the senior year. Prerequisites, courses 1225 and 1226 or their equivalents. Special investigations of an advanced nature of the properties of structural units and the materials of construction. The aim of the course is to secure results by proper investigational methods which are of the caliber and scope deemed essential for publication.

1215. *MATERIALS SEMINAR.* One to six hours credit. Elective. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the materials field. One one-hour period a credit hour.

1221. *ENGINEERING MATERIALS.* Credit three hours. Three lecture periods a week. Prerequisites, Organic Chemistry, Chemistry 301, and Physical Chemistry, Chemistry 402. An elementary lecture course in Engineering Materials covering the metallurgy of iron and steel, the constitution of metals and alloys, the metallography of iron and steels, alloy steels, non-ferrous metals and alloys.

1222. *ENGINEERING MATERIALS.* Credit three hours. Three lecture periods a week. Prerequisite, Engineering Materials 1221. An elementary lecture course in Engineering Materials covering corrosion, fuels and their combustion, refractories, cementing materials and concrete, wood, rubber, plastics, lubricants, and the testing and inspection of materials.

1223. *ENGINEERING MATERIALS.* Credit three hours. Two lectures and one laboratory period each week. Prerequisites, Organic Chemistry, Chemistry 301, and Physical Chemistry, Chemistry 402. A study of the properties of ferrous and non-ferrous metals and alloys, and non-metallic materials such as cementing materials and concrete, plastics, wood, rubber, thermal and electrical insulating materials. Special attention will be given to electrical and magnetic properties. The laboratory will illustrate materials testing, including mechanical and electrical properties of these materials. Messrs. JEFFREY and MOYNIHAN.

1225. *MATERIALS OF CONSTRUCTION.* Required of all Civil Engineering juniors in the four-year curricula. Either term. Credit three hours. Prerequisite course 1138. The materials studied are lime, cement, stone, brick, sand, timbers, ores, cast iron, wrought iron, steel, and some of the minor metals and alloys. The chemical and physical properties, uses, methods of manufacture, methods of testing, and unit stresses of each material are considered, particular emphasis being laid on the points of importance to engineers. Three recitations a week.

1226. *MATERIALS LABORATORY.* Required of all Civil Engineering juniors in the four-year curricula. Either term. Credit three hours. Prerequisite course 1138 and must be taken with or preceded by courses 1225 and 2715. Experimental determination of the properties of materials by mechanical tests. Study of testing machines (their theory, construction, and manipulation); calibration of testing machines and apparatus; commercial tests of iron and steel; tensile, compressive, torsional, shearing, and flexure tests of metal and various woods with stress-strain observation; test of cement, concrete aggregate, concrete, plain and reinforced, and of road material and paving brick. The course is planned to supplement Course 1225 with its study of the properties of materials by the actual handling of the materials and by observations of their behavior under stress. Laboratory work five hours a week.

1231. *ENGINEERING MATERIALS LABORATORY—METALS AND ALLOYS.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, Engineering Materials 1221 and Strength of Materials 1153. May be taken simultaneously with the latter course.

A course dealing with materials testing and the properties of metals and alloys. The following types of tests with testing machines and strain measurement will be performed: tension, torsion, compression, bending, impact, fatigue, hardness, ductility, and calibration. The relation between the properties, structure, selection, inspection and use of metals and alloys will be shown by the following experiments: carbon steels, cast irons, heat treatment, non-ferrous metals and alloys, metallography, spectrography, radiography, and magnaflux.

1232. *ENGINEERING MATERIALS LABORATORY—NON-METALLIC MATERIALS.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, Engineering Materials 1222 and 1231. A course dealing with materials testing and the properties, composition, selection and use of the following non-metal-

lic materials: oils and lubricants, fuels (solid, liquid, and gaseous) and combustion, plastics, wood, cementing materials, and concrete.

1233. *ENGINEERING MATERIALS LABORATORY—MATERIALS TESTING.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, Materials of Construction 1255, 1256 and Strength of Materials 1127. May also be taken simultaneously with the latter two courses.

A course dealing with materials testing and the determination of the properties of materials and their significance.

1251. *ENGINEERING MATERIALS RESEARCH.* Credit, from one to three hours, depending upon the hours of actual work, forty hours of work being equivalent to one credit hour. Prerequisites, Engineering Materials Laboratory 1231, 1232 or 1233.

This course is open to a limited number of seniors and graduate students who have shown suitable proficiency in the required courses in Materials Laboratory to enable them to carry on special problems and investigations under the supervision of the staff.

1252. *APPLIED PHYSICAL METALLURGY.* Credit three hours. Two lectures and one recitation period each week. Prerequisite 1231. This course covers the applications of physical metallurgy to problems in engineering. This will include all processing operations including casting, mechanical working and heat treatment, and the subsequent inspection and use of ferrous and non-ferrous metals and alloys. The significance and control of mechanical properties will be emphasized.

1253. *PHYSICS OF ENGINEERING MATERIALS.* Credit, from one to three hours, depending upon the hours of actual work, forty hours of work being equivalent to one credit hour. Prerequisites, Engineering Materials 1231, 1232, and 1233.

This course is open to a limited number of seniors and graduate students who have shown suitable proficiency in the required courses in engineering materials and physics to enable them, under staff supervision, to carry on special problems and investigations in the field of the physical properties of engineering materials and the application of physical methods to production control.

1255, 1256. *MATERIALS OF CONSTRUCTION.* Two terms. Credit three hours each term. Prerequisite or parallel course, Physical Chemistry 403, 404. Messrs. MASON and WIEGANDT. Lectures.

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.

Non-metallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

Primarily for students in Chemical and Metallurgical Engineering.

Civil Engineering

Required courses in the Civil Engineering curriculum given outside of the College of Engineering:

Chemistry 105, 106, 301, 402 (p. 130)
Economics 107. Introduction to Economics (p. 131)
Economics 201. Money and Banking (p 131)
Economics 401. Labor Conditions and Problems (p. 132)

English 111, 112. Reading and Writing (p. 132)
Geology 113. Engineering Geology (p. 132)
History 165, 166. Science in Western Civilization (p. 132)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (p. 132)
Physics 115. Mechanics (p. 133)
Physics 116. Wave Motion, Sound, and Heat (p. 133)
Physics 117. Electricity and Magnetism (p. 134)
Physics 118. Physical Electronics and Optics (p. 134)
Public Speaking 101 (p. 135)
Psychology 440. Psychology for Engineering Students (p. 135)

Required courses in Mechanics and Engineering Materials are described on pages 72–76.

Courses in Regional and City Planning in cooperation with the College of Architecture are described on page 128.

Courses given in the School of Civil Engineering are listed under the following headings. Descriptive Geometry and Drawing. Surveying. Hydraulics. Sanitary Engineering. Transportation Engineering. Structural Engineering. Special and Graduate Courses. Administrative Engineering.

DESCRIPTIVE GEOMETRY AND DRAWING

2001. *DRAWING.* First term. Credit three hours. A course in the fundamentals of the graphic language as used in engineering. It is laid out to include the care and use of drafting instruments, freehand lettering, titles, geometrical problems, simple orthographic projection, freehand and technical sketching, and print reproduction. Text: "Engineering Drawing", Carter and Thompson. Messrs. JENKINS, HEWITT, and others.

2002. *DRAWING.* Second term. Credit three hours. Prerequisite course 2001. Instruction and drill in the fundamental conception of Descriptive Geometry, dealing with the graphic solution of advanced space problems, both theoretical and practical. This course develops a complete grasp of the principles of projection and gives further training in visualization. Practical Civil Engineering problems such as topographic mapping, structural drafting, and charts and graphs are included in the course. Messrs. JENKINS, HEWITT, and others.

2004. *ADVANCED DRAWING.* Elective for upperclassmen. Either term. Credit one to three hours. Problems in concrete, structural, topographical, highway, and sanitary drafting; engineering drawings, rendered in color, to enable the student to supplement ordinary drawings with artistic representations, so portrayed as to be readily intelligible to non-technical persons. Mr. JENKINS.

SURVEYING

2101. *ELEMENTARY SURVEYING.* Required of all freshmen in Civil Engineering. First term as assigned. Credit three hours. Use of steel tape, level, and transit; fundamental surveying methods; measurements of lines, angles, and differences of elevation; land surveying, areas and plotting. Textbook: Breed and Hosmer's *Elementary Surveying.* First term, one recitation and two field, computation, or mapping periods a week. Second term, three recitation periods a week for the first six weeks and three field, computation, or mapping periods a week during the remainder of the term. Messrs. UNDERWOOD, SPRY, and others.

2102. *ADVANCED SURVEYING.* Required of sophomores in the five-year course. Credit three hours. Prerequisite, Elementary Surveying 2101. City and mine surveying, surveys of the United States public lands; volumetric, topographic, hydrographic, and geodetic surveying; elements of photographic surveying; map projections; ele-

ments of practical astronomy. Textbooks: Breed and Hosmer's *Elementary Surveying, Volume I, and Higher Surveying, Volume II.* Three recitations a week. Messrs. UNDERWOOD and SPRY.

2103. *SUMMER SURVEY:* (Topographic, Hydrographic, and Geodetic Survey Camp.) Required of all Civil Engineering students, following the sophomore year. Credit five hours. Prerequisite, Advanced Surveying 2102. Practical experience in surveying under field conditions. An extensive topographic survey with the transit and stadia and the plane table, and a hydrographic survey of a portion of Cayuta Lake are executed, and field maps are made. Triangulation and precise leveling control the topographic and hydrographic work. A base line is measured with invar tapes. Solar observations for azimuth and time are made and results computed. Each student takes part in all branches of the work. Field and office work six days a week. Attendance for five weeks. Date of beginning of the camp will be announced in the second term. Messrs. UNDERWOOD, SPRY, and others.

2104. *TOPOGRAPHIC SURVEYING AND MAPPING.* Elective for upperclassmen and graduate students. Three hours credit. Prerequisite, course 2103. Methods of making topographic surveys for mapping to large scales. The use of the plane table. Solutions of the three-point problem; the two-point problem; location of details by direction and distance. Mapping, including the construction of a final topographic map of the area covered by the field work of course 2103 during the preceding summer. Lectures, recitation, field work, and mapping. One lecture and two laboratory periods a week. Mr. UNDERWOOD.

2105. *LEAST SQUARES: ADJUSTMENT OF OBSERVATIONS.* Elective for upperclassmen and graduate students. Either term. Credit three hours. Prerequisites, Calculus and Physics. The course is designed for students who have experimental investigations in view. The fundamental principles of least squares with application to the adjustment of typical surveying work, such as leveling and triangulation. Applications are also made to problems in physics, astronomy, mechanics, etc., with some attention to the derivation of empirical formulae. Textbook: Leland's *Practical Least Squares.* Lectures, recitations, and laboratory periods, three a week as may be arranged. Mr. UNDERWOOD.

2106. *ADVANCED TOPOGRAPHIC SURVEYING.* Elective. Upperclassmen. Second term. Credit two hours. Prerequisite, course 2103. Economics of surveying methods. Surveys for special purposes, such as extensive construction work, and storage distribution of water for irrigation; earthwork on a large scale, lines of communication, topographic reconnaissance, etc.; photographic surveying. Lectures, recitations, and assigned readings. Mr. UNDERWOOD.

2107. *GEODESY AND GEODETIC LABORATORY.* Elective for upperclassmen. Any term. Credit three hours. Prerequisites, course 182 and 2102. A course for the consideration of special problems in geodetic work. Precise leveling, deflection of the plumb line, figure of the earth, use and investigation of geodetic instruments and apparatus such as circles, levels, micrometer microscopes, standards of length, thermometers, pendulums, magnetic apparatus, etc. Subject to arrangement to meet the special needs of students. Lectures, reading, discussions, and laboratory work. Three periods a week. Mr. UNDERWOOD.

2108. *PHOTOGRAPHIC AND AERIAL SURVEYING.* Elective for upperclassmen. Any term. Credit three hours. Prerequisite, Advanced Surveying 2102. The principles of photographic surveying; surveys with camera stations on the ground, including stereoscopic methods; aerial surveys and making of maps from such surveys; ground control. Recitations, lectures, and collateral reading. Three hours a week. Mr. UNDERWOOD.

2109. *MAP PROJECTIONS AND MAPPING.* Elective for upperclassmen and graduate students. Credit three hours. The theory of map projections. Construction of projections. Plane coordinate systems. Map reproduction. Practice in topographic surveying and in mapping. One recitation and two laboratory periods a week. Mr. UNDERWOOD.

2110. *ROUTE SURVEYING.* Required of all Civil Engineering freshmen. Either term. Credit two hours. The recitations cover the theory of simple, transition, and vertical curves, and earthwork computations; with applications to practical problems for purposes of illustration. The field periods take up about two-thirds of the term and are devoted to computing, laying out, and checking simple, transition, and vertical curves. The drawing periods take up the remaining third of the term and in them each student makes a pencil map of a preliminary line surveyed in Course 2103 and prepares a detailed "paper location" report based on these data. A tracing and profile of the final location as run in the field is then required, also a computation of part of the earthwork. Textbooks: Pickels & Wiley, *Route Surveying* and Crandall, *Earthwork Tables.* One recitation and one field or drawing period a week. Messrs. UNDERWOOD, CRANDALL, PERRY, SPRY, and others.

2131. *ELEMENTARY SURVEYING.* For students in Mechanical and Electrical Engineering. Either term. Credit one hour. Use of steel tape, level, and transit. Fundamentals. Problems of particular interest to Mechanical and Electrical Engineering. Textbook: *Surveying,* Breed. One 2½-hour period a week. Messrs. UNDERWOOD, SPRY, and assistants.

2132. *ADVANCED SURVEYING.* For students in Landscape Architecture. Second term in alternate years. Credit two hours. Prerequisite, Elementary Surveying 2101. Profile leveling; cross-sectioning; earth-work; circular curves and spirals; vertical curves. Textbook: Breed and Hosmer's Vol. I, *Elementary Surveying.* Recitations, computation, and field work.

2142. (a) *GEODETIC ASTRONOMY.* Any term. Prerequisites, courses Astronomy 186 and 2105. Investigations of instrumental errors; variation of latitude and azimuth; and all questions relating to work of the highest precision connected with astronomical problems and geodetic operations. The field is so broad that the interest of the student is given consideration as to the actual research undertaken. Mr. UNDERWOOD.

(b) *GEODETIC ENGINEERING RESEARCH.* Either term. Prerequisites will depend upon the line of work to be pursued. Special problems in least squares, reduction of triangulation, and photographic surveying as may be arranged. Mr. UNDERWOOD.

2143. *SEMINAR IN GEODESY.* One to six hours credit. Elective. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the geodetic field.

HYDRAULICS

Including Theoretical and Experimental Hydraulics and Hydraulic Engineering.

2301. *ELEMENTARY FLUID MECHANICS.* Fifth term, five-year curriculum. Credit three hours. Prerequisite 1132. Statics, dynamics of fluid flow, viscosity, law of continuity, energy equation, turbulence, and resistance of submerged bodies. Simple applications of mechanics principles to the flow of fluids through orifices, pipes, open channels, and weirs. Textbook: *Elementary Fluid Mechanics,* Vennard. Three recitations a week. Messrs. BOGEMA, PRIEST, and REID.

2302. *HYDRAULICS.* Sixth term, five-year curriculum. Credit three hours. Prerequisite 2301. A correlation of existing hydraulic data and flow relations with the

principles of fluid mechanics to provide the student with a practical means of attacking the common problems of flow of liquids. Consideration is given to such control and measuring devices as the orifice, weir, venturi meter, and nozzle; flow in pipe systems; pressure waves; flow in open channels; turbines and centrifugal pumps. Two recitations and one laboratory period a week. Messrs. BOGEMA, PRIEST, REID, and assistants.

2303. *ADVANCED HYDRAULICS.* Elective. Credit three hours. Prerequisite 2302 (or 2351). This course involves more detailed and extended theory and application than the first course. Problems considered include stability of flotation, barometric leveling, fluids subject to acceleration, hydraulic similitude, water hammer, open channel flow, and hydraulic jump. Three lectures and recitations a week. Mr. BOGEMA.

2304. *HYDRAULIC MEASUREMENTS.* Elective. Credit three hours. Prerequisite 2302. Experiments involving current meters and floats in canal or river; Pitot tubes; water meters, weirs, characteristics in detail of orifices, nozzles, Venturi meters, pipes, the determination of efficiency, capacity, and characteristics of hydraulic machinery. Two periods a week in laboratory or computing room and one lecture period. Mr. REID.

2305. *HYDRODYNAMICS.* Elective. Credit three hours. Prerequisite 2302 (or 2351) and Differential Equations. Physical properties of fluids, equations of motion, circulation, irrotational motion, conformal transformation, laboratory methods for determining flow nets, pressure distribution on submerged surfaces, vorticity, equations of viscous flow, separation, drag, turbulence, dimensional analysis and similitude. Three recitations a week. Mr. PRIEST.

2306. *PUMPS AND TURBINES.* Elective. Credit three hours. Prerequisite, 2302 (or 2351). Theory and characteristics of the hydraulic ram; reciprocating and centrifugal pumps; impulse, reaction, and propeller type turbines; selection and testing of hydraulic machinery. Two recitations and one laboratory or computation period a week. Mr. BOGEMA.

2307. *FLOW IN OPEN CHANNELS.* Elective. Credit three hours. Prerequisite, 2302. Uniform flow, gradually varied flow, rapidly varied flow, hydraulic jump, waves, transitions, bends, obstructions, steep slopes, spillways, energy dissipation, and hydraulic models. Two lectures and one computing period a week. Mr. PRIEST.

2308. *HYDRAULIC MODELS.* Elective. Credit three hours. Prerequisite, 2303. Theory and practical use of models in designing hydraulic structures. One recitation and two laboratory or computing periods a week. Mr. REID.

2331. *FLUID MECHANICS.* Required for students in Mechanical and Electrical Engineering. Credit three hours. Either term. Prerequisite, Mechanics 1152. Statics, dynamics of fluid flow, law of continuity, energy equation, turbulance, flow of compressible and incompressible fluids, impulse momentum relations, resistance of submerged bodies, lubrication, and hydraulic machinery. Several demonstration lectures are given to illustrate Fluid Mechanics principles. Textbook: Elementary Fluid Mechanics, Vennard. Three recitations a week. Messrs. BOGEMA, PRIEST, REID, LYON, WILLIS, and assistants.

2342. *HYDRAULIC RESEARCH.* Elective. Either term. Prerequisite, course 2351 or its 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 often desirable and is permissible for two students to work together on the same investigation. Written reports are required but the text need not be typewritten in thesis style. These reports are kept by the department. In most cases it is necessary to arrange a definite schedule for work in the laboratory to avoid conflicts. Messrs. BOGEMA, PRIEST, and REID.

2343. *HYDRAULICS SEMINAR.* One to six hours credit. Elective. Open to specially selected seniors or graduate students. Abstraction and discussion, of technical papers and publications in the hydraulic field.

2351. *HYDRAULICS.* Required of all Civil Engineering juniors in the four-year programs. Either term. Credit four hours. Prerequisites, courses 1131 and 1132 (or 1136). Hydrostatic pressure; manometers; strength of pipes; stability of dams; immersion and flotation; flow of liquids through orifices, nozzles, Venturi meters, and pipes, and over weirs; time required to empty tanks and reservoirs; simple, compound, branching, and looping pipes; flow of water in open channels; pressure on stationary solids due to deviated flow. Elementary consideration of modern water wheels. Textbook: Schoder and Dawson's *Hydraulics.* Three recitations and one laboratory period a week. Messrs. BOGEMA, PRIEST, and WILLIS.

2401. *APPLIED HYDROLOGY.* Required of all Civil Engineering students. Either term. Credit two hours. Prerequisite, Hydraulics 2351 or 2302. Two lecture and recitation periods a week. The occurrence, properties, transformations, combinations, and movements of the waters of the globe, together with the processes of evaporation, condensation, precipitation, run-off, and stream-flow are presented. The principal factors affecting these processes, the instruments for measuring these factors, the collection and analysis of data obtained, and the application of such data to the investigation of available water resources and their development and utilization are discussed. Problems and demonstrations include measurement of stream flow, development and use of mass and duration curves for stream discharges, determination of annual and monthly precipitation, maximum expected floods, and development of design criteria for hydraulic structures. Mr. DONLEY.

2402. *HYDRAULIC ENGINEERING.* Required of all Civil Engineering students in the five-year curricula. Either term. Credit two hours. Prerequisite, Applied Hydrology 2401. Two lectures a week. An introductory course designed to give a comprehensive view of the Hydraulic Engineering field, to awaken interest in the study and development of water resources, and to provide a basis for later specialization in this field. Fundamental concepts relating to the control of floods, the development of water power, the construction of harbors and navigable channels, the planning of irrigation projects, the establishment and operation of drainage districts, and the development of multiple-purpose projects, are presented. Typical existing projects in each major section of the field are reviewed, the basic principles underlying their planning and development are given, as well as the general principles for their operation after they are constructed. Mr. DONLEY.

2403. *HYDRAULIC STRUCTURES.* Elective. Seniors and graduates. Fall term. Credit three hours. Prerequisite, Applied Hydrology 2401. Three lecture and recitation periods each week. The various types of hydraulic engineering structures required for the development of water resources are presented. These include conveyance structures such as canals, pipelines, tunnels, and penstocks; diversion structures such as low dams, movable dams, and barrages; and storage structures such as concrete, rock-fill, and earth dams. The basic considerations controlling the selection and use of each type of structure, their characteristics, design and operation, and their limiting dimensions are given. Brief reports on typical projects are prepared, from reviews of existing literature, and presented in class by the students. Mr. DONLEY.

2404. *WATER POWER.* Elective. Seniors and graduates. Spring term. Credit three hours. Prerequisite, Applied Hydrology 2401. Two lectures and one computing period each week. History of water power development; hydrologic, hydraulic, and geologic studies of water power sites; power output of streams; selection of turbines, power plant layout, and equipment; economic considerations; and preparation of

engineering reports on water power development are presented. Problems cover determination of available power, selection of turbines, use of pondage and storage, development of load curves, and determination of annual power output. Mr. DONLEY.

2405. *DESIGN OF CONCRETE DAMS.* Elective. Seniors and graduates. Fall term. Credit three hours. Prerequisites, Applied Hydrology 2401, Soil Mechanics 2725, Concrete Construction 2715. One lecture and two computing periods each week. The theory of design for concrete dams including gravity, arch, and buttress types and the distribution of stresses in such structures; design of spillway and outlet structures; including stilling basins and other energy dissipators; investigation of proposed dam sites and treatment of foundation materials. Problems include design of typical non-overflow and spillway sections for a high gravity-type concrete dam as well as those required for a buttress-type hollow dam. The determination of required capacities for spillway and conduits are also included in the assigned problems. Mr. DONLEY. Text: *Engineering for Dams,* by Creager, Justin, & Hinds.

2406. *FLOOD CONTROL.* Elective. Seniors and Graduates. Fall term. Credit three hours. Prerequisite, Applied Hydrology 2401. Text: *Drainage and Flood Control Engineering,* by Pickels. Two lectures and one computing period each week. Analysis of general flood control problem; application of flood formulas; determination of design flood criteria; comparison of flood control methods; review typical flood control projects; study of methods for determination of flood damage; and economic analysis of proposed projects; and methods of operation during flood periods. Problems include determination design floods by unit hydrograph methods; the routing of floods down natural channels; determination of levee locations; capacity of flood channels, and amount of storage required. Mr. DONLEY.

2407. *PUMPING PLANTS.* Elective. Seniors and graduates. Spring term. Credit three hours. Prerequisites, Applied Hydrology 2401, and Flood Control 2406. Two lectures and one computing period each week. Investigation of factors governing the design and selection of pumping equipment; the determination of capacities required; the location of equipment; selection of prime movers; and design of hydraulic structures required for levee or drainage projects. Cost of construction and operation is also considered. Problems include selection of design storm; calculation of required pump capacity; and balancing of limited storage with pump installation. Mr. DONLEY.

2408. *HARBOR ENGINEERING.* Elective. Seniors and graduates. Spring term. Credit three hours. Prerequisites, Hydraulic Engineering 2402, and Soil Mechanics 2725. Two lectures and one computing period each week. Study of wave action, tides and currents; methods of making hydrographic surveys of harbors and channels; selection and performance of hydraulic dredges; reclamation of tidal lands with dredged material; layout and construction of navigation channels, anchorages, and slips; and the design and construction features of bulkheads, jetties, and docks. Problems include those relating to tidal characteristics; the measurement and computation of tidal flow in inlets and estuaries; the estimating of yardage required for channel construction; and other problems relating to harbor improvements. Mr. DONLEY.

2409. *PORTS AND TERMINALS.* Elective. Seniors and graduates. Spring term. Credit three hours. Prerequisites, Harbor Engineering 2408. Design, construction, and operation of ocean, river, and lake ports including the design of structures required for the docking and unloading of ships, the transfer of their cargo to waterway, highway, or air transportation facilities, and the temporary storage in the port area of excess cargo awaiting such transfer and movement. Course includes the design of structures such as quays, docks, wharves, piers, and bulkheads; the selec-

tion of warehouses, and cargo handling equipment; the location and layout of roads and railroads in the port area and their connections to major trunk systems. Mr. DONLEY.

2441. *HYDRAULIC ENGINEERING DESIGN.* Elective. Seniors and graduate students. Fall term. Credit three hours. Prerequisites, Water Power 2404; Flood Control 2406; and Applied Hydrology 2401. Two lectures and one computing period each week. The development of a selected site for multiple-purpose use, including coordination of available storage capacity for control of flood waters, development of water power, and release of water for navigation, water supply or irrigation. Determination of relative benefits from each purpose and the economics of the project as a whole. Review of existing multiple-purpose developments. Mr. DONLEY.

2442. *HYDRAULIC ENGINEERING RESEARCH.* Elective. Graduate students. Either term. Prerequisites, Applied Hydrology 2401 and one additional elective course in field of selected research. Subject and scope of investigation to be undertaken is selected by conference at beginning of term. Preparation of extensive bibliography after extended search of available literature; extraction of pertinent data from all available sources; construction and operation of hydraulic laboratory models; and preparation of concise summary report covering selected investigation. Mr. DONLEY.

2443. *HYDRAULIC ENGINEERING SEMINAR.* Elective. Graduate students or specially selected Senior students. Either term. Credit one to six hours. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the hydraulic engineering field. Mr. DONLEY.

SANITARY ENGINEERING

2501. *SANITARY SCIENCE.* Required of all students in the five-year curriculum. Credit three hours. Prerequisite, Chemistry 106. The fields of chemistry and bacteriology, and bacteriological technique are covered, special attention being given to the methods of examination of public water and milk supplies, swimming pools and bathing beaches, domestic and industrial wastes, and to the interpretation of such examinations. Two recitations and one laboratory a week. Messrs. GIFFT, BOND, and GATES.

2502. *WATER SUPPLY AND TREATMENT.* Required of all students in Civil Engineering. Credit three hours. Prerequisite course 2351. Sources of water supply, quantity available, uses, and rates of demand. Quality, examination, treatment, and purification. Collection, storage, pumping, and distribution systems. Laboratory periods will include examination and reports on water supply systems, simple design problems, and cost estimates. Textbook: *Public Water Supplies,* Turneaure & Russel. Two recitations and one computing period a week. Messrs. GIFFT, BOND, and GATES.

2503. *SEWERAGE AND SEWAGE TREATMENT.* Required of all students in Civil Engineering. Elective for Chemical Engineering students and for others having prerequisite training. Either term. Credit three hours. Prerequisite, course 2351. The design of sanitary and of storm sewers, and the methods of treating sewage are considered in the recitations; and in the computing period, problems are assigned dealing with design and operation and with subject matter considered in recitation and class-room work. The problems are largely of the nature of separate designs. Textbook: Babbitt—*Sewerage and Sewage Treatment.* Two recitations and one computing period a week. Messrs. GIFFT, BOND, and GATES.

2504. *SANITARY BIOLOGY.* Elective for juniors, seniors, and graduate students. Credit three hours. The subject matter of the course includes the fundamentals of bacteriology and of bacteriological methods; the application of these fundamentals

and methods to civil engineering, with special emphasis on the bacteriology and the biology of water, sewage, sewage effluents, and waste-polluted streams. One recitation and two laboratories a week. Mr. GATES.

2506. *ADVANCED WATER SUPPLY.* Elective for seniors and graduates. Second term. Credit three hours. Prerequisite, course 2502. This course comprises a comprehensive study of the general principles and methods involved in furnishing safe water supplies of satisfactory quality. The topics studied include the character of surface and underground water supplies; inspection of sources; relation of communicable diseases to water supplies; standards of quality and examination procedures to determine quality and safety of supplies; water treatment methods including coagulation, sedimentation, aeration, slow and rapid sand filtration, tastes and odor control, softening and iron removal, corrosion control, sterilization, and miscellaneous treatment methods. Also some study of design and operation of water treatment plants is included. Two recitations and one computation period a week Mr. GIFFT.

2507. *ADVANCED SEWERAGE WORKS.* Elective for seniors and graduates. First term. Credit three hours. Prerequisite, course 2503. A comprehensive study of principles and methods involved in the design, construction, and operation of sewers and sewage treatment works, including reference to existing typical plants. In general, the study includes the determination of capacity and design of sewers; the disposal of sewage by dilution or broad irrigation; stream pollution and self-purification; sewage treatment methods, including preparatory devices, sedimentation, chemical precipitation, intermittent sand, and trickling filters, activated sludge, sludge digestion, sludge dewatering and incineration, and miscellaneous treatment methods. Two recitations and one computation period a week. Mr. GIFFT.

2508. *INDUSTRIAL WASTES.* Elective for seniors and graduates in Civil Engineering and for Chemical Engineers. First term. Credit three hours. Prerequisite, course 2503. The treatment of municipal and industrial wastes such as garbage, and the wastes from tanneries, packing-houses, mines, canning factories, textile mills, paper and pulp mills, creameries, cheese factories, condensaries, breweries, sugar refineries, etc. Flow or process charts are used to show the general character of the waste, and methods of treatment applicable are considered. Special attention is given to experimental studies of waste treatment, and to plant-scale treatment. Numerous references, bulletins, reports. Three lectures or recitations a week. Mr. GIFFT.

2509. *PUBLIC HEALTH.* Elective for advanced and graduate students in Civil Engineering and students outside the School by permission of the instructor. Second term. Credit three hours.

A general course outlining basic principles in transmission of disease and communicable disease control; organization and functions of Federal, State, and Local Health Departments; standards of environmental sanitation including water supply, waste disposal, milk, restaurant and school sanitation; insect and rodent control; industrial hygiene; vital statistics. Content of course adjusted to the needs of the students enrolled in order to demonstrate the responsibility of the individuals and their professions for maintaining the public health. Three recitations or lectures a week. Messrs. GIFFT and BOND.

2510. *ENVIRONMENTAL SANITATION.* Elective for advanced and graduate students. Credit three hours. A course dealing with public health engineering practice in the control of problems of environmental sanitation. Emphasis is on the engineering aspect of industrial hygiene, milk, and food sanitation, swimming pool design, and housing. Lectures, reports, and recitations. Three periods a week. Mr. BOND.

2511. *WATER AND SEWAGE ANALYSIS.* Elective for juniors and seniors. First term. Credit two hours. The purpose of the course is to acquaint the student with

the standard procedures followed in making physical and chemical analyses of water and of sewage, as well as the fundamental principles of chemistry. Textbooks: Standard Methods of Water Analysis, A.P.H.A., Water and Sewage Analysis, Eldrige, Theroux, and Mallman. One recitation and two laboratory periods a week with lectures, recitations, and laboratory work. Messrs. GIFFT and GATES.

2541. *SANITARY ENGINEERING DESIGN.* Either term. Credit three hours. This course should be preceded by Courses 2502 and 2503, or equivalent courses. The purpose of the course is to teach methods of determining the capacity, basis of design, computations, sketches, and general plans and profiles involved in the design of sewerage, industrial waste, and water treatment works. Problems may be elected such as the design of a separate or combined sewerage system, an intercepting sewer, a municipal or an institutional sewage treatment plant, a plant for the treatment or disposal of an industrial waste, or a plant for the treatment of an industrial, institutional, or municipal water supply. Mr. GIFFT.

2542. *SANITARY ENGINEERING RESEARCH.* Either term. Prerequisites for work in this field will depend upon the particular problem to be pursued, but in general will include work in water analysis, bacteriology, and courses in Hydraulics and Sanitary Engineering dealing with the field in which the work is to be undertaken. Hours, credit for work, prerequisites, and other questions relating to contemplated research in this field will be arranged by conference. Messrs. GIFFT, BOND, and GATES.

2543. *SANITARY ENGINEERING SEMINAR.* One to six hours credit. Elective. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the sanitary field. One one-hour period a week for each credit hour.

TRANSPORTATION

2602. *TRANSPORTATION.* Required of Civil Engineering students in the five-year curricula. Elective for seniors and graduates. Second term. Credit three hours. A course covering travel and transport agencies with special reference to their facilities, ownership, financing, regulation, and coordination. A brief review of the development of transportation throughout the world is used as a background for an intensive study of the present situation in the various countries and comparison of the policies and practices in use. Particular attention is given to the various proposals designed to promote more efficient use of the various transportation agencies in the United States by better coordination, pooling of facilities, etc., and economic studies are made of some of the new projects which are under discussion. Lectures and recitations three hours a week. Mr. PERRY.

2603. *RAILROAD MAINTENANCE OF WAY.* Elective. Seniors and graduates. First term. Credit three hours. Prerequisite, course 2601. The subjects treated are track materials (with special reference to the section, method of manufacture, and composition of steel rails, to the economics of tie preservation and the use of metal ties, and to the effect of quality of ballast upon maintenance); machine and other methods of grading for second track; drainage; track laying by both machine and hand methods, ballasting and bringing new track to line and grade; turnouts and switches; derailing switches; side tracks and yard tracks; sorting and terminal yards; track maintenance; track tools, work trains; action of car wheels on curves; widening of gage; double tracking; separation of grades; and improvement in grades and alignment. Textbook: Tratman, *Railway Track and Maintenance.* Lectures and recitations three hours a week. Mr. PERRY.

2604. *RAILROAD OPERATION AND MANAGEMENT.* Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite, course 2601. Under organization, the following subjects are treated: general principles underlying organization and the effect of each on efficiency; principal departments of railway service with a brief outline of the work of each; departmental and divisional systems of organization, with examples on various roads and discussion of adaptability of each. The duties of officers and the work of the different departments are taken up in considerable detail. The most important laws affecting railroads are given in discussing the work of the legal department. Freight traffic, freight houses, classification yard, car service rules, accounting, etc., are among the topics considered under operation. Signaling and interlocking and train rules are also considered. Lectures and recitations three hours a week. Mr. PERRY.

2610. *HIGHWAY ENGINEERING.* Required of all Civil Engineering students. Credit three hours. Prerequisite, 2110 and preceded by or taken concurrently with 2725. Design, construction and maintenance of highways and city streets. Location and alignment (aerial photographic methods included), width, capacity, and geometrical design based on traffic demands. Drainage, soils, stabilization, aggregates. Bituminous materials. Structures; traffic control; landscaping. Economics and administration. Construction methods and equipment for grading and paving of low cost, flexible, and rigid pavements. Analysis and correction of characteristic pavement failures. Two lectures, one computing period or field assignment each week. Messrs. LEWIS and HODGE.

2612. *HIGHWAY LABORATORY—BITUMINOUS.* Elective. Seniors and graduates. Spring term. Credit three hours. Prerequisite, course 2610 or may be taken concurrently with course 2610. Non-bituminous and bituminous materials are tested. Subgrade soils are sampled and their properties examined; subgrade stabilization admixtures are also tested and studied. Bituminous mixtures are designed, and their properties examined. Two laboratory periods a week. Messrs. BELCHER and LEWIS.

2613. *HIGHWAY LABORATORY—STABILIZATION.* Elective. Seniors and graduates. Fall term. Credit three hours. Prerequisites, 2725 and 2610 or may be taken concurrently with course 2610. Non-bituminous and bituminous materials are tested and their characteristics studied. Soils are sampled and examined, and investigations made of the behavior of mixtures of soils with bituminous and non-bituminous materials. Special investigations and tests are made to determine the properties of various combinations of materials and the effects of modifications in design. Two laboratory periods a week. Messrs. BELCHER and LEWIS.

2614. *ADVANCED HIGHWAY ENGINEERING.* Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite 2610. *Part I.* Soils and subgrades. Surveying sampling, compaction, and stabilization practices. Special problems in excavation. *Part II.* Design and construction of base and surface courses for flexible pavements. *Part III.* Design and construction of rigid pavements. *Part IV.* Highway planning. Urban route selection, geometrical design; design of regional systems of highways, freeways, and parkways. Messrs. BELCHER and LEWIS.

2617. *AIRPORTS.* Elective. Seniors and graduate students. Credit three hours. Prerequisite, 2610 and 2725. The location, design, construction, and maintenance of airports. Two recitations and one computing period a week. Mr. HODGE.

2618. *LOW COST ROADS.* Elective. Seniors and graduate students. Either term. Credit three hours. Prerequisite, course 2610 or its equivalent. Study of economic importance of routes and selection of (farm-to-market) 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. BELCHER.

2620. *TRAFFIC ENGINEERING.* Elective. Credit three hours. Prerequisite, 2610. City and highway traffic surveys. Accidents, congestion, delay, speed, volume, density, parking, channelization, lighting. Traffic control and routing. Signs, signals, and markings. Regulation; truck and bus units as traffic elements. Urban traffic consideration in city planning. Driver reactions and habit patterns; design of safety features and effectiveness of signs. Also air traffic for those specializing in airports. Three recitations a week. Mr. LEWIS.

2621. *ENGINEERING INTERPRETATION OF AERIAL PHOTOGRAPHS.* Elective. Credit three hours. Prerequisites, 2610, 2725. A study of the soil and rock areas of the United States and the patterns that they present in aerial photographs. Fundamental elements of soil patterns are analyzed to permit determination of soil texture, type of bedrock, and drainage properties. Special emphasis is placed on the interpretation of engineering information dealing with construction, excavation, clearing, water supply, drainage requirements, and foundation problems. Two recitations and one computing period a week. Mr. BELCHER.

2641. *TRANSPORTATION ENGINEERING DESIGN.*

(a) *RAILROAD ENGINEERING.* Either term. The problems are those encountered in the location and construction of railroads, and include the following subjects: Economic location of railroads; culverts; bridges; retaining walls; tunnel and subway design; small depot buildings; freight houses; water supply and coaling plants; icing stations; turntables and engine-houses; gravel washing plants; track layouts with details of signals and interlocking; yard and terminal design, etc. Bills of material and estimates of cost are usually required. The field is so broad that the interest of the student is given consideration in assigning problems. Mr. PERRY.

(b) *HIGHWAY ENGINEERING.* Either term. The problems are those encountered in the selection, location, design, and construction of highways. They include the following: Economic selection of routes; economic location; design of highways; highway intersections; culverts; highway bridges; retaining walls; and other highway structures. Bills of material and estimates of cost are usually required; also layouts and methods of executing work. Mr. LEWIS.

2642. *TRANSPORTATION ENGINEERING RESEARCH.*

(a) *RAILROAD ENGINEERING.* Either term. Special problems in the economics of location, construction, maintenance, and operation of railroads, comparison of transportation agencies, traffic studies, and economics of various systems of transport. Mr. PERRY.

(b) *HIGHWAY ENGINEERING.* Either term. Prerequisites, courses 2610 and 2614. Studies of traffic and traffic regulation and legislation may be made. The field of economics of highway engineering offers a wide variety of problems. Laboratory investigations of subgrade soil, subgrade stabilization, and the effects of modifications in design of bituminous and non-bituminous mixtures provide a wide range of topics for research. Messrs. BELCHER and LEWIS.

2643. *TRANSPORTATION ENGINEERING SEMINAR.* One to six hours credit. Elective. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the transportation field.

STRUCTURAL ENGINEERING

2701. *ELEMENTARY STRUCTURAL ANALYSIS.* Required of all Civil Engineering students. Prerequisite, 1133. Credit three hours. A first course in structural

theory. Determination of reactions, and internal forces and moments in beams, girders, trusses, and three-hinged arches due to stationary and moving loads. Use is made of graphical and analytical methods, and of influence lines. Analysis of simple gravity structures. Two recitations and one problem period a week. Textbook: *Structural Theory,* by Sutherland and Bowman. Mr. WINTER.

2702. *ELEMENTS OF METAL AND TIMBER STRUCTURES.* Required of all Civil Engineering students. Prerequisites, 1134 and 2701. Credit three hours. Characteristics, properties, and mechanics of timber. Grading and working stresses. Design of single timber members and connections. Properties and physical metallurgy of structural carbon steel, and of structural steel and aluminum alloys. Technology and properties of welding. Effects of fatigue, and stress concentration. Design of bolted, riveted, and welded connections and of single steel members. Three recitations a week. Messrs. WINTER, BURROWS, and FISHER.

2703. *STEEL AND TIMBER DESIGN.* Required of all Civil Engineering students. Prerequisite, 2702. Credit three hours. Detailed, partial designs are carried out of timber roof trusses, riveted and welded steel roof trusses, welded plate girders, riveted plate girder bridges, steel building frames. Use of timber in construction work. Methods of fabrication and erection of steel structures. Three problem periods a week. Messrs. BURROWS and FISHER.

2704. *STATICALLY INDETERMINATE STRUCTURES.* Required of all Civil Engineering students in the five-year curriculum. Credit three hours. Prerequisite, 2701 and 2715. Common methods of structural analysis applied to continuous beams, rigid frames, indeterminate trusses. Deflections of trusses. Use of influence lines in design. Design problems, including reinforced concrete building frame. Textbook: *Structural Theory,* by Sutherland and Bowman. Two recitations and one problem period a week. NOTE: Students intending to take elective courses in structures in the 9th and 10th terms should register for this course in their 8th term. Mr. MAINS.

2706. *STEEL BUILDINGS.* Elective for seniors and graduates. Credit three hours. Prerequisite, courses 2702 and 2703. Design of steel frame building with traveling crane of the prevailing type used for power house, shop, or warehouse construction. Maximum stresses are obtained for all members by combination of various loads. The design includes columns, column footings, crane runways, partial design of bridge crane, girts, location, number and size of windows. Detail drawings. Three two-hour periods a week. Textbook: Ketchum, *Steel Mill Buildings.* Mr. BURROWS.

2707. *STEEL HIGHWAY BRIDGES.* Elective for seniors or graduates. Prerequisite, courses 2702 and 2703. Credit three hours. Complete design of a three lane truss bridge with cantilever sidewalks or of a three hinged spandrel braced arch bridge using either reinforced concrete slab or steel grid for the floor. Determination of deflection both analytically and graphically, amount of camber to be used and in case of the truss span, thickness of various wedges to be used on erection bents. Reference book: Johnson, Bryan, and Turneaure, *Modern Framed Structures,* Volume III. Three two-hour periods a week. Mr. BURROWS.

2708. *INVESTIGATION AND RATING OF EXISTING STEEL STRUCTURES.* Elective for seniors and graduate students. Prerequisite, courses 2702, 2703. Credit three hours. Preferably first term. The complete measurement of span and length of members of an existing steel bridge or other structure in order to determine size and weight of structural shapes and reduced sections due to corrosion. Determination of deflection, dead load stresses, and allowable stresses in individual members and from this data determination of safe capacity or rating of structure as governed by the weakest member. Hours as assigned. Mr. BURROWS.

2709. *ADVANCED STRUCTURAL ANALYSIS.* Elective for advanced undergraduate and graduate students. Credit three hours. Prerequisite, 2704. Review and criti-

cal comparison of fundamental methods for the solution of statically indeterminate structures and extension to more involved problems. Column analogy, members of variable cross-section, secondary stresses, wind stresses, Vierendeel trusses. Use of influence lines, numerical methods and model analysis for design. Design problems. Textbook: *Statically Indeterminate Structures,* by Maugh. Three periods a week. Mr. MAINS.

2710. *STRENGTH OF STRUCTURES.* Elective for graduate students and advanced undergraduate students. Credit three hours. Prerequisite, 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, buckling, and impact. Structural materials under load, strain hardening, residual stresses, hysteresis, stress concentration, alternating stress. Design for fatigue. Stresses beyond the elastic limit. Plastic or ultimate design of steel and reinforced concrete structures. Critical discussion of current design specifications. Three recitations a week. Mr. WINTER.

2711. *BUCKLING OF STRUCTURES.* Elective for graduate students. Advancd undergraduate students by special permission. Credit three hours. Prerequisite, 2710 and 1145 or equivalent. Analysis and design involving elastic stability. Determination of buckling loads and maximum stresses of columns with and without initial crookedness and eccentricity. Solid and open web columns with variable cross-section. Beam columns. Lateral strength of unbraced beams. Buckling loads and ultimate strength of thin, compressed plates. Design of thin-walled steel structures. Critical discussion of current design specifications. Three recitations a week. Mr. WINTER.

2712. *TANKS AND BINS.* Elective for graduate students. Advanced undergraduate students by special permission. Credit three hours. Prerequisite, 2704 and 1145 or equivalent. Analysis and design of domes, tanks, reservoirs, bunkers, bins, and long-span roofs in reinforced concrete (plain and prestressed). Methods of analysis include theory of plates and shells, advanced beam theory, hipped plate construction. Three recitations a week. Mr. WINTER.

2715. *REINFORCED CONCRETE DESIGN.* Required of all Civil Engineering students. Either term. Credit three hours. Prerequisite, 1134. A first course in reinforced concrete. Elementary theory of reinforced concrete is applied to rectangular beams, slabs, T-beams, beams reinforced for compression, columns, and footings. Shear, diagonal tension, and direct stress combined with flexure are treated. Several design reports are required which include reinforcement drawings, schedules, and formwork. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures.* Three two-hour periods a week. Messrs. WINTER, MAINS, and TAYLOR.

2716. *ADVANCED REINFORCED CONCRETE DESIGN.* Elective for seniors and graduate students. First term. Credit three hours. Prerequisite 2715. Comparative design of large retaining walls. Multiple footings. Flat slab construction. Special floor systems. Elements of arch analysis with application to a simple design. Three two-hour periods a week. Messrs. WINTER and MAINS.

2717. *REINFORCED CONCRETE BRIDGES.* Elective for seniors and graduate students. Prerequisites, 2715 and 2704. Credit two hours. The design of various reinforced concrete bridges according to current specifications. Single span and multi-span slab, through and deck girder, culvert, and rigid frame bridges are included. Two two-and-one-half-hour periods a week.

2720. *FOUNDATIONS.* Required of all Civil Engineering students. Credit three hours. Prerequisite, 2725. Study of the structural problems encountered in foundation work. Retaining walls, sheet piling, spread footings, piles, piers, abutments, cofferdams, caissons, underpinning. Design problems. Textbook: *Substructure Analysis and Design,* Andersen. Two lectures and one computing period a week. Mr. MAINS.

2725. *ELEMENTS OF SOILS ENGINEERING.* Required of all students in Civil Engineering. Either term. Credit three hours. Prerequisites, 113, 1134 or 1138 and 2301. The elements of the formation and composition of soil, its fundamental properties, and its behavior as an engineering material. Instruction in principles of soil identification and classification, basic terminology and soil characteristics such as gradation, permeability, compressibility, consolidation, and shearing strength with applications to simple problems of seepage, settlement, bearing capacity, stability of earth slopes. Theory of lateral earth pressure. Discussion of methods and equipment for soil exploration. Laboratory tests for experimental determination of above mentioned soil characteristics and evaluation and use of data. Two lectures and one laboratory period a week. Mr. HOUGH.

2726. *SOILS ENGINEERING THEORY.* Elective for seniors and graduate students. First term. Credit three hours. Prerequisite, 2725. Principles of mechanics and strength of materials relating to typical soils engineering problems and the fundamental physical and chemical characteristics of soil which affect their application. Methods for determining the distribution of stresses induced in semi-infinite soil masses by surface and body forces, variation of stress at a point and the Mohr theory of rupture. Composition, structure, and stress-strain characteristics of soil. Calculation of the amount and rate of settlement of structures, the stability of earth slopes and of embankment foundations. Basic principles of flow of water through soil, flow net construction, rate of seepage and effect of seepage on stability of structures. Lateral earth pressure theory. Three lectures a week. Mr. HOUGH.

2727. *APPLIED SOILS ENGINEERING.* Elective for seniors and graduate students. Second term. Credit three hours. Prerequisite, 2726. Application of Soils Engineering Theory to practical problems. Planning and conduct of subsurface investigations for various types of work, determination of significant physical and chemical soil characteristics by test or other means including appropriate laboratory exercises, analysis of actual designs of proposed structures for prediction of settlement, stability, rate of seepage or other service requirements, methods for inspection and control of earth works construction, selection and placement of materials, compaction and stabilization. Two lectures and one long period a week. Mr. HOUGH.

2731. *ELEMENTS OF STRUCTURAL ENGINEERING.* Required of all students in Electrical Engineering. Either term. Credit two hours. Analysis and design of beams of steel, timber and concrete, columns, and footings. Textbook: Urquhart and O'Rourkes' *Elementary Structural Engineering.* One lecture and one computing period a week. Messrs. FISHER and TAYLOR.

2741. *STRUCTURAL ENGINEERING DESIGN.* Either term. Prerequisite, courses 2702, and 2715. The student may select a problem such as the following: (a) an arch bridge, (b) a cantilever bridge, (c) a rigid frame bridge, (d) a special problem in steel or concrete building design, (e) the design of any other structure of particular interest to the student provided he has had the proper preparation for such design. The work is submitted in the form of reports. Drawings of typical details must accompany reports. Messrs. WINTER, BURROWS, MAINS, and others.

2742. *STRUCTURAL ENGINEERING RESEARCH.* Any term. 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 or theoretical work with a view to simplifying present methods of design or proposing new methods. Messrs. WINTER, BURROWS, MAINS, and others.

2743. *STRUCTURAL ENGINEERING SEMINAR.* One to six hours credit. Elec-

tive. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the structural field.

2751. *STRESS ANALYSIS AND STRUCTURAL DESIGN.* Required of all juniors in Civil Engineering in the 4-year curricula. Either term. Credit four hours. Prerequisites, courses 1136 and 1138.

STRESS ANALYSIS. Graphic analysis of simple and cantilever beams, roof trusses, and framed bents. Determination of position of moving concentrated loads for maximum shears and moments in beams and deck girders; also for through girders and maximum floor beam reactions for same. Stresses due to dead load, live load, impact, and wind load in the principal types of simple trusses employed in modern construction. Stiff web systems and counter bracing. Three-hinged roof and bridge arches. Practical problems in actual stress computation throughout the course. Textbook: Urquhart and O'Rourke, *Stresses in Simple Structures.* Three recitations a week.

STRUCTURAL DESIGN. Graphic analysis of stresses in a timber truss. Design of truss members and joint details. Computations, systematically arranged in the form of reports, and working drawings. Textbook: Hansen's *Modern Timber Design.* Computation and drawing, two and one-half hours a week. Messrs. BURROWS and GAZDA.

2752. *ENGINEERING PROBLEMS.* Required of Civil Engineering seniors in the four-year curricula. Either term. Credit two hours. Prerequisites, courses 1138, 2302, or 2351. The object of this course is to provide a review involving additional practice in using the principles and methods of applied mechanics. A series of problems, such as occur in ordinary engineering practice, and covering a wide range of topics, is given out for solution. Computations and reports. Five hours a week. Messrs. HOWELL and GAZDA.

SPECIAL AND GRADUATE COURSES

2801. *THESIS.* Elective. Seniors. Either or both terms. Credit three or more hours. The thesis gives the student, desiring to work out a special problem or make an engineering investigation, and to record the result of his work, the opportunity of so doing. 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.

2850. Inspection Trip. For eighth-term students.

A supervised field inspection trip of several days in length to include a variety of Civil Engineering projects. Each student is required to submit a comprehensive written report. No academic credit is given but the course is required of all students for graduation.

SPECIAL NOTE

All the elective courses are suitable for graduate and advanced students, and may be taken by them in the regular classes. Other special courses will be arranged to suit the requirements of graduate students. These special courses 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.

ADMINISTRATIVE ENGINEERING

2901. *CONSTRUCTION METHODS.* Required of all Civil Engineering students. Credit three hours. A fundamental course designed to acquaint the student with the financial and economic principles underlying human enterprises, both public and

private; and with the agencies — money, men, materials, and machines — utilized in carrying out construction projects, and their correlation and control. Methods and processes of construction with special attention to the equipment available and its adaptability to various kinds of work. Problems and reports on references to periodical literature are required of all students. Lectures and recitations three hours a week. Messrs. CRANDALL and PERRY.

2902. *ENGINEERING LAW*. Required in fourth year. Either term. Credit three hours. An introductory course in the laws of contract, tort, agency, real property, water rights, form of business organization, sales, and negotiable instruments; special emphasis on contract documents required on construction work; collateral topics such as workmen's compensation, mechanics' liens, arbitration, and patent law are also included. Lectures and recitations three hours a week. Textbook: *Contracts in Engineering,* Tucker. Messrs. THATCHER, CRANDALL, and PERRY.

2903. *ECONOMICS OF ENGINEERING*. Required in the fourth year. Either term. Credit three hours. Prerequisite, Construction Methods, Economics 3, and Accounting. The economic aspects of engineering and the application of principles of management to the work of the engineer; economic selection of materials, equipment, and structures; studies for the replacement of existing units; plant layouts; public works economy; the technique of estimating quantities and costs for various types of engineering projects. Three recitations a week. Messrs. THATCHER and CRANDALL.

2904. *PUBLIC ADMINISTRATION*. Required in fifth year. Either term. Credit three hours. A course to acquaint the prospective city engineer, superintendent of public works, city manager, or executive engineer in charge of various government bureaus or departments with the administrative problems he must face in addition to strictly technical engineering duties. Budgets, controlling legislation, civil service regulations, city planning, and public administration practices are included. Lectures and recitations three hours a week. Mr. CRANDALL.

2905. *VALUATION ENGINEERING*. Elective for fourth- and fifth-year students. Credit three hours. Prerequisites, Construction Methods, Accounting, Engineering Law or concurrently therewith. Theory and practice of valuation for purposes of utility rate making, purchase or sale, eminent domain or condemnation cases, securities, bank loans and mortgages, insurance, uniform systems of accounting, and improved management. Lectures and recitations three hours a week. Mr. CRANDALL.

2906. *ADVANCED ENGINEERING LAW*. Elective for fourth- and fifth-year students. Credit three hours. Prerequisite, Engineering Law 2902. An extension, by the use of case material, of some of the legal principles covered in Course 2902, particularly the laws applying to the various phases of construction contracts and employer-employee relationships; additional fields included are suretyship, insurance, bailments, and conditional sales. Lectures and recitations three hours a week. Textbook: *Law for Engineers and Architects,* Simpson and Dillavou. Mr. THATCHER.

2907. *CONSTRUCTION MANAGEMENT*. Elective for fourth- and fifth-year students. Credit three hours. Prerequisites, Construction Methods, Economics of Engineering, Accounting. Planning and operation of construction projects by the civil engineer, including coordinated organization of men and machines, scheduling and estimating, purchasing, selection and training of men, operation and maintenance of equipment, cost keeping and reports, pay systems, accident prevention, and other related factors. Lectures and recitations three hours a week. Mr. CRANDALL.

2941. *GENERAL CIVIL ENGINEERING*. Either term. Problems in practical design may be taken in any department, the work to be supervised by the department concerned in cooperation with the Department of Structural Engineering in regard to structural features.

2942. *ADMINISTRATIVE ENGINEERING RESEARCH.* Either term. Special problems relating to the economic, legal, and financial aspects of engineering construction projects, management of public works and appraisals. Messrs. THATCHER and CRANDALL.

2943. *ADMINISTRATIVE ENGINEERING SEMINAR.* One to six hours credit. Elective. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the field of administrative engineering.

Mechanical Engineering

NUMBERING SYSTEM IN THE SCHOOL OF MECHANICAL ENGINEERING. The first digit (3) of the number designates the School of Mechanical Engineering, the second digit indicates the department in the school, and the third and fourth digits constitute the course numbers within the department. In most cases the old course numbers are retained, the only change being the substitution of the department numbers for the former department letters. The Departments of Industrial Engineering and Administrative Engineering have been combined to form the new Department of Industrial and Engineering Administration, and the Departments of Engineering Materials and Mechanics have become service departments. The courses in Aeronautical Engineering fall under the Graduate School of Aeronautical Engineering. Department numbers (and former letters): O, General (G); 1, Engineering Drawing (C); 2, Industrial and Engineering Administration (A and I); 4, Materials Processing (S); 5, Heat-Power Engineering (P); 6, Mechanical Engineering Laboratory (X); 7, Automotive Engineering (B). The following are the numbers of the service courses: Mechanics, 1100 and up; Engineering Materials, 1200 and up. The courses in Aeronautical Engineering have 7 as the initial digit.

The courses in Mechanical Engineering are listed under the following headings: Automotive Engineering, Drawing and Descriptive Geometry, Heat-Power Engineering, Industrial and Engineering Administration, Machine Design, Materials Processing, Mechanical Engineering Laboratory.

Required courses in the Mechanical Engineering curricula given outside of the Engineering College:

Chemistry 105, 106. General Chemistry (p. 130)
Chemistry 301. Introduction to Organic Chemistry (p. 130)
Chemistry 402. Introduction to Physical Chemistry (p. 131)
Economics 107. Introduction to Economics (p. 131)
English 111, 112. Introductory Course in Reading and Writing (p. 132)
History 165, 166. Science in Western Civilization (p. 132)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (p. 132)
Physics 115. Mechanics (p. 133)
Physics 116. Wave Motion, Sound, and Heat (p. 133)
Physics 117. Electricity and Magnetism (p. 134)
Physics 118. Physical Electronics and Optics (p.)134
Psychology 440. Psychology for Engineering Students (p. 135)
Public Speaking 105 (p. 135)

Required courses in Mechanics of Engineering, Strength of Materials, and Engineering Materials are described on pages 72–76.

GENERAL

3051. *A.S.M.E. STUDENT BRANCH.* Credit one hour. 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 hour may be earned in this manner. Application for membership should be made in October of each year at the A.S.M.E. office, West Sibley Basement, or to the Honorary Chairman of the Student Branch, H. H. MABIE, Assistant Professor of Machine Design.

DRAWING AND DESCRIPTIVE GEOMETRY

Messrs. BAIRD, CLEARY, MORDOFF, SEIGFRIED, and TOWNSEND.

3111. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit three hours. First term. One recitation and two drawing periods a week. Studies in subject matter prerequisite to professional application of Mechanical Drafting. Lettering, delineation, Mongean descriptive geometry, and pictorial representation.

3112. *BASIC MECHANICAL DRAFTING.* Credit three hours. Second term. Prerequisite, course 3111. One recitation and two drawing periods a week. Studies in professional techniques for applying drafting fundamentals to the creation, expression, and interpretation of specifications for mechanical anatomy. Layout and detail drafting practice and related studies of mechanical anatomy, drafting standards, drawing interpretation, tracing, and sketching.

3114. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit two hours. First term. One recitation and one drawing period a week. Studies in subject matter prerequisite to professional application of Mechanical Drafting. Lettering, delineation, descriptive geometric anatomy, pictorial representation, and tracing.

3115. *BASIC MECHANICAL DRAFTING.* Credit two hours. Second term. Prerequisites, 3114. One recitation and one drawing period a week. Studies in professional techniques for applying drafting fundamentals to the creation, expression, and interpretation of specifications for mechanical anatomy. Layout and detail drafting practices and related studies of mechanical anatomy, drafting standards, drawing interpretation, and sketching.

3116. *FREEHAND AND PERSPECTIVE DRAWING.* Credit two hours. Prerequisites, courses 3111 and 3112, or equivalents. Elective. Freehand sketching, parallel projection, perspective drawing, with engineering application. Production illustration. Offered only when there is sufficient demand for the course and conditions permit giving it.

3117. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit two hours. First term. Two drawing periods, including lectures, a week. Content similar to 3114.

3118. *BASIC MECHANICAL DRAFTING.* Credit two hours. Second term. Prerequisite, 3117. Two drawing periods, including lectures, a week. Content similar to 3115.

3131. *MECHANICAL DRAFTING RESEARCH AND DEVELOPMENT.* Credit to depend upon hours of actual work. Elective any term for limited number of qualified seniors and graduates. Special problems and investigations in the subject matter, tools, materials, and processes of Mechanical Drafting.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

Messrs. ALLEN, LOBERG, MILLARD, SAMPSON, SAUNDERS, SCHULTZ, SCOTT, and WHITE.

3231. *PRINCIPLES OF INDUSTRIAL ACCOUNTING AND COST FINDING.* Credit three hours. Two recitations and one computing period a week. A basic course in modern industrial accounting and in cost finding.

3232. *PERSONNEL MANAGEMENT.* Credit three hours. Three recitations a week. Prerequisites, 3235, 3241, Junior standing. This course involves an investigation and evaluation of the techniques in the handling of personnel functions. The major topics are selection and evaluation of the employee, job analysis, job rating, training, and motivation as well as the organization of the personnel department and its relationship to other departments in an industrial organization. The course is conducted with lectures, recitations, and demonstrations involving members of the class.

3235. *INDUSTRIAL ORGANIZATION AND MANAGEMENT.* Credit three hours. Three lectures a week. An introductory course in the field of industrial management. The course starts with the industrial revolution and deals briefly with the principles of mass production, types of business enterprises, and the location and growth of industry. Then, in somewhat more detail are discussed the organization of the plant facilities and the plant personnel with special emphasis on the layout of the plant, types of organizational control, personnel functions, motion and time study, and wage payment systems.

3236. *ORGANIZATION AND MANAGEMENT OF PRODUCTION.* Credit three hours. Three lectures a week. An introductory course in the field of industrial management covering Organizational Structure including types of organization and a discussion of the organization of specific companies; Production Control including layout, materials handling, planning, scheduling, routing, dispatching, and inspection; Worker Productivity including motion study, time study, job evaluation and incentive wage plans; and a brief discussion of problems in engineering economy involving alternate solutions of problems, replacement of equipment, etc. This course is offered specifically for the School of Industrial and Labor Relations students. Engineers may not register for this course. Other students may by permission of the instructor.

3241. *ELEMENTARY INDUSTRIAL STATISTICS.* Credit three hours. Two recitations and one computing period a week. The elementary technique of statistical analysis as applied to engineering and industrial problems.

3242. *STATISTICAL QUALITY CONTROL.* Credit three hours. Two recitations and one computing period a week. Prerequisite, 3241 or equivalent. Study of basic statistical applications in the field of industrial production and inspection. Various sampling, control, and inspection techniques are studied with special reference to practical applications. Underlying assumptions and limitations are discussed.

3247. *PRINCIPLES OF COST CONTROL.* Credit three hours. Two recitations and one computing period a week. Prerequisite, course 3231 or its equivalent. This course covers in detail, through work in the laboratory, manufacturing cost systems for job orders and for continuous processes. Budgets and statements are discussed.

3250. *INDUSTRIAL ACCOUNTING AND COST CONTROL.* Credit four hours. Two recitations and two computing periods a week. Prerequisite, 3235. A basic course in modern industrial accounting including detailed study of job order and process manufacturing cost systems. Standard costs and budgetary control are discussed.

3252. *INDUSTRIAL AUDITING.* Credit two hours. Prerequisite, 3231. A study

of auditing theory and practice by the use of illustrative problems pertaining to manufacturing concerns. Not given in 1948–49.

3253. *CHEMICAL ENGINEERING ECONOMICS.* Credit three hours. One recitation and two computing periods a week. The course includes a basis of accounting theory and discussion of cost finding as applied to chemical plants, of the making and analysis of financial statements, and of certain problems peculiar to the chemical industry.

3254. *STANDARD COSTS AND MANAGEMENT CONTROL.* Credit three hours. One lecture and two computing periods a week. Prerequisite, 3250 and 3263 or 3261. A detailed study of the use of standard costs and general control of production and sales through the records of costs. Profit analysis, flexible budgets, setting of material, labor, and overhead standards and the control of material, labor, and overheads are thoroughly discussed. The establishment of executive controls through cost reports and construction of such reports are also included.

3255. *ELEMENTS OF INDUSTRIAL ACCOUNTING.* Credit three hours. One lecture and two computing periods a week. A basic course in modern industrial accounting and cost finding.

3261. *INDUSTRIAL ENGINEERING.* Credit three hours. One lecture and two computing periods a week. Prerequisites, 3235, 3250, Economics. A study of fundamental problems in industrial management including consideration of the principles of economy involved. Study is built around a series of practical problems involving the principles and practices of: industrial organization; location and design of industrial plants; equipment selection; departmental and machine layouts; materials handling and warehousing equipment and methods; plant maintenance; time and motion study; purchasing; production control; quality control; economic lot sizes; and wage payment plans.

3262. *METHODS ENGINEERING.* Credit three hours. One lecture and two computing periods a week. Prerequisite, 3235. A study of work simplification, the establishment of standard methods, and the setting of standard time for manufacturing and administrative operations. This covers the fundamentals of analyzing and charting operations in broad aspect, operations at a particular workplace (man-machine operation), motion study of man movements, micro-motion analysis of detailed man movements, and the time study of jobs to determine time standards applicable for the job as performed. Laboratory periods are devoted to working practical problems in motion economy during which motion pictures are taken of operations and the films used in micro-motion analysis to arrive at improved methods. Time studies are taken in laboratory, shops, and actual factory operations from which time standards are computed.

3263, 3264. *PRODUCTION ENGINEERING.* Credit six hours. Prerequisites, 3235, 3262, 3250, Economics. One recitation and two laboratory periods a week throughout the year. A study of the technical and economic principles governing the manufacture of a product. The course covers problems dealing with an analysis of the product, the materials and operations required for its manufacture, the selection of machines and tools, materials handling methods, machine layout and plant layout together with problems of operating a plant including consideration of the production budget, purchasing, inventory control, economic lot size, routing scheduling, machine loads, dispatching, inspection, progress charts, machine replacement, plant maintenance and problems of engineering economy concerned. Not given until 1948–1949.

3265. *PRODUCTION CONTROL.* Credit three hours. Two recitations and one computing period a week. Prerequisite, 3263 and 3264. A detailed study of the principles and methods of production control, including: job estimating; planning,

routing, scheduling, and dispatching of manufacturing operations; inspection and quality control; storekeeping; machine records and machine loading; tool crib operation; forms design; Gantt charts and the use of control boards. Not given in 1948–1949.

3269. *MOTION AND TIME STUDY.* Credit two hours. One lecture and one computing period a week. Similar to 3262. Discontinued after Fall Term 1948.

3270. *INDUSTRIAL MARKETING.* Credit three hours. Three recitations a week. Prerequisites, 3235, 3250, 3241. A study of industrial marketing as related to product planning, policy, and research; sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Aspects of related purchasing problems are also covered. Not given in 1948–1949.

3271. *INDUSTRIAL MARKETING RESEARCH.* Credit three hours. Prerequisite, 3270. Techniques of market research applied to specific problems related to industrial goods.

3272. *INDUSTRIAL SALESMANSHIP.* Credit two hours. One recitation and one computing period a week. Prerequisite, 3270. A study of basic principles of selling and the application of these principles to case problems.

3290. *SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION.* Credit as arranged. Offered to qualified students individually or in small groups. Involves the study, under direction, of special problems in the field of Industrial and Engineering Administration.

MACHINE DESIGN

Messrs. BLACK, BURR, DUBOIS, HINKLE, HOLT, MABIE, PHELAN, ROGERS, and STAMETS.

3327. *KINEMATICS.* Credit two hours. For Electrical Engineering students. Two recitations a week. Prerequisite, courses 3112 and Mathematics 162. A brief study of the displacements, velocities, and accelerations in and forms of linkages, cams, gears, belts, and trains of mechanism.

3337. *DESIGN OF MACHINE MEMBERS.* Credit three hours. Offered last time in Spring 1949. Prerequisite, courses 1112 or 1153, 1221, 3325 or 3351 or 3327, 3402 or 3403. One lecture, one recitation, one computation period a week. Application of mechanics, kinematics, materials, and processes to the design and selection of machine members such as fastenings, links, springs, translation screws, belts, wire-rope, chains, couplings, clutches, brakes, gears, shafts, and bearings.

3338. *DESIGN OF MACHINES.* Credit two hours. Offered last time in Fall 1949. Prerequisite course, 3337. Two design-room periods a week. Application of mechanics, kinematics, materials, and processes to the design of complete machines or sub-assemblies of machines. Computations and layout drawings as required.

3351. *MECHANISM.* Credit three hours. Two recitations and one design-room period a week. Prerequisite courses: For four-year students, 3112 and Math 162; for five-year students, 3112 and 1151. A study of displacements and forms of mechanism, linkages, cams, gears, belts, and trains of mechanism.

3352. *DYNAMICS OF MACHINERY.* Credit three hours. Two recitations and one design-room period a week. Prerequisite courses, 3351 and 1152 (for four-year students, simultaneous registration in 1152 is acceptable). Graphical and analytical studies of velocities and accelerations and of static and inertia forces in mechanism; engine force analysis, flywheels, and balancing.

3353. *DESIGN OF MACHINE MEMBERS.* Credit three hours. Offered first time in Fall 1949. Prerequisite courses, 1154, 1231, 3352, and 3404 (for four-year students, simultaneous registration in 1154 is acceptable). One lecture, one recitation, and one computation period a week. Application of mechanics, kinematics, materials, and processes to the design and selection of machine members such as fastenings, links, springs, translation screws, belts, wire-rope, chains, couplings, clutches, brakes, gears, shafting, and bearings.

3354. *DESIGN OF MACHINES.* Credit three hours. For students in Option A. Prerequisite, courses 3353, 6113. One lecture and two design periods a week. Application of mechanics, kinematics, materials, and processes to the design of complete machines or sub-assemblies of machines. Computations and layout drawings as required.

3356. *DESIGN OF MACHINES.* Credit three hours. For students in Option B. Prerequisite, courses 3353, 6113. One lecture and two design periods a week. Similar to 3354, but with design of production machines or sub-assemblies, including jigs and fixtures.

3361. *ADVANCED MACHINE DESIGN.* Credit three hours. Elective. Prerequisite, course 3353. Three lecture-discussion periods a week. Advanced problems in the design and analysis of machine members. Stress-concentration, fatigue, creep, surface-failure, lubrication, shrink-fits, curved-beam sections, pressure vessels, weldments, thermal stresses, rotors, and graphical determination of shaft deflection.

3366. *ADVANCED KINEMATICS.* Credit three hours. Elective. Prerequisite, courses 3351 and 3352. Two lecture-discussion periods and one design period a week. Advanced graphical and semi-graphical treatment of velocities and accelerations. Further treatment of Coriolis' acceleration. Advanced analysis and design of cams, gears, and unique linkages. Synthesis of mechanism.

3367. *ADVANCED DYNAMICS AND VIBRATIONS OF MACHINERY.* Credit three hours. Elective. Prerequisite, courses 1155, 3352, 3353. Two lecture-discussion periods and one computation period a week. Applications of dynamics and vibration theory to the design of machinery; vibration mountings and damping devices, critical speeds of crankshafts, inherent-balance, balancing machines, bearing pressures due to gyroscopic action, mechanical stability.

3370. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN.* Credit arranged. Each term. Individual work or work in small groups under guidance in the design and development of a complete machine, in the analysis or experimental investigation of a machine or component of a machine, or studies in a special field of machine design.

3371. *MACHINERY DEVELOPMENT LABORATORY.* Credit two hours. One lecture and one laboratory period a week. Prerequisite, course 3337 or 3353. Investigations and special tests to obtain design data, and tests to determine performance or modifications of machinery and machinery members utilizing balancing machines, photoelastic apparatus, torque meters, and the measurement of wear, temperature, vibration, and strain.

3373. *CREATIVE DESIGN.* Credit two hours. Two design periods a week. Prerequisite, course 3338 or 3354. The development of improved designs by successive steps. Use of simple rules and sketches to stimulate ideas. Selection from resulting designs by comparisons of performance, cost of manufacture, and maintenance.

3375. *MACHINERY SURVEY.* Credit three hours. Three recitations a week. Prerequisite, course 3337 or 3353. A study of the design features of industrial machinery such as power transmission equipment, automatic and semi-automatic machinery, and machinery for hoisting and conveying.

MATERIALS PROCESSING

Messrs. GEER, HENRIKSEN.

3401. *PATTERNMAKING.* Credit one hour. One laboratory period a week. Study of woods and other materials used in pattern construction. Analysis of various casting techniques as they affect pattern design with regard to size, quantity, and materials of articles to be cast. Operation of hand and power tools used in the modern pattern shop.

3402. *MACHINE TOOLS.* Credit two hours. One lecture and one laboratory period a week. Demonstrations, discussions, and operation of the fundamental and production type machine tools and their accessories.

3403. *FUNDAMENTALS OF MACHINE TOOLS.* Credit one hour. One laboratory period a week. Demonstrations and operation of the basic machine tools and their accessories. Study of structural elements as applications of mechanism.

3404. *PRODUCTION MACHINE TOOLS.* Prerequisite, 3403. Credit two hours. One lecture and one laboratory period a week. Demonstrations and operation studies on the use of machine tools for volume production. Tooling techniques, jigs and fixtures, and equipment arrangement.

3405. *GAGE LABORATORY.* Credit one hour. One laboratory period a week. Must be taken with or after 3404. A study of measuring instruments for the control of size, form, and alignment of commercial goods and tools, including gages. Standard techniques of Ordnance, American Standards Association, and others will be demonstrated. Practice in the use of precision equipment.

3407. *ADVANCED MATERIALS PROCESSING.* Work and credits as arranged with Mr. GEER and Mr. HENRIKSEN.

HEAT-POWER ENGINEERING AND MECHANICAL ENGINEERING LABORATORY

Messrs. ANDRAE, CLARK, DROPKIN, ERDMAN, FAIRCHILD, GAGE, GAY, HOOK, KATZ, MACKEY, OTTO, SHEPHERD, SKINNER, TRACY, WATSON, and WATT.

3501. *ENGINEERING THERMODYNAMICS.* Credit four hours. Three lectures and one computing period a week. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106, 402. Fundamental principles of engineering thermodynamics; energy concepts and energy equations; laws of thermodynamics; equilibrium, availability, and reversibility; thermodynamic properties of fluids including perfect gases, actual gases, vapors, mixtures; non-flow and flow processes; cycles.

3502. *HEAT-POWER LABORATORY.* Credit two hours. Two laboratory periods a week. Prerequisite, 3501, or else 3501 must be taken in the same term. Laboratory study of application, calibration, and accuracy of instruments used in heat-power laboratory, including pressure gages, manometers, planimeters, indicators, tachometers, dynamometers, fluid flow meters, calorimeters, gas analyzers, psychrometers.

3503. *HEAT TRANSFER AND THERMAL MEASUREMENTS.* Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 3501, 1155. The fundamentals of heat transfer by conduction, convection, and radiation; heat transfer in engineering apparatus. Laboratory instruction in measurement of temperature, thermal conductivity, and film coefficients of heat transfer.

3504. *FUELS AND COMBUSTION.* Credit two hours. Two recitations a week. Prerequisites, 3501, 3503 (3503 may be taken in the same term). A study of the properties of solid, liquid, and gaseous fuels affecting the design and performance of engineering apparatus. Study of the combustion process including combustion in furnaces and engines.

3505. *REFRIGERATION AND AIR CONDITIONING.* Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503. Study of the fundamental theory of refrigeration; analysis of compression, absorption, and steam jet systems; refrigerating equipment and engineering applications. Principles and practice in the conditioning of air including heating, humidifyng, cooling, and dehumidifying.

3506. *STEAM POWER.* Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503, 3504. A study of vapor cycles, combustion equipment, draft apparatus, boilers, condensers, evaporators, feedwater heaters, economizers, air preheaters, feed pumps, steam engines, steam turbines, and complete plants. Industrial uses of steam, heat, and power.

3507. *COMBUSTION ENGINES.* Credit four hours. Three recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503, 3504. Study of combustion engines with particular emphasis upon thermodynamics and the combustion process. Application and performance of spark-ignition and compression-ignition engines, gas turbines, jet engines, and auxiliaries.

3510. *ELEMENTARY FOOD ENGINEERING.* Fall term only. Credit three hours. Three lecture-recitation periods a week. Prerequisites, elementary physics and chemistry. Primarily for students in the College of Agriculture and School of Nutrition. Not open to Engineering students.

3530. *THERMODYNAMICS.* Credit three hours. Three recitations a week. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106. Fundamental concepts involved in the release, transfer, and conversion of thermal energy; energy equations; properties of gases, vapors, and mixtures; non-flow and flow processes; cycles.

3531. *HEAT-POWER ENGINEERING.* Credit two hours. Two recitations a week. Prerequisite, 3530. Fuels, combustion, steam-generating units; steam turbines, condensers, combustion engines, and performances of complete power plants.

3532. *HEAT-POWER ENGINEERING.* Credit one hour. One laboratory period a week taken with 3531.

3535. *HEAT-POWER ENGINEERING.* Credit three hours. Three recitations a week. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106. Fundamental concepts involved in the release, transfer, and conversion of thermal energy; energy equations; properties of gases, vapors, and mixtures; non-flow and flow processes; cycles.

3536. *HEAT-POWER ENGINEERING.* Credit three hours. Three recitations a week. Prerequisite, 3535. Flow of fluids through nozzles, orifices, and turbines; steam turbine types and their applications; heat transfer; condensers; fuels and combustion; steam generating units; furnaces, stokers, and fuel-burning equipment.

3541. *HEAT-POWER 1.* Credit three hours. Two lectures and one two-hour laboratory or computing period a week. Required of students in the School of Civil Engineering. First term. Prerequisites, Mathematics 161, 162, 163; Physics 116. Energy concepts and energy equations; laws of thermodynamics; properties, processes, and cycles of gases. Internal combustion engines; the compressed air plant. (To be offered for the first time in the Fall of 1949.)

3542. *HEAT-POWER 2.* Credit two hours. Two lectures a week. Required of students in the School of Civil Engineering. Second term. Prerequisite, 3541. Properties and processes of vapors; steam engines; steam turbines; the elementary steam power plant. The fundamentals of heat transfer by conduction, convection, and radiation; applications to problems in heat transfer of special interest to students in civil engineering. (To be offered for the first time in the Spring of 1950.)

3543. *HEAT-POWER ENGINEERING.* Required of all seniors in Civil Engineering. Credit three hours. Not open to students in Mechanical or Electrical Engineering. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106 (or equivalent). Two lectures and one two- and one-half-hour period used for laboratory, inspection, computing, or quiz purposes. Basic consideration of the behavior of gases and vapors as applied to heat engines; also the operation, maintenance, application, performance, first cost, and operation cost of air compressors, compressed-air equipment, internal combustion engines of both the carburetor and the compression-ignition types, steam boilers, engines, and turbines.

3551. *STEAM TURBINES.* Elective for seniors. Alternate terms. Credit two hours. Prerequisites, 3535, 3536, or equivalent. Two lectures a week. Classification of turbines and description of leading features of the various types; mechanical and thermal considerations underlying the action of steam in turbines; calculations involved in turbine design; discussion of building, erecting, and testing; adaptability to special conditions of service; economic results of the use of turbines in engineering practice.

3563. *ADVANCED THERMODYNAMICS.* Elective for advanced students. Credit two hours. Two recitations a week. Prerequisites, 3535, 3536, or equivalent. The Carnot Principle; temperature scales; entropy; the state properties of a substance, their experimental determination and correlation; equations of state, kinetic theory of gases; mixtures of ideal gases; special topics in mathematics will be considered as needed.

3581. *INTERNAL COMBUSTION ENGINES.* Credit three hours. Three recitations a week. Prerequisite, 3535, or equivalent. The fundamentals of internal combustion engines with emphasis on thermodynamics and the combustion process. Both spark-ignition and compression-ignition engines are considered and topics studied include air standard cycles, the combustion process, ideal cycles of air-fuel mixtures, deviations from ideal processes, performance of actual engines, fuels and fuel supply systems, ignition of the charge, and mechanical details.

3582. *STEAM-POWER PLANTS.* Credit three hours. Three recitations a week. Prerequisites, 3535, 3536, or equivalent. A review of the thermodynamics of vapors is followed by a further study of combustion and combustion-control equipment, draft apparatus; boilers, condensers, evaporators, feedwater heaters, feed pumps, economizers, and air preheaters; turbines, and plant auxiliaries; performance and cost of steam engines, turbines, and plants.

3588. *REFRIGERATION AND AIR CONDITIONING.* Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 3535, 3536, or equivalent. The general principles of refrigeration with particular emphasis on the equipment; principles and practice in the conditioning of air, including cooling, heating, dehumidifying, and ventilating; application of refrigeration in cold storage.

3590. *GAS-TURBINE PLANTS.* Elective for graduate students and seniors in Mechanical Engineering. Credit two hours. Prerequisite, course 3535. Two recitations a week. A fundamental study of the various cycles and apparatus involved in the modern gas-turbine plant. Performances and suitability of this type of power plant for various applications.

3620. *INTRODUCTORY MECHANICAL LABORATORY.* Credit four hours. One lecture and one laboratory period a week. Prerequisites, 3535, 3536, or equivalents (may be taken simultaneously with 3536). Experiments commonly taken from the following group: temperature measurement; pressure measurement and control; steam calorimetry; indicators and planimeters; fluid flow and flow measurements; exhaust gas analysis and boiler water conditioning; dynamometers; jet pumps; steam engines.

3630. *MECHANICAL LABORATORY.* Credit four hours. Prerequisites, courses 3535 and 3536. One lecture and one laboratory period a week. Laboratory instruction on steam power plants and power plant auxiliaries, internal combustion engines and accessories, hydraulic machinery, and pneumatic machinery.

3651. *HEAT-POWER RESEARCH.* Credit to depend upon hours of actual work. Recitation and laboratory instruction will be given to a limited number of undergraduates and graduate students interested in work to supplement that given in required courses in the fields of internal combustion engines, heat transfer, refrigeration, air conditioning, and instruments.

3653. *TEMPERATURE MEASURING INSTRUMENTS.* Elective for seniors and graduates. Credit two hours. Prerequisites, courses 3535 and 3536. One lecture and one laboratory period a week. This course covers the theory, construction, calibration, and application of: liquid-in-glass thermometers, solid expansion thermometers, pressure-spring thermometers, electrical resistance thermometers, thermoelectric thermometers, optical pyrometers, radiation pyrometers, and other temperature measuring devices.

3654. *DIMENSIONAL ANALYSIS.* Elective for juniors and seniors. Credit one hour. One lecture-recitation period a week. Dimensions of physical units. Use of dimensional analysis. Derivation of dimensionless constants. Geometric, dynamic, and kinematic similarity. The principles of similitude and their application to solutions of problems with particular stress on the use of dimensional analysis and the principles of similitude in experimental work.

3655. *GRAPHICAL COMPUTATION AND REPRESENTATION.* Elective to undergraduate students who have completed four terms or to graduate students. Credit two hours. Two recitations a week. Design of slide rules, network charts, and alignment charts; derivation of empirical equations to fit experimental data.

3656. *ADVANCED AIR CONDITIONING.* Credit three hours. Two recitations and one laboratory period a week. Prerequisite, 3588 (or equivalent). Selected problems in the study of air conditioning principles and apparatus; panel heating and cooling; the heat pump.

3660. *AIRCRAFT POWER PLANTS.* Credit three hours. Three recitations a week. Prerequisite, sophomore standing. Operating principles and mechanical and thermal characteristics of reciprocating and rotating types of aircraft power plants. Studies augmented by reading of technical papers and solutions of problems.

3661. *AIRCRAFT ENGINE DESIGN.* Credit three hours. Two laboratory-computing periods a week. Prerequisites, 3581, 3660, 3337. Engine design principles and pertinent thermodynamic calculations. Design of engine components with regard to functions and loads.

3670. *AUTOMATIC CONTROL ENGINEERING.* Credit three hours. Prerequisite or parallel courses, 3620 and 2331. Two lectures and one laboratory period a week. A study of the commercially available automatic controllers commonly used in current industrial practice, with special reference to type of construction, installation requirements, and available control patterns. The problems existing in various

plants and processes will be discussed, and the influence of the control modes on process behavior will be studied.

3680. *DIESEL ENGINEERING.* Credit three hours. Two lecture-recitation periods, one laboratory or computing period a week. Prerequisites, 3501 (or 3535), 3581. Consideration will be given, both in the classroom and the laboratory, to the following topics: design and construction of typical diesel engines, fuel injection systems, combustion chamber design and combustion phenomena, engine governors, supercharging, fuels and lubricants for diesel engines, and engine performance. The objective of this course is to emphasize the basic concepts influencing the performance of a diesel engine and its accessories and to provide an opportunity for experimental study of the characteristics of the diesel engine.

AUTOMOTIVE ENGINEERING

3741. *AUTOMOTIVE ENGINEERING.* Seniors and graduates. Credit three hours. Three lectures a week. Prerequisite, 3337. An analysis of the application of engineering principles to the design and operation of automotive vehicles. Vehicle stability, weight distribution and wheel location, flotation, steering, driving, braking, and riding comfort of the vehicle are studied. Engine design is not extensively considered, but engine performance abilities and limitations are considered for their effect on clutch, transmission and drive system. Power demands of the vehicle are analyzed, and the matching of engine supply power and car demand power is studied.

3743. *AUTOMOTIVE COMPUTATIONS.* Credit two hours. Two computing periods a week. Must be accompanied or preceded by 3741. Detailed studies to acquaint students with methods of attack on problems in operation or design.

3744. *AUTOMOTIVE POWER COMPUTATIONS.* Credit two hours. Two computing periods a week. Must be acompanied or preceded by 3581. Detailed study of operation and design of internal combustion engines for automotive, marine, and industrial uses.

3750. *ADVANCED AUTOMOTIVE ENGINEERING.* Elective for qualified seniors and graduates. Credit two to five hours as arranged. Selected advanced topics and special problems.

Electrical Engineering

COURSES BY GROUPS. . . Within the School of Electrical Engineering, courses are numbered in groups, with each course designated by a four-digit number in which the first digit is 4. The second digit denotes the course group, and the third and fourth digits identify the course within the group.

The index of course descriptions follows; details are given on following pages.

GENERAL COURSES

4021 Composition of Technical Reports
4035 Operational Analysis
4036 Advanced Operational Analysis
4041 Non-Resident Lectures
4051 Patents

COURSES IN BASIC ELECTRICAL ENGINEERING

4111 Basic Electrical Engineering
4112 Alternating Current Circuits
4116 Electric Circuit Laboratory
4121 Electron Tubes and Circuits
4122 Electronic Circuit Elements
4126 Electronics Laboratory
4128 Electronic Equipment Shop
4131 Basic Communication Systems

COURSES IN MACHINERY

4211 Direct Current Machinery
4216 Electrical Machinery Laboratory
4221 Alternating Current Machinery
4226 Electrical Machinery Laboratory

COURSES IN POWER

4311 Advanced Circuit Analysis
4321 Electrical Machine Theory
4326 Power Laboratory
4331 Electrical Design Economics
4334 Economics of Public Utilities
4341 Motor Control
4342 Application of Motors
4343 Aircraft and Marine Electric Power and Control Systems
4351 Low Frequency Heating and Industrial Distribution
4361 Power Systems
4362 Transmission of Electric Energy
4363 Stability of Electric Power Systems
4364 Protection and Relaying on Power Circuits
4365 Symmetrical Components
4371 High Voltage Phenomena
4391 Project
4392 Project

COURSES IN INDUSTRIAL ELECTRONICS

4411 Electronic Control Equipment
*4415 Advanced Electronic Controls
4421 Electronic Power Converters
*4422 Electronic Inverters
*4451 High Frequency Heating
4491 Project
4492 Project

*One of these to be chosen as Option Elective in Industrial Electronics Option.

COURSES IN RADIO AND COMMUNICATION

4511 Radio and Communication Theory
4512 Radio and Communication Theory
4513 Communication Networks
4516 Radio and Communication Laboratory
4517 Radio and Communication Laboratory
*4521 Radio Broadcasting
*4522 Telephone and Telegraph Systems
*4526 Design and Construction of Vacuum Tubes
*4531 Television Systems
*4541 Applied Acoustics
*4551 Radio Aids to Navigation
4561 Ultra High Frequency Systems
4563 Pulse Technique in Communication and Radar
4565 Electromagnetic Waves
4566 Electromagnetic Waves
4571 Advanced Communication Networks
4591 Project
4592 Project

*At least three hours to be chosen from these for Option Elective in Radio and Communication Option.

COURSES IN ILLUMINATION

4611 Introductory Illumination
4612 Illuminating Engineering
4615 Illumination Seminar
4691 Project
4692 Project

COURSES IN SERVOMECHANISMS

4711 Servomechanisms and Automatic Control Systems
4712 Advanced Servomechanisms

COURSES FOR CIVIL, MECHANICAL, AND CHEMICAL ENGINEERS

4921 Electrical Engineering (for Civil Engineers) (p. 118)
4922 Electrical Equipment (for Civil Engineers) (p. 119)
4931 Electrical Engineering (for Mechanical Engineers) (p. 119)
4932 Electrical Engineering (for Mechanical Engineers) (p. 119)
4933 Electrical Engineering (for Mechanical Engineers) (p. 119)
4934 Principles of Automatic Control (for Mechanical Engineers) (p. 119)
4951 Electrical Engineering (for Chemical Engineers) (p. 119)
4952 Electrical Engineering (for Chemical Engineers) (p. 119)

REQUIRED COURSES GIVEN OUTSIDE THE COLLEGE OF ENGINEERING

Chemistry 105, 106 General Chemistry (p. 130)
Chemistry 301 Engineering Organic Chemistry (p. 130)
Chemistry 402 Engineering Physical Chemistry (p. 131)
Economics 107 Introduction to Economics (p. 131)
English 111, 112 Introductory Course (p. 132)
History 165, 166 Modern Economic History (p. 132)
Mathematics 161, 162, 163 Analytic Geometry and Calculus (p. 132)
Mathematics 607 Applied Mathematics for Electrical Engineers (p. 132)
Mathematics 608 Differential Equations for Electrical Engineers (p. 133)
Modern Physics
Physics 115 Mechanics (p. 133)
Physics 116 Wave Motion, Sound, and Heat (p. 133)
Physics 117 Electricity and Magnetism (p. 134)
Physics 118 Electricity, Magnetism, and Light (p. 134)
Physics 210 Advanced Physics Laboratory (p. 134)
Physics 225 Electricity and Magnetism (p. 134)
Physics 236 Electricity and Magnetism (p. 134)
Physics 243 Atomic Theory of Properties of Matter (p. 135)
Physics 254 Electronic Theory of Properties of Matter; Physics of Solids and Liquids (p. 135)
Psychology 440 Psychology for Engineering Students (p. 135)
Public Speaking 101 Public Speaking (p. 135)

GENERAL COURSES

4021. *COMPOSITION OF TECHNICAL REPORTS.* Term 9. Required. Credit three hours. One lecture and one recitation each week. Texts: *Writing the Technical Report,* NELSON; *Report Writing,* GAUM and GRAVES. Scheduled for fall term 1950.

The objective of this course is to develop the basic principles of exposition, the knowledge of suitable form, and the appreciation of function that will enable students to design and construct technical reports which meet professional standards.

4035. *OPERATIONAL ANALYSIS.* Term 9. Elective. Credit three hours. Two recitations and one computing period each week. Prerequisite, 4311. Fall term only.

Among the topics of the course are: functions of real and of complex variables; infinite series; integral equations; Laplace and Fourier transforms; generalized expansion theorems for differential equations and difference equations.

4036. *OPERATIONAL ANALYSIS.* Term 10. Elective. Credit three hours. Two recitations and one computing period each week. Prerequisite, 4035. Spring term only.

The methods of the prerequisite course are applied to the analyses of ladder networks and of transients in circuits with lumped and with distributed parameters.

4041. *NON-RESIDENT LECTURES.* Term 10. Required. Credit one hour. One lecture each week. Spring term only.

Representatives of industry are invited to deliver a series of lectures intended to assist students in their selection of employment and to aid in the transition from college to industrial life. Certain lectures given under the auspices of the Ithaca Section of AIEE may be specified for required attendance.

4051. *PATENTS.* Elective. Credit one hour. One lecture-recitation each week. Text: *mimeographed notes.* Open to Seniors in Electrical or Mechanical Engineering and to others by special permission. Fall term only.

Patent laws of the United States are studied, including the procedure in obtaining a patent. Typical patents are discussed. Additional topics include: interference actions; actions coming before the Federal courts; the engineer as an expert witness; and the rights of inventors.

COURSES IN BASIC ELECTRICAL ENGINEERING

4111. *BASIC ELECTRICAL ENGINEERING.* Term 4. Required. Credit four hours. One lecture, two recitations, and one computing period each week. Prerequisites, Mathematics 163; Physics 117; Chemistry 102 or 106. Text: *Electrical Engineering,* STRONG. Spring term only.

This is the first of two successive courses presenting the basic elements of electrical engineering which are common to the several branches of study which follow. They present the elemental concepts and laws of electricity and their application with emphasis on analysis rather than the memorization of formulas. The student is encouraged to regard the physical significance of problems and to question the mathematical result of a combination of formulated principles.

The material covered in the first course is identified with the following topics: conductors and resistance; electrical measuring instruments; resistance measurement; electromotive force and its sources; electromagnetic induction; alternating emf; power-distribution circuits; d-c electrical networks and methods of solution; conductors of non-uniform section or material; mapping of current paths; magnetics, magnetic circuits and forces; electromagnets; self and mutual inductance, coupling, reactors; electrostatic energy, fields, and forces; capacitance; transient and alternating currents in circuits with resistance and inductance, in circuits with resistance and capacitance, and in series circuits with resistance, inductance, and capacitance.

4112. *ALTERNATING-CURRENT CIRCUITS.* Term 5. Required. Credit four hours. One lecture, two recitations, and one computing period each week. Prerequisites, 4111 and Mathematics 607. Text: *Alternating-Current Circuits,* KERCHNER and CORCORAN. Fall term only.

The study of alternating-current circuits is made under the following topics: average and effective values; vectors and vector algebra; power and power factor; series circuits; series resonance, and loci; parallel circuits; series-parallel circuits, and loci; a-c networks, and theorems for solution; equivalent circuits; coupled circuits; air-core and iron-core transformers; transmission lines; power-factor correction; three-phase circuits; balanced three-phase relations; three-phase power; measurement of three-phase power and energy; three-phase transmission; determination of phase sequence; non-sine waves in single-phase and in polyphase circuits; harmonics in three-phase circuits.

4116. *ELECTRIC-CIRCUIT LABORATORY.* Term 5. Required. Credit three hours. One lecture and one lecture-laboratory period each week. Prerequisite, 4111.

Must be preceded or accompanied by 4112. Text: *Mimeographed Notes,* supplemented by reference to *Electrical Measurements, LAWS,* and to *Electrical Engineering,* STRONG. Fall term only.

This course and the two machinery laboratory courses which follow it require a preparatory study of references, a laboratory experiment, a written report consisting primarily of solutions of problems based on laboratory and other data, and a group discussion of the reports. The principal topics studied are: basic direct-current circuits, with constant and with varying resistors; application and analysis of circuits in bridges and in other measuring apparatus; thermocouple circuits; temperature measurement and the basic steady-state heat-flow conditions in electrical machines; construction, characteristics, and circuit connections of permanent-magnet moving-coil instruments and of the wattmeter; equipment, procedure, and circuits used in calibrating, checking, and standardizing electrical instruments and secondary standards; the construction, characteristics, and circuit connection of copper-oxide rectifiers and of instruments for measuring alternating voltage and alternating current; characteristics of ideal and of practical resistors, inductors, and capacitors; characteristics of single-phase circuits under approximately sinusoidal conditions of waveform, at power frequencies; characteristics of thermal circuits under elementary transient conditions.

4121. *ELECTRON TUBES AND CIRCUITS.* Term 6. Required. Credit three hours. Two lecture-recitations and one computing period each week. Prerequisite, 4112. Must be accompanied by 4126. Text: Electronic Engineering Principles, RYDER; and supplementary notes. Spring term only.

This is the first of a group of courses which present and expand the fundamental laws of electron behavior and correlate such behavior with the functioning of simple electronic circuits.

The material covered in this first course includes: the theory of matter and of electron emission; emitters; conduction in high vacuum and in gas; diode characteristics; photoelectric cells; the construction, characteristics, and control of the cathode-ray tube; rectification and filtering with L and π filters; high-vacuum triode characteristics, tube parameters, and equivalent-circuit studies; multi-grid tube characteristics; and R-C coupled amplifier characteristics.

4122. *ELECTRONIC CIRCUIT ELEMENTS.* Term 7. Required. Credit four hours. Two lectures, one laboratory and report-writing period, and one computing period each week. Prerequisites, 4121 and 4126. Text: Fundamentals of Vacuum Tubes, EASTMAN; and supplementary notes. Fall term only.

Topics of the course include: applications of linear equivalent circuits in devices using multi-element high-vacuum tubes; studies of air-core and iron-core transformers as used in communication systems; studies of class A, class B, and class C amplifiers; analyses of non-linear circuits used for the production and detection of amplitude modulation and of angular modulation.

4126. *ELECTRONICS LABORATORY.* Term 6. Required. Credit two hours. One lecture-laboratory period each week. Prerequisite, 4112. Must be accompanied by 4121. Text: Electronic Engineering Principles, RYDER; and supplementary notes. Spring term only.

This course is a laboratory study of topics selected from the accompanying theory course. The characteristics of typical electron tubes are determined, and these tubes are then utilized in appropriate circuits for more complete tests and analyses.

4128. *ELECTRONIC-EQUIPMENT SHOP.* Term. 6. Required. Credit one hour. One lecture-laboratory period each week. Prerequisite, 4112. Must be preceded or accompanied by 4121 and 4126. Text: mimeographed notes. Given in both fall and spring terms.

Simple electronic circuits are studied to develop an intelligent use of a variety of measuring instruments, and to promote a general familiarity with the form and proper use of circuit components and their combinations. Good construction is specifically noted; resistor and condenser sizes and color codes are observed; faulty parts as recognized and replaced. Skill in handling tools is developed, and the use of approved methods of construction is encouraged. Although generally simple circuits such as amplifiers and power supplies are studied, a moderately skilled student may construct, repair, or redesign a more complicated unit such as a small radio receiver or transmitter, an electronic instrument, or an experimental circuit in which he is interested.

4131. *BASIC COMMUNICATION SYSTEMS.* Term 7. Required. Credit two hours. Two lectures each week. Prerequisites, 4121 and 4126. Must be preceded or accompanied by 4122. Text: Electrical Communication, second edition, ALBERT. Fall term only.

The elements of wire and radio telephone and telegraph systems are studied. Attention is given to microphones, antennas, loud speakers, manual and automatic telephone exchanges, repeaters, multiplex circuits, teletype and picture transmitters, and radio transmitters and receivers.

COURSES IN MACHINERY

4211. *DIRECT-CURRENT MACHINERY.* Term. 5. Required. Credit three hours. One lecture, one recitation, and one computing period each week. Prerequisite, 4111. Text: *Direct-Current Machinery,* KLOEFFLER, BRENNEMAN, and KERCHNER. Fall term only.

A study is made of the construction, operating characteristics, applications, and control of direct-current generators, motors, and motor-generator sets.

Among the topics studied are: generator and motor parts and construction; armature windings; operating characteristics; armature reaction; commutation, and brush setting; losses and efficiency; rating; parallel operation of generators; motor applications; manual and automatic motor controllers; special generators such as boosters, welders, Amplidyne, Rototrol, aircraft, and marine types, and dynamotors; generators and motors for bus, train, and marine service; storage-battery charging equipment and circuits.

4216. *ELECTRICAL MACHINERY LABORATORY.* Term 6. Required. Credit four hours. One lecture, one recitation, and one lecture-laboratory period each week. Prerequisites, 4116 and 4211. Must be preceded or accompanied by 4221. Text: mimeographed notes. Spring term only.

Following a study of direct-current magnetization in general and the magnetic circuits of dynamos, the course proceeds to measured and predicted characteristics of direct-current generators and motors with all common methods of excitation; characteristics of generators in parallel; detection and correction of faulty commutation; construction, connection, and operating characteristics of typical direct-current motor-controllers; measurement of segregated losses, and prediction of efficiency of dynamos by mechanical-drive and by retardation methods; characteristics and typical applications of the Amplidyne. There is also a continuation of the study of elementary single-phase a-c circuits, and a study of a-c bridge circuits and the detectors commonly used in such circuits.

4221. *ALTERNATING-CURRENT MACHINERY.* Term 6. Required. Credit three hours. Two recitations and one computing period each week. Prerequisite, 4112. Text: *Principles of Alternating Current Machinery,* BRYANT and JOHNSON. Spring term only.

A study is made of the construction, operating characteristics, applications, and control of transformers, synchronous machines, and single-phase and polyphase induction motors.

Among the topics studied are: equivalent-circuit diagrams; regulation; losses and efficiency; single-phase and polyphase connection of transformers; parallel operation of synchronous generators; circle diagrams of polyphase induction motors. Vector diagrams and graphical methods are used extensively.

4226. *ELECTRICAL MACHINERY LABORATORY.* Term 7. Required. Credit four hours. One lecture, one recitation, and one lecture-laboratory period each week. Prerequisites, 4116, 4211, and 4221. Text: mimeographed notes. Fall term only.

The course begins with a general study of basic principles of alternating-current magnetization, and circuit relations involving non-sinusoidal current and voltage, including detailed analysis of balanced and of unbalanced polyphase circuits in which harmonics arise in the load or in the generator. Application of these principles is then made in analyzing selected operating characteristics of single-phase constant-potential transformers, single-phase and three-phase induction motors, and synchronous motors and generators, including parallel operation of the latter.

COURSES IN POWER

4311. *ADVANCED CIRCUIT ANALYSIS.* Term 8. Required in the following options: Power Generation and Distribution, Power Utilization, Industrial Electronics, and Illumination. Credit three hours. Two lectures and one computing period each week. Prerequisites, 4221 and Mathematics 608. Spring term only.

This course treats of typical circuits by which electric energy is transmitted. The physical meaning of the parameters which are used in describing transmission circuits is considered. A review of single-energy transients precedes a detailed analysis of double-energy transients. Ladder networks are viewed as approximate equivalents of circuits having distributed parameters. The behavior of polyphase circuits on which there are faults or unbalanced loads is analyzed by the method of symmetrical components.

4321. *ELECTRICAL MACHINE THEORY.* Term 8. Required in the following options: Power Generation and Distribution, Power Utilization, Industrial Electronics, and Illumination. Credit two hours. Two recitations each week. Prerequisite, 4221. Text: *Alternating-Current Machinery,* TARBOUX; supplementary notes. Given in both fall and spring terms.

This course extends the analysis of certain subjects of the prerequisite course. Among its topics are: analysis of magnetomotive force and of air-gap flux in synchronous and in induction machines for harmonics in time and in space; effects of such harmonics on induced voltage and on torque; two-reaction analysis of salient-pole synchronous machines; analyses of single-phase induction motors and commutator alternating-current motors.

4326. *POWER LABORATORY.* Term 9. Required in the following options: Power Generation and Distribution, Power Utilization, Industrial Electronics, and Illumination. Credit two hours. One lecture and lecture-laboratory period each week. Prerequisites, 4226 and 4321. Text: mimeographed notes. Given in both fall and spring terms.

This course continues the study of basic principles of alternating-current magnetization, and the exemplification of these principles under the favorable conditions provided by selected transformers. Salient-pole synchronous-machine principles are examined from the standpoint of the two-reaction theory. The reactances are measured by several methods and the theory is applied to the analysis of torque-angle

relations, steady-state stability, and the voltage regulation of generators. The measurement and the significance of the transient reactances are briefly studied. The special combinations of conditions that arise in commutating alternating-current motors are analyzed for a selected machine. The course includes circuit studies applied to selected alternating-current bridges and to symmetrical-component analysis of faults on transmission lines.

4331. *ELECTRICAL DESIGN ECONOMICS.* Term 9. Required in Power Generation and Power Utilization Options. Credit three hours. Two recitations and one computing period each week. Prerequisites, 4211 and 4221. Text: *Elements of Electrical Design,* STILL; mimeographed notes. Scheduled for fall term, 1950.

The object of the course is to acquaint the student with technical and economic problems encountered in the design of resistors, electro-magnets, cables, condensers and condenser bushings, transformers, and rotating electrical machines.

4334. *ECONOMICS OF PUBLIC UTILITIES.* Elective. Credit two hours. Two recitations each week. Prerequisite, Economics 107. Text: *Elements of Utility Rate Determination,* BRYANT and HERRMANN. Scheduled for spring term, 1951.

The course is a study of the following topics: the development of public utilities and governmental regulatory bodies; principles of capitalization and depreciation of utility property; the capital structure of power companies; analysis of costs, and principles of rate-making; long-term trends of size of plant, efficiency, costs, and rates; the relation of the industry to other segments of the economic system.

4341. *MOTOR CONTROL.* Term 9. Required in the following options: Power Generation and Distribution, Power Utilization, Industrial Electronics, and Illumination. Credit two hours. One lecture and one recitation each week. Prerequisites, 4211, 4216, 4221, and 4226. Text: *Controllers for Electric Motors,* JAMES and MARKLE. Fall term only.

The course is a study of the design and the functioning of typical controllers and protective devices for direct-current and for alternating-current motors. Among the topics are: problems of manual and automatic acceleration, dynamic braking, power regeneration, plugging, and voltage control for direct-current motors; design of resistors and magnetic contactors; interpretation of controller diagrams.

4342. *APPLICATION OF MOTORS.* Term 10. Required in Power Utilization Option. Credit three hours. One lecture, one recitation, and one computing period each week. Prerequisites, 4326 and 4341. Text: *Elective Motors in Industry,* RIFE, SHOULTS, and JOHNSON. Spring term only.

Characteristics of motors and requirements of typical loads are analyzed and correlated so that a proper motor may be selected. The course includes a study of motor duty cycles, adjustable-speed alternating-current drives, coordinated-drive systems, and "synchro" systems.

Inspection trips may replace several of the computing periods.

4343. *AIRCRAFT AND MARINE ELECTRIC POWER AND CONTROL SYSTEMS.* Term 10. Elective. Credit two hours. Two recitations each week. Prerequisites, 4321 and 4341. Text: mimeographed notes. Spring term only.

Modern developments in aircraft electric systems are studied, with attention given to meeting the special requirements imposed by rapid and extreme changes in temperature, pressure, and humidity. Selected topics include: relative advantages of alternating-current and direct-current systems; selection of voltage and of frequency; methods of driving generators; reliability of operation; saving of weight.

After outlining the problems and principles of ship propulsion, a study is made of the relative advantages of available main drives, the design of power-distribution systems, and the selection of motors and control equipment.

4351. *LOW-FREQUENCY HEATING AND INDUSTRIAL DISTRIBUTION SYSTEMS.* Term 8. Required in Power Utilization Option. Credit three hours. Two lectures and one computing period each week. Must be preceded or accompanied by 4311. Text: *Industrial Electric Heating,* STANSEL. Spring term only.

The first part of this course deals with the construction, characteristics, and application of all varieties of electric heating apparatus commonly employed in industry except those based on high-frequency dielectric heating. Principal emphasis is given to arc furnaces and to low-frequency induction furnaces.

The remainder of the course is devoted to current practice and to the apparatus employed in the design of electric-power distribution systems in industrial plants.

4361. *POWER SYSTEMS.* Term 8. Required in Power Generation and Distribution Option. Credit three hours. Two lectures and one computing period each week. Prerequisite, 4221. Text: *Electric Power Equipment,* TARBOUX. Given in both fall and spring terms.

The function and the form of the electrical apparatus included in modern power systems are studied. Among the power-system components considered are generators, switchgear, protective devices, power transformers, converters, transmission-line towers and conductors, and voltage-regulating devices.

Inspection trips to nearby power stations are planned to supplement class-room discussions.

4362. *TRANSMISSION OF ELECTRIC ENERGY.* Term. 9. Required in Power Generation and Distribution Option. Credit three hours. Two lectures and one computing period each week. Prerequisite, 4311 and 4361. Text: *Introduction to Electric Power Systems,* TARBOUX. Given in both fall and spring terms.

The performance of transmission lines is analyzed through the following sequence of topics: evaluation of transmission-line parameters from the physical dimensions of the circuit; expressions for voltage and for current at sending and at receiving ends; classification of lines as short, moderately long, and long; equivalent π and T networks; development of circle diagrams to facilitate calculations of performance.

4363. *STABILITY OF ELECTRIC POWER SYSTEMS.* Term 10. Elective. Credit two hours. Two lectures each week. Must be preceded or accompanied by 4371. Texts: *Introduction to Electric Power Systems,* TARBOUX, and *Power System Stability,* CRARY. Spring term only.

The conditions of stability of synchronous machines and of electric power systems under both steady and transient loads are investigated by mathematical analysis.

4364. *PROTECTION AND RELAYING ON POWER CIRCUITS.* Elective. Credit two hours. Two lectures each week. Must be preceded or accompanied by 4371. Text: mimeographed notes supplemented by manufacturer's bulletins. Fall term only.

The principles of the operation of typical relays and of the application of relaying systems are considered. The course includes a study of telemetering and supervisory-control equipment.

4365. *SYMMETRICAL COMPONENTS.* Term 9. Elective. Credit three hours. Three lectures each week. Prerequisites, 4311, 4321, and 4361. Text: *Applications of the Method of Symmetrical Components,* LYON. Fall term only.

The fundamental concept of symmetrical components is developed, and application is then made in the analysis of such circuits and machinery as transmission lines, transformers with either two or three windings, synchronous machines, power networks, and three-phase and single-phase induction motors and other asymmetrical motor windings.

4371. *HIGH-VOLTAGE PHENOMENA.* Term 10. Required in Power Generation and Distribution Option. Credit three hours. Two lectures and one lecture-comput-

ing period each week. Prerequisite, 4362. Text: mimeographed notes. Spring term only.

The course is a study of the problems encountered in the normal operation of electric-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.

4391 and 4392. *PROJECT*. Terms 9 and 10. Required in Power Utilization and in Power Generation and Distribution Options. Credit two hours for the ninth term and four hours for the tenth term. Scheduled for 1950–1951.

To develop self reliance and initiative in working with engineering problems, each student, in his final terms, studies a special problem which is normally closely related to his option. The choice of a problem is made by the student after consultation with members of the teaching staff. This consultation begins during the term preceding that in which actual work on the project is begun.

Project problems may include the following: analysis and study of advanced theory in one of the several branches of engineering or allied fields; analysis and testing of equipment under conditions not considered in regular courses of study; design, construction, and testing of special apparatus in which the student is particularly interested.

Throughout the work the student is expected to conform to good engineering practice in keeping a complete notebook of day-by-day tests and investigations. At frequent intervals he is required to submit this notebook to the supervising staff member for discussion, comments, and suggestions. He is expected to submit a well-written technical paper which describes his investigation and summarizes the results.

COURSES IN INDUSTRIAL ELECTRONICS

4411. *ELECTRONIC CONTROL EQUIPMENT*. Term 8. Required in Industrial Electronics Option. Credit three hours. Two lectures and one lecture-laboratory period each week. Prerequisites, 4121 and 4126. Text: mimeographed notes. Given in both fall and spring terms.

The course deals with the principles of electronic instrumentation and electronic control systems. A study is made of the methods of interpreting electronically a stimulus appearing in the form of heat, light, sound, or mechanical movement; and of typical electronic circuits through which such electrical effect causes the controlled device to make the desired response. Among these circuits are timing circuits, photoelectric controls, motor controls, welder controls, voltage regulators, and frequency-varying and frequency-discriminating circuits.

4415. *ADVANCED ELECTRONIC CONTROLS*. Term 10. Elective. Credit three hours. Two recitations and one computing period each week. Prerequisite, 4411. Text: References and mimeographed notes. Scheduled for spring term, 1951.

This course is an intensive study of the theory and the operating characteristics of electronic circuits and equipment used to control and regulate welders, motors, generators, and other machines. These circuits are generalized, compared, and analyzed rigorously. Methods of precise control of time intervals, voltage, current, and frequency are included.

4421. *ELECTRONIC POWER CONVERTERS*. Term 9. Required in Industrial Electronics Option. Credit three hours. Two lectures and one lecture-laboratory period each week. Prerequisite, 4411. Text: mimeographed notes. Scheduled for fall term, 1950.

This course continues the study of the characteristics and the applications of some of the electronic power-converting devices that were considered in introductory

courses; such as power amplifiers, oscillators, single-phase and polyphase rectifiers and inverters, X-ray equipment, and welders. Laboratory work includes inspection and testing of typical equipment, with an analysis of performance.

4422. *ELECTRONIC INVERTERS.* Term 10. Elective. Credit three hours. Two lectures and one computing period each week. Prerequisite, 4421. Text: mimeographed notes. Scheduled for spring term, 1951.

After a survey of electronic inverter circuits of series and of parallel types, the course proceeds to the problems of inversion from high direct voltage to alternating voltage; combined conversion changing 60-cycle alternating voltage to alternating voltage of higher frequency; and feedback inversion. The operation of the parallel inverter is analyzed mathematically. Theoretical and laboratory studies are analyzed and coordinated to determine the effects of loads, supply voltage, and circuit components upon wave form, frequency, and output voltage.

4451. *HIGH-FREQUENCY HEATING.* Term 10. Elective. Credit three hours. Two lectures and one laboratory period each week. Prerequisite, 4421. Text: mimeographed notes. Schedule for fall term, 1950.

The course develops the theory of high-frequency heating of dielectrics of high and of low power factor; and of induction heating, with some consideration of unusual coil forms required for surface heating or other special applications. A study is made of the operation and the adjustment of oscillators of the types usual for these purposes.

4491 and 4492. *PROJECT.* Terms 9 and 10. Required in Industrial Electronics Option. Credit: Six hours total for both courses. Scheduled for 1950–1951.

To develop self reliance and initiative in working with engineering problems, each student, in his final terms, studies a special problem which is normally closely related to his option. The choice of a problem is made by the student after consultation with members of the teaching staff. This consultation begins during the term preceding that in which actual work on the project is begun.

Project problems may include the following: analysis and study of advanced theory in one of the several branches of engineering or allied fields; analysis and testing of equipment under conditions not considered in regular courses of study; design, construction and testing of special apparatus in which the student is particularly interested.

Throughout the work the student is expected to conform to good engineering practice in keeping a complete notebook of day-by-day tests and investigations. At frequent intervals he is expected to submit this notebook to the supervising staff member for discussion, comments, and suggestions. He is expected to submit a well-written technical paper which describes his investigation and summarizes the results.

COURSES IN RADIO AND COMMUNICATION

4511. *RADIO AND COMMUNICATION THEORY.* Term 8. Required in Radio and Communication Option. Credit three hours. Two lectures and one recitation or computing period each week. Prerequisite, 4122. Texts: *Radio Engineering,* TERMAN; supplementary notes. Given in both fall and spring terms.

The course begins with a study of video amplifiers, feedback amplifiers, oscillators, mixer circuits, and pulse-shaping circuits. The latter part of the course deals with the integration of these components into complete transmitters and receivers. The study includes both amplitude-modulated and frequency-modulated equipment.

4512. *RADIO AND COMMUNICATION THEORY.* Term 9. Required in Radio and Communication Option. Credit three hours. Two lectures and one computing period each week. Must be preceded or accompanied by 4511. Text: Theory and

Applications of Microwaves, BRONWELL and BEAM; supplementary notes. Given in both fall and spring terms.

This course is a study of communication circuits with distributed constants and also a study of production and propagation of electro-magnetic radiation.

The topics included are: transmission-line theory and applications; impedance matching; ultra-high-frequency generation; introduction to vector analysis and electromagnetic theory; propagation phenomena; and antenna characteristics and radiation.

4513. *COMMUNICATION NETWORKS.* Term 8. Required in Radio and Communication Option. Credit three hours. Three recitations each week. Must be preceded or accompanied by 4122. Text: *Transmission Networks and Wave Filters,* T. E. SHEA; supplementary notes. Given in both fall and spring terms.

After a review of fundamental principles dealing with linear networks, a study is made of two-terminal networks, reciprocal structures, ideal reactance structures, and balancing networks. A generalized analysis of the four-terminal transmission network is made. There is an introductory study of filter characteristics and design, and of amplitude - and delay equalizers. The course includes: general equivalence theorems; analogies between lumped networks and smooth lines; continuous and concentrated loading of lines; use of line segments as network elements.

4516. *RADIO AND COMMUNICATION LABORATORY.* Term 8. Required in Radio and Communication Option. Credit three hours. One recitation and one laboratory period each week. Must be preceded or accompanied by 4511. Texts: *Radio Engineering,* TERMAN; supplementary notes. Given in both fall and spring terms.

This course consists of a series of experiments closely paralleling the work of the accompanying course.

4517. *RADIO AND COMMUNICATION LABORATORY.* Term 9. Required in Radio and Communication Option. Credit three hours. One recitation and one laboratory period each week. Must be preceded or accompanied by 4512. Texts: *Theory and Applications of Microwaves,* BRONWELL and BEAM; supplementary notes. Scheduled for fall term 1950.

This course consists of a series of experiments closely paralleling the work of the accompanying course.

4521. *RADIO BROADCASTING.* Elective. Term 9 or 10. Credit three hours. Two lectures and one lecture-laboratory or computing period each week. Prerequisite, 4511. Must be preceded or accompanied by 4512. Text: References to current manuals and literature. Spring term only.

The course deals with the engineering aspects of radio broadcasting, including the following topics: studio equipment, and problems of studio operation; transmitting equipment, and problems of operation; determination of coverage; station interference, allocation of channels, and use of directional radiating systems; performance tests and maintenance procedures; network interconnections; purpose and policy of governmental regulating bodies.

The alternate laboratory and computing periods offer an opportunity to gain practical knowledge through the facilities of the University broadcasting station and through inspection of other nearby stations.

4522. *TELEPHONE AND TELEGRAPH SYSTEMS.* Term 9 or 10. Elective. Credit two hours. Two recitations each week. Prerequisite, 4131. Text: *Electrical Communication,* ALBERT. Scheduled for fall term, 1950.

This course continues in greater detail the study begun in the prerequisite course. The methods of machine switching in telephone systems are studied. Consideration is given to the relative advantages of the several systems, and to the proper choice of

system as influenced by the size of the community. Carrier telephony in both cable and open-wire circuits is given some attention.

Modern telegraphic methods, such as multiplex printing and facsimile transmission are studied.

Inspection trips to nearby telephone and telegraph exchanges will be arranged.

4526. *DESIGN AND CONSTRUCTION OF VACUUM TUBES.* Term 10. Elective. Credit three hours. Two lecture-recitations, and one laboratory period each week. Prerequisite, 4511. Text: *Fundamentals of Engineering Electronics,* DOW. Spring term only.

The purpose of this course is two-fold; first, to acquaint the student with methods by which an electron tube may be designed and its performance predicted; and second, to give a practical insight into the methods and problems of electron-tube manufacture.

The conformal transformation of the electric field in certain simple tubes and its aid in the determination of tube parameters; effects of auxiliary grids, focusing structures; and the equivalent diode and other related topics will be considered in some detail. In connection with the consideration of gas and vapor tubes, the fundamental principles of the conduction of electricity through gases with particular stress upon their application to practical tube design and construction will be reviewed.

The laboratory exercises will be devoted to the actual construction of several forms of simple tubes of both high vacuum and vapor types. The student will assemble the elements, complete the necessary glass working and evacuation, and compare the performance with that predicted.

4531. *TELEVISION SYSTEMS.* Term 10. Elective. Credit three hours. Two lectures and one lecture-computing period each week. Texts: *Principles of Television Engineering,* FINK; *Television,* volumes III and IV, RCA REVIEW; *Transients in Linear Systems,* GARDNER and BARNES. Scheduled for spring term, 1951.

The objectives of the course are to demonstrate the application of physical principles in the field of television engineering, and to acquaint the student with modern practice in the design and operation of television transmitters and receivers.

Basic work in transient analysis, vacuum-tube amplifiers, cathode-ray pick-up and viewing tubes, cathode-ray beam deflection, pulse shaping, modulation, and antenna characteristics serves as a background for further study of television problems. In addition, such problems as optics, illumination, scanning, synchronization, blanking, and shading are considered.

Computations involving the design of various units required for transmission and reception are carried out in the computing periods. An inspection of nearby television facilities serves to emphasize practical aspects.

4541. *APPLIED ACOUSTICS.* Term 9 or 10. Elective. Credit two hours. One recitation and one lecture-laboratory period each week. Texts: *Applied Acoustics,* OLSEN and MASSA, and *Vibration and Sound,* MORSE. Not offered in 1949–1950.

A review of the laws of ideal gases, the thermodynamic properties of air, and the laws of the propagation of compressional waves precedes a study of the transmission of sound through tubes, horns, and unbounded media. The design of sound sources, microphones, loudspeakers, and disc recorders in keeping with acoustical principles is considered. The phenomena of reflection, absorption, and reverberation, and the limitations which these phenomena impose upon architectural design, are studied. There are laboratory experiments on absolute-pressure calibration and free-field directivity characteristics of microphones and loudspeakers, the measurement of reverberation time, and the measurement of reflection coefficients and absorption coefficients of typical materials for acoustic treatment.

4551. *RADIO AIDS TO NAVIGATION.* Term 8 or later. Elective. Credit two

hours. Recitations each week. Prerequisite, 4131. Text: *Radar Aids to Navigation,* HALL; selected references. Spring term only.

Analysis of the principles of directive antennas is followed by discussion of long-wave and medium-wave direction finders and radio beacons. Atmospheric effects and limitations on the accuracy of determinations made by such equipment are considered. Attention is also given to medium-frequency pulsed transit-time systems and to high-frequency return-signal systems.

4561. *ULTRA-HIGH FREQUENCY SYSTEMS.* Term 10. Elective. Credit two hours. One recitation and one laboratory period each week. Must be preceded or accompanied by 4565. Fall term only, in 1949–1950.

This course consists of a theoretical and laboratory study of electrical equipment particularly applicable to ultra-high frequency operation, such as magnetrons, klystrons, and other similar generators, measuring devices, transmission systems, wave guides, coaxial lines, radiators, cavity resonators, etc.

4563. *PULSE TECHNIQUE IN COMMUNICATION AND RADAR.* Term 10. Elective. Credit three hours. Three recitations each week. Prerequisites, 4512, 4516, and 4517. Texts: Principles of Radar, MIT Radar School Staff; and supplementary notes. Spring term only.

The course begins with a study of the frequency analysis of pulses and related signals, and of the basic principles of pulse generation, transmission, and reception. The modulation systems known as pulse-amplitude, pulse-time, pulse-position, and pulse-code are then considered.

Applications of pulse technique in radar, long-range navigation (Loran) and moving-target indication (MTI) are discussed.

4565. *ELECTROMAGNETIC WAVES.* Elective. Credit three hours. Three lecture-recitations each week. Prerequisites, 4512 and 4517. Text: Fields and Waves in Modern Radio, RAMO and WHINNERY. Fall term only.

This course is a study of the fundamental Maxwell's Equations and of their application in electrical engineering problems. The topics considered include: wave propagation in free space, reflection, refraction and guided propagation in wave guides, cavity resonators, horns, and other radiators.

4566. *ELECTROMAGNETIC WAVES.* Elective. Credit three hours. Three lecture-recitations each week. Prerequisite, 4565. Texts: Volume 3 of Summary Technical Report of the Committee on Propagation, NDRC; Electromagnetic Waves, SCHELKUNOFF. Spring term only.

This course is a continuation of course 4565. It includes a study of radio-wave propagation over considerable distance, radiation from double antennas, power transfer between antennas, propagation over plane and spherical earth, ionosphere reflection, guide propagation in atmospheric ducts, and kindred topics.

4571. *ADVANCED COMMUNICATION NETWORKS.* Term 10. Elective. Credit three hours. Three lecture-recitations each week. Prerequisite, 4513. Text: Communication Networks, volume II. GUILLEMIN. Spring term only.

A general review of the basic methods of steady-state analysis of active and passive linear networks is followed by a study of transmission lines including the effects of dissipation and non-ideal terminations. This is followed by the application of matrix algebra to steady-state linear network problems including network transformations, combination of networks by matrix methods, and a development of the linear parameters of the general four-terminal network.

Foster's reactance theorem is presented and the results used in the synthesis of reactance elements with assigned characteristics. Foster's theorem is extended to include dissipative cases, and Brune's method for the synthesis of physically realizable impedance functions is briefly presented.

The methods previously developed are used in the design and semirigorous analysis of electric wave filters with special emphasis on practical terminations and the effects of incidental dissipation.

4591 and 4592. *PROJECT*. Terms 9 and 10. Required in Radio and Communication Option. Credit three hours each term. Scheduled for 1950–1951.

To develop self reliance and initiative in working with engineering problems, each student, in his final terms, studies a special problem which is normally closely related to his option. The choice of a problem is made by the student after consultation with members of the teaching staff. This consultation begins during the term preceding that in which actual work on the project is begun.

Project problems may include the following: analysis and study of advanced theory in one of the several branches of engineering or allied fields; analysis and testing of equipment under conditions not considered in regular courses of study; design, construction and testing of special apparatus in which the student is particularly interested.

Throughout the work the student is expected to conform to good engineering practice in keeping a complete notebook of day-by-day tests and investigations. At frequent intervals he is expected to submit this notebook to the supervising staff member for discussion, comments, and suggestions. He is expected to submit a well-written technical paper which describes his investigation and summarizes the results.

COURSES IN ILLUMINATION

4611. *INTRODUCTORY ILLUMINATION*. Term 8. Required in Illumination Option. Credit four hours. Two recitations, one lecture-laboratory period, and one computing period each week. Prerequisite, Physics 118. Text: *Scientific Basis of Illuminating Engineering*, MOON. Spring term only.

The course is intended to acquaint the student with the general nature of the field of illuminating engineering. Introductory study in several basic aspects of the subject is sufficiently pursued to provide an appreciation of the problems commonly encountered and of the methods of solution.

The following topics are considered: sources of light; visual perception and illusion; light control, both spectral and directional; the units and the measurement of the strength of light sources and of the intensity of illumination; general illumination design; perception, production, and mixing of colors; shadows, desirable and undesirable; architectural objectives.

4612. *ILLUMINATING ENGINEERING*. Term 9. Required in Illumination Option. Credit three hours. Two recitations and one lecture-laboratory period each week. Prerequisite, 4611. Text: *Scientific Basis of Illuminating Engineering*, MOON. Fall term only.

This course extends the study of some of the topics introduced in the prerequisite course. Study of current literature supplements the text. Computation of light-flux distribution and study of more difficult lighting problems are pursued. Emphasis is placed on industrial lighting problems more specialized than the problems of general lighting.

4615. ILLUMINATION SEMINAR. Term 10. Required in Illumination Option. Credit two hours. One two-hour period each week. Prerequisite, 4611. Spring term only.

Reports on selected topics of current interest in illuminating engineering are presented and discussed.

4691 and 4692. *PROJECT*. Terms 9 and 10. Required in Illumination Option. Credit two hours first term and four hours second term. Scheduled for 1950–1951.

To develop self reliance and initiative in working with engineering problems, each student, in his final terms, studies a special problem which is normally closely related to his option. The choice of a problem is made by the student after consultation with members of the teaching staff. This consultation begins during the term preceding that in which actual work on the project is begun.

Project problems may include the following: analysis and study of advanced theory in one of the several branches of engineering or allied fields; analysis and testing of equipment under conditions not considered in regular courses of study; design construction and testing of special apparatus in which the student is particularly interested.

Throughout the work the student is expected to conform to good engineering practice in keeping a complete notebook of day-by-day tests and investigations. At frequent intervals he is expected to submit this notebook to the supervising staff member for discussion, comments, and suggestions. He is expected to submit a well-written technical paper which describes his investigation and summarizes the results.

COURSES IN SERVOMECHANISMS

4711. *SERVOMECHANISMS AND AUTOMATIC CONTROL SYSTEMS.* Elective. Credit three hours. Two lecture-recitations and one laboratory or computing period each week. Must be preceded or accompanied by 4121, 4126, 4216, and 4221. Text: *Servomechanism Fundamentals,* LAUER, LESNICK, and MATSON. Fall term only.

The purpose of the course is to develop an understanding of the basic principles of servomechanisms and of the application of those principles in typical devices. The course begins with a study of elementary forms of electric, hydraulic, and electro-hydraulic servo-control systems of both the open-cycle and the closed-cycle type. Differential devices, discontinuous and continuous controls, and follow-up links are then considered. Throughout the course, attention is given to the factors influencing error, damping, and speed of response.

The subject of the transfer function or frequency analysis of servomechanisms is introduced. The systematic procedure followed in the design of practical servo-mechanisms is demonstrated.

4712. *ADVANCED SERVOMECHANISMS.* Elective. Credit three hours. Two lecture-recitations and one laboratory or computing period each week. Prerequisite, 4711. Text: mimeographed notes. Spring term only.

This course is a continuation of course 4711. Servomechanism theory is approached from an advanced analytical point of view which includes the use of transfer functions. Error-rate stabilization networks and forms of integral control are considered. The design of several automatic control systems is investigated quantitatively, and quantitative performance tests of typical systems are made in the laboratory.

COURSES FOR CIVIL, MECHANICAL, AND CHEMICAL ENGINEERS

4921. *ELECTRICAL ENGINEERING.* Term 5. Required of students in Civil Engineering. Credit three hours. One lecture, one recitation, and one computing period each week. Prerequisites, Mathematics 163, Physics 117, and Mechanics 1132. Fall term only.

The course consists of 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; and instruments and techniques appropriate for making measurements in all such circuits.

4922. *ELECTRICAL EQUIPMENT.* Term 6. Required of students in Civil Engineering. Credit three hours. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4921. Spring term only.

The course is intended to develop a general understanding of d-c generators and motors, motor starters and controllers, transformers, storage-battery charging equipment, induction motors, synchronous machines, and a-c single-phase motors. All machines are considered as to construction, general theory of operation, and operating characteristics.

4931. *ELECTRICAL ENGINEERING.* Term 7. Required of students in Mechanical Engineering. Credit three hours. One lecture, one recitation, and one computing period each week. Prerequisites, Mathematics 163, Physics 117, and Mechanics 1152. Fall term only.

The course consists of 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; and instruments and techniques appropriate for making measurements in all such circuits.

4932. *ELECTRICAL ENGINEERING.* Term 8. Required of students in Mechanical Engineering. Credit three hours. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4931. Spring term only.

The course is intended to develop a general understanding of d-c generators and motors, motor starters and controllers, transformers, induction motors, synchronous machines, a-c single-phase motors, and d-c and a-c selsyn units. All machines are considered as to construction, theory of operation, and operating characteristics.

4933. *ELECTRICAL ENGINEERING.* Term 9. Required of students in Mechanical Engineering. Credit three hours. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4932. Fall term only.

The first half of the course deals with maintenance and application of equipment under the topics of: commutation; meaning of ratings and guarantees; properties of insulation; determination of losses and efficiency; special equipment; and equipment selection. The second half of the course deals with basic electronics under the topics of: electron emission, high-vacuum and gas diodes; grid-controlled tubes; rectifiers; and photo-sensitive tubes and cells.

4934. *PRINCIPLES OF AUTOMATIC CONTROL.* Term 10. Required of Mechanical Engineering students in Option A. Credit three hours. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4933. Spring term only.

The course is a study of the mathematics of automatic control as exemplified in "servo" devices, with analysis of electrical, mechanical, and hydraulic applications. Considerable attention is given to problems of electrical instrumentation in automatically controlled operations and processes.

4951. *ELECTRICAL ENGINEERING.* Term 9. Required of students in Chemical Engineering. Credit four hours. Two lectures, one recitation, and one laboratory or computing period each week. Prerequisites, Mathematics 163 and Physics 117. Text: *Basic Electrical Engineering,* FITZGERALD. Fall term only.

This course further develops the principles of electric and magnetic circuits already studied in Physics. Its purpose is to provide for the student of Chemical Engineering an understanding of the performance and the application of such apparatus as motors, generators, controllers, transformers, meters, and protective devices.

4952. *ELECTRICAL ENGINEERING.* Term 10. Required of students in Chemical Engineering. Credit four hours. Two lectures, one recitation, and one laboratory or

computing period each week. Prerequisite, 4951. Text: *Electronics for Industry*, BENDZ. Spring term only.

This course is a continuation of 4951. Topics studied are illumination, electronic fundamentals, rectifiers, industrial heating, storage batteries, control methods and mechanisms. Design considerations are avoided except where, as in control equipment, the application and assembly of available commercial components constitutes a design problem involving the chemical engineer.

Chemical and Metallurgical Engineering

Required courses in the Chemical and Metallurgical Engineering curricula given outside of the school.

Chemistry 111, 112. Introductory Inorganic Chemistry (p. 130)
115. Introductory Inorganic Laboratory (p. 130)
212. Introductory Qualitative Analysis (p. 130)
220. Introductory Quantitative Analysis (p. 130)
222. Introductory Quantitative Laboratory (p. 130)
240. Special Methods of Quantitative Analysis (p. 130)
307, 308. Introductory Organic Chemistry (p. 131)
311. Introductory Organic Laboratory (p. 131)
312. Intermediate Organic Laboratory (p. 131)
403, 404. Introductory Physical Chemistry (p. 131)
411, 412. Introductory Physical Laboratory (p. 131)
English 111, 112. Introductory course in Reading and Writing (p. 132)
Electrical Engineering 4951, 4952 (p. 119)
History 165, 166. Science in Western Civilization (p. 132)
Mathematics 161, 162, 163. Analytical Geometry and Calculus (p. 132)
201. Elementary Differential Equations (p. 132)
Mechanics and Materials of Engineering (p. 72–76)
Mechanical Engineering Courses (p. 93–103)
Physics 115. Mechanics (p. 133)
116. Wave Motion, Sound, and Heat (p. 133)
117. Electricity and Magnetism (p. 134)
118. Physical Electronics and Optics (p. 134)
Public Speaking 101 (p. 135)
Geology 712, Metallurgical Raw Materials (p. 132)

CHEMICAL ENGINEERING

5103. *CHEMICAL ENGINEERING THERMODYNAMICS.* Fall term. Credit three hours. Prerequisite course, Chemistry 403 and 404. Mr. VON BERG.

Lectures. The development of the fundamental principles of thermodynamics, with special attention to their applications to chemical engineering processes.

5104. *CHEMICAL ENGINEERING THERMODYNAMICS.* Spring term. Credit two hours a term. Prerequisite course, Engineering 5103. Mr. VON BERG.

Lectures. Continuation of course 5103.

5203, 5204. *CHEMICAL ENGINEERING TECHNOLOGY.* Consecutive terms. Credit two hours a term. Mr. WIEGANDT.

Lectures. A discussion of the important chemical engineering processes and industries. The first term is devoted to the consideration of inorganic chemical technology; in the second term, the discussion deals with the organic chemical engineering industries.

5303, 5404. *UNIT OPERATIONS OF CHEMICAL ENGINEERING.* Consecutive terms. Credit three hours a term. Prerequisite courses, Chemistry 404 and Engineering 5203 and 5204. Mr. RHODES.

Lectures. A critical discussion of the unit operations of chemical engineering.

5353, 5354. *UNIT OPERATIONS LABORATORY.* Two terms. Credit three hours a term. Parallel courses, Engineering 5303, 5404. Messrs. RHODES, SMITH, and assistants.

5501. *CHEMICAL ENGINEERING STOICHIOMETRY.* Two hours credit. Mr. RHODES.

Lectures and recitations. Material balances and energy balances in chemical engineering; combustion reactions.

5503, 5504. *CHEMICAL ENGINEERING COMPUTATIONS.* Consecutive terms. Credit two hours a term. Prerequisite or parallel course, Engineering 5304. Mr. WINDING.

Conferences and lectures. Problems in fluid flow and heat transfer, distillation, evaporation, drying, humidification and air conditioning, and filtration.

5505. *ADVANCED PROBLEMS IN HEAT TRANSFER.* Fall term. Credit three hours. Prerequisite courses Engineering 5503 and 5504, or equivalent. Messrs. RHODES, WINDING, and SMITH. (Not offered in 1948–1949)

Conferences and lectures. Advanced topics in heat transfer. Heat transfer to fluids in streamline flow; heat transfer under unsteady-state conditions; heat transmission in mixed-flow heat exchangers, etc. Primarily for graduate students.

5506. *ADVANCED PROBLEMS IN DIFFUSIONAL OPERATIONS.* Spring term. Credit three hours. Prerequisite courses, 5503, 5504, or equivalent. Mr. WINDING.

Conferences and lectures. Advanced topics in distillation, gas absorption, liquid-liquid extraction, and drying. Primarily for graduate students.

5603, 5604. *CHEMICAL ENGINEERING EQUIPMENT.* Credit two hours a term. Prerequisite course, Engineering 5304. Mr. SMITH.

Two lectures a week. Details of design and construction of chemical engineering equipment; piping, design of pressure vessels, detailed design of process equipment.

5605, 5606. *CHEMICAL PLANT DESIGN.* Two terms. Credit two hours a term. Messrs. RHODES, WINDING, SMITH, VON BERG, and WIEGANDT.

Individual problems in the design of complete chemical plants, with estimation of costs of construction and operation.

5701. *PLANT INSPECTIONS.* Spring term. Credit one hour. Messrs. RHODES and WINDING.

A series of supervised inspection trips to manufacturing plants representing various chemical engineering industries. Each student is required to submit a critical and comprehensive report.

5711. *LIBRARY USE AND PATENTS.* Spring term. Credit one hour. Messrs. RHODES and MASON.

The effective use of technical literature; literature searches; abstracts and bibliographies; patent law.

5741. *PETROLEUM REFINING.* Alternate terms. Credit three hours. Prerequisite course Engineering 5304. Mr. WIEGANDT. Three lectures a week. Processes employed in petroleum refining.

5742. *SYNTHETIC RESINS AND PLASTICS.* Alternate terms. Credit three hours. Prerequisite or parallel course, Engineering 5304. Mr. WINDING.

Polymerization reactions; manufacture and properties of synthetic resins, plastics, and rubbers.

5743. *SPECIAL TOPICS IN CHEMICAL ENGINEERING.* Either term. Credit three hours. Prerequisite course Engineering 5304 or special permission. Messrs. WINDING, RHODES, and visiting lecturers.

Lectures; hours to be arranged. A series of lectures by resident staff members and visiting lecturers in some general field of chemical engineering.

5745. *CONTROL OF CHEMICAL ENGINEERING PROCESSES.* Fall term. Credit two hours. Prerequisite courses Engineering 5304 and 5354. Mr. RHODES.

Lectures. Hours to be arranged. The methods used for operation control and quality control in chemical engineering processes.

5851. *CHEMICAL MICROSCOPY.* Either term. Credit three hours. Prerequisite or parallel course, Chemistry 403 or 404 and Physics 117 or 118 or special permission. Mr. MASON and assistants. One lecture and two laboratory periods each week.

The use of microscopes and their accessories in chemical and technical investigations. Micrometry; quantitative estimations; microscopical characteristics and physical chemistry of crystals; lens systems and photomicrography; study of industrial materials such as textile and paper fibres.

5853. *MICROSCOPICAL QUALITATIVE ANALYSIS (INORGANIC).* Either term. Credit two or more hours. Prerequisite, Engineering 5851. Mr. MASON. Laboratory periods to be arranged.

Laboratory practice in the analysis of inorganic substances containing the more common elements.

5854. *MICROSCOPICAL METHODS IN ORGANIC CHEMISTRY.* Either term. Credit two or more hours. Prerequisites, Engineering 5851 and special permission. Mr. MASON. Day and hour to be arranged.

Laboratory practice. General manipulative methods applicable to small amounts of material, crystallization procedures, determination of melting points and molecular weights, chemical tests and reactions for elements, radicals, and various types of organic compounds. Preparation of simple derivatives.

5859. *ADVANCED CHEMICAL MICROSCOPY.* Either term. Credit one or more hours. Prerequisite course, Engineering 5851 and special permission. Mr. MASON and assistants.

Laboratory practice in special methods and special applications of chemical microscopy.

5953, 5954. *RESEARCH PROJECT.* Consecutive terms. Credit three hours a term; additional credit by special permission. Prerequisite course, Engineering 5304. Messrs. RHODES, MASON, WINDING, SMITH, VON BERG, and WIEGANDT.

Research on an original problem in Chemical Engineering.

METALLURGICAL ENGINEERING

6110. *CASTING, WORKING, AND WELDING OF METALS.* Either term. Credit two hours. Messrs. KYLE, BURTON, HARPER, HODGES, and JOYCE. One lecture and one laboratory period each week.

An elementary course covering the important industrial processes used in the casting, hot working, cold forming, and welding of metals.

6111. *INTRODUCTORY METALLURGY.* First term. Credit two hours. Messrs. KYLE, BURTON, HARPER, HODGES, and JOYCE. One lecture and one laboratory period each week. For students in Metallurgical Engineering.

An elementary course covering the important principles of metallurgy.

6113. *CASTING, WORKING, AND WELDING OF METALS.* Fall term. Credit three hours. Prerequisite courses, Engineering 1231 and Engineering 6110. Messrs. KYLE, BURTON, and assistants. Two lectures and one laboratory period each week.

An advanced course for students in Mechanical Engineering covering the application of metallurgical principles to foundry, metal working, and welding problems.

6114. *CASTING, WORKING, AND WELDING OF METALS.* Spring term. Credit three hours. Prerequisite courses, Engineering 1233, Engineering 6111, and Engineering 6811. Messrs. KYLE, BURTON, and assistants. Two lectures and one laboratory period each week.

An advanced course for students in Metallurgical Engineering.

6203. *SMELTING AND REFINING.* Fall term. Credit three hours. Prerequisite courses, Engineering 1256, Chemistry 404, and Engineering 6501. Mr. GREGG. Lectures.

Theory of the reactions involved in the reduction and refining of metals, carburization and decarburization, slag control, furnace-atmosphere generation, and related topics.

6253. *UNIT PROCESSES IN METALLURGY.* Fall term. Credit three hours. Prerequisite or parallel course, Engineering 6203. Mr. GREGG. One lecture and one laboratory period each week, with reports.

Experimental study of important processes in metallurgy, including ore dressing, temperature measurements, generation and control of furnace atmospheres, furnace design and performance, smelting and refining operations and electrodeposition.

6254. *UNIT PROCESSES IN METALLURGY.* Spring term. Credit two hours. Prerequisite course, Engineering 6253. Mr. GREGG. One lecture and one laboratory period each week with reports. Continuation of course 6253.

6311. *PHYSICAL METALLURGY.* Fall term. Credit three hours. Prerequisite course, Engineering 6811. Mr. MASON. Lectures.

Detailed discussion of plastic deformation, recrystallization and grain growth, diffusion in alloys, precipitation from solid solution, and transformation mechanisms in heat treatment.

6323. *ADVANCED FERROUS METALLURGY.* Fall term. Credit three hours. Prerequisite courses, Engineering 6203 and 6311. Lectures.

Discussion, at an advanced level, of steels, cast irons and heat treatment. (Not offered in 1949–1950)

6324. *ADVANCED NON-FERROUS METALLURGY.* Spring term. Credit three hours. Prerequisite courses, Engineering 6203 and 6311. Lectures.

Detailed discussions of advanced topics in non-ferrous metallurgy. (Not offered in 1949–1950)

6351. *PHYSICAL METALLURGY LABORATORY.* Fall term. Credit three hours. Parallel course, Engineering 6311. Messrs. MASON and BURTON. Laboratory periods and conferences.

Experiments to illustrate the important phenomena of physical metallurgy and special techniques for their investigation.

6501. *METALLURGICAL CALCULATIONS.* Fall term. Credit two hours. Prerequisite or parallel course, Engineering 1255. Mr. GREGG. Lectures and recitations.

An introductory course in the application of the principles of chemistry and

physics to metallurgical problems, including combustion, heat balances, gas reactions, and furnace charges.

6602. *METALLURGICAL DESIGN.* Spring term. Credit three hours. Prerequisite course, Engineering 6311, or special permission. Lectures.

The application of metallurgical principles to the study of the performance of metal parts in service. Includes metallurgical consideration in the choice of metals for various types of service, factors governing the choice of methods of fabrication of metal parts and equipment, and a study of metal failures and their causes and remedies. (Not offered in 1949–1950.)

6701. *PLANT INSPECTIONS.* Spring term. Credit one hour.

A series of supervised inspection trips to manufacturing plants representing various metallurgical engineering industries. Each student is required to submit a comprehensive report.

6811. *INTRODUCTORY METALLOGRAPHY.* Spring term. Credit three hours. Prerequisite courses, Engineering 1255 or 1222. Messrs. MASON and BURTON. One lecture and two laboratory periods each week.

Microstructures of alloys, as related to composition, thermal history, and physical properties. Preparation of specimens; principles and use of metallographic microscopes.

6953, 6954. *SENIOR PROJECT.* Two terms. Credit three hours each term. Prerequisite course, Engineering 6254.

Research on an original problem in Metallurgical Engineering. (Not offered in 1949–1950.)

Aeronautical Engineering

UNDERGRADUATE COURSES

7001. *INTRODUCTION TO AERONAUTICAL ENGINEERING.* Credit three hours. An introductory course for students in all branches of engineering. Emphasis on airplane mechanics: aerodynamic forces, airplane performance, airplane stability and control. Prerequisite, Engineering Mechanics. Each term.

GRADUATE COURSES

7101. *MECHANICS OF AIRPLANES.* Credit four hours. Introduction; the nature of fluid forces; characteristics of airfoils; airplane performance; wind-tunnel methods. Prerequisite, Engineering Mechanics. Fall term. Mr. WILD.

7102. *MECHANICS OF AIRPLANES.* Credit four hours. Airplane stability; airplane dynamics; control surfaces; flight-test methods. Prerequisite, 7101. Spring term. Mr. WILD.

7103. *AIRCRAFT PROPELLER DESIGN.* Credit three hours. The aerodynamics of propellers: Betz-Glauert theory of lightly-loaded propellers; refined theories, theory of fans. Prerequisite, 7101.

7104. *MECHANICS OF ROTARY-WING AIRCRAFT.* Credit 3 hours. Fundamentals of propeller theory. Rotor in vertical flight; dynamics of blade flapping; rotor in forward flight. Estimation of performance of rotary-wing aircraft. Helicopter control. Blade loading and bending. Survey of vibration problems. Prerequisite, 7101. Not given in 1948–1949. Spring term 1949–1950. Mr. FLAX.

7203. *AERODYNAMICS OF POWER PLANTS.* Credit three hours. Engine-supercharger characteristics at altitude; characteristics of turbojets, ramjets, etc.; aerodynamic problems of cooling, cowling, and combustion. Principles of aerodynamic design of compressors and turbines. Prerequisites, 7101, Physics. Each term. Mr. WILD.

7204. *GASDYNAMICS.* Credit four hours. One-dimensional steady flow of a perfect gas with heat addition etc., wave-propagation phenomena, method of characteristics for 2-dimensional and axi-symmetric supersonic steady flow and unsteady channel flow. Experimental methods. Prerequisites, Physics, Integral Calculus, Engineering Thermodynamics. Spring term. Mr. KANTROWITZ.

7205. *KINETIC THEORY.* Credit two hours. Topics in kinetic theory and thermodynamics related to gasdynamics. Equation of state of gases, Maxwell distribution law and relation to thermodynamics, transport phenomena, heat capacity of gases. Prerequisites, Physics, Integral Calculus, Engineering Thermodynamics. Fall term. Mr. KANTROWITZ.

7301. *THEORETICAL AERODYNAMICS I.* Credit three hours. Introduction to theoretical hydrodynamics; the theory of ideal fluids; potential flows; conformal transformation. Prerequisites, Differential Equations, Intermediate Mechanics or Introduction to Theoretical Physics. Six hours a week during the first half of the fall term. Mr. SEARS.

7302. *THEORETICAL AERODYNAMICS II.* Credit three hours. Wing theory: thin-airfoil theory, two-dimensional airfoil theory, Prandtl wing theory, lifting surfaces, general multiplane theory, non-stationary wing theory. Corrections for compressibility (linearized theory). Wing theory for supersonic speeds. Prerequisite, 7301. Spring term. Mr. SEARS.

7303. *THEORETICAL AERODYNAMICS III.* Credit three hours. The aerodynamics of compressible fluids: equations of motion, small-perturbation theory (subsonic and supersonic), Janzen-Rayleigh theory, the hodograph methods, the limiting line, the method of characteristics, Prandtl-Meyer flow, hypersonic flow. Prerequisite, 7201, 7202, 7301. Six hours a week during the second half of the fall term. Messrs. KUO and SEARS.

7304. *THEORETICAL AERODYNAMICS IV.* Credit three hours. The aerodynamics of viscous fluids: the boundary layer, heat transfer, fundamentals of boundary-layer stability. Turbulence, the fundamentals of isotropic turbulence. Experimental methods. Prerequisite, 7301. Spring term. Mr. KUO.

7401. *AIRPLANE STRUCTURES.* Credit three hours. Stress analysis: reinforced panels in tension and compression; bending, shear, and torsion of unsymmetrical semimonocoque members; diagonal-tension-field beams; mechanical properties of materials; allowable stresses; columns, plates in compression and shear; strain measurements. Prerequisite: Strength of Materials. Fall term. Mr. CONWAY.

7402. *AIRPLANE STRUCTURES.* Credit three hours. Stress analysis continued: fundamentals of air and ground loads determination and distribution, load factors, design conditions, design requirements; static testing; applied stress analysis of wing, fuselage, details. Prerequisites, 7101, 7401. Spring term.

7403. *AIRPLANE DESIGN.* Credit one hour. Orientation: the airplane and its

components; the philosophy of airplane design; aircraft materials and processes. Fall term. Mr. SEARS.

7404. *AIRPLANE DESIGN.* Credit one hour. Orientation (continued). Prerequisite, 7403. Spring term. Mr. SEARS.

7405. *AERO-ELASTIC PROBLEMS.* Credit three hours. Flutter, divergences, and aileron reversal; control-surface vibration at high speeds. Prerequisites, 7101, 7102.

7801. *RESEARCH IN AERONAUTICAL ENGINEERING.* (Credit to be arranged). Independent research in a field of aeronautical science. Such research must be under the guidance of a member of the staff, and must be of a scientific character. Prerequisites, admission to the Graduate School of Aeronautical Engineering and approval of the Director.

7901. *AERONAUTICAL ENGINEERING COLLOQUIUM.* Credit one hour. Lectures by staff members, graduate students, personnel of Cornell Aeronautical Laboratory and visiting scientists on topics of interest in aeronautical science, especially in connection with new research. Prerequisite, admission to the Graduate School of Aeronautical Engineering.

7902. *ADVANCED SEMINAR IN AERONAUTICS.* Credit two hours. Same as 7901, but devoted to topics of advanced scientific interest. Prerequisite, approval of the Director.

General Courses of Instruction

Described in this section are certain courses, prescribed for students in Engineering, given in the College of Arts and Sciences, the College of Architecture, or other divisions of the University as indicated below.

MILITARY SCIENCE AND TACTICS

This department conducts a basic course and an advanced course in Military Science and Tactics. The University requires most undergraduate men who are able-bodied American citizens to take the two-year course in their first four terms. This course consists of instruction in leadership, dismounted drill, rifle marksmanship, evolution of warfare, world military situation, map reading and aerial photography, and other subjects.

The advanced course is an elective and appeals to those who are aware of the country's need for specially trained men in its reserve army, and those who desire a fundamental training in military leadership. Courses are conducted in Field Artillery, Ordnance, Signal Corps, Quartermaster Corps, and Air Force. Upon completion of the course the student is qualified for a commission as a Second Lieutenant in the Officers' Reserve Corps of the Army or Air Force. In addition to his uniform, the student receives approximately $430 from the Government while taking the advanced course. Most World War II veterans are eligible without taking the basic course, and nearly all basic-course graduates are eligible. Opportunities are afforded for direct appointment as Second Lieutenants in the Regular Army or Air Force.

1. *BASIC COURSE.* Required. Throughout the year. The complete course covers two years. Three hours a week, M T W Th or F 1:40–4:30. Barton Hall.

2. *ADVANCED COURSE.* Elective. Throughout the year. The complete course covers two years. Credit three hours a term. Five hours a week. Barton Hall.

Further details may be obtained in the Announcement of the Department of Military Science and Tactics, or at Barton Hall.

NAVAL SCIENCE

The Department of Naval Science offers an integrated four-year course which normally requires three hours a week plus certain laboratory periods. Summer cruises or tours of duty at shore establishments are also required.

Completion of the first two years of Naval Science courses either as a Regular or a Contract student in the NROTC fulfills the University requirement for military training. Contract students, in their last two years, receive uniforms and approximately $480 from the Government. Regular trainees, who are selected by the Navy Department before admission to the University, receive free tuition, fees, books, uniforms, and retainer pay at the rate of $600 a year for four years. Upon completion of the four-year course, the Contract student is qualified for a commission as Ensign in the Naval Reserve or Second Lieutenant in the Marine Corps Reserve. The Regular trainee is qualified for a commission as Ensign in the Regular Navy, or as Second Lieutenant in the Marine Corps. When the needs of the Navy permit, commissions in the Regular Navy and Marine Corps may also be offered to the Contract students on graduation.

Students with the necessary preparation may fulfill the requirements of the NROTC program and also qualify for appropriate degrees from the College of Engineering, if they are careful in the selection of courses. Such students must meet all of the regular requirements for graduation from the College as well as those prescribed by the Bureau of Naval Personnel.

NROTC Curriculum:

NS101 and NS102. *Introduction to Naval Science.* Three hours throughout the first year.

NS201 and NS202. *Ordnance and Fire Control.* Three hours throughout the second year.

NS301 and NS302. *Piloting and Navigation.* Three hours throughout third year.

NS401 and NS402. *Naval Engineering.* Three hours throughout fourth year.

Note: For candidates who request commissioning in the Marine Corps upon graduation, specialized courses are substituted for NS302, NS401 and NS402 during the last three semesters.

Additional NROTC requirements:

(a) Every student must achieve proficiency in written and oral expression. The College in which the student is enrolled will prescribe standards of proficiency and determine procedures necessary to achieve them.

(b) Four years of physical training must be taken by every student. This requirement shall be compatible with the facilities of the University.

(c) Each student shall take such instruction in swimming as to qualify him as a first-class swimmer as described in NavPers 15007, *Physical Fitness Manual of the U. S. Navy.* In addition, skill in elementary life saving and resuscitation should be acquired.

Academic Credits:

Students who complete the NROTC course are given University credit for twenty-four hours of college work. This credit is, however, primarily for record and transcript purposes. At present net credit toward degree requirements of the various schools of the College of Engineering are as follows, provided the entire course is completed:

School of Mechanical Engineering	— 11 hours
School of Electrical Engineering	— 12 hours
School of Chemical Engineering	— 9 hours
School of Civil Engineering	— 7 hours
Department of Engineering Physics	— none

For further information write to the Professor of Naval Science, Naval ROTC Unit, Cornell University, Ithaca, New York.

ARCHITECTURE

REGIONAL AND CITY PLANNING

(In cooperation with the School of Civil Engineering)

700. *HISTORY OF CITY PLANNING.* Fall term. Credit three hours. Open to graduates and upperclassmen. The history of the planning of communities from ancient times to the present. Lectures, assigned readings, and examinations.

710. *PRINCIPLES OF REGIONAL AND CITY PLANNING.* Elective. Registration limited to 50. Open to graduates and upperclassmen in all colleges of the

University. Fall term. Credit three hours. The history of the planning of communities, including provisions for housing from ancient times to the present. A review of the basic influences in the development of cities. A general view of the theory and accepted practice of city and regional planning including a study of the social, economic, and legal phases. Occasional lectures may be given by members of other faculties and by outside lecturers selected because of their special experience and skill in certain phases of planning. Lectures, assigned reading, and examinations. Messrs. CLARKE and MACKESEY.

711. *CITY PLANNING PRACTICE.* Elective. Spring term. Credit three hours. Prerequisite, course 710. The precedures and techniques of gathering and analyzing data for municipal planning studies. The selection and integration of data for use in planning. Practical application of the theories of city planning. Office practice. Lectures, assigned reading, reports. Messrs. CLARKE and MACKESEY.

713. *HOUSING.* Elective. Registration limited. Fall term. Credit two hours. Prerequisite course 710. An introduction to the theory and standards of housing practice through analysis and comparison of various existing examples, considering the social, economic, and technical sides of the work. Lectures, assigned reading, and reports. Hours to be arranged. Mr. CLARKE and Mr. MACKESEY.

717. *ZONING PRINCIPLES AND PRACTICE.* Spring term. Credit two hours. Prerequisite, Course 710. Technical and legal aspects of drafting and administering zoning regulations. Open to graduates and upperclassmen in all colleges of the University.

ASTRONOMY

182. *FIELD ASTRONOMY.* Spring term. Credit two hours. One lecture and one afternoon or evening observation period to be arranged. Prerequisite, Plane Trigonometry. Mr. SHAW.

Basic theory and practice in the determination of Latitude, Longitude, Time, and the Azimuth of a Line. Practice with the surveyor's transit, the sextant, and the theodolite. Fundamentals of spherical trigonometry will be included in the course.

CHEMISTRY

101–102. *GENERAL CHEMISTRY.* Throughout the year. Credit three hours a term. Chemistry 101 is prerequisite to Chemistry 102. Open only to those students who have not offered high school chemistry for entrance. Lectures, laboratory, and conference each week. Mr. WOOD, Mr. POSVIC, and assistants.

This course gives an introduction to chemistry, with emphasis on the fundamental concepts and principles which deal with the nature of matter and its behavior. The states of matter, the quantitative aspects of chemical changes, chemical equilibrium, oxidation-reduction, electrolytic dissociation, and solution phenomena are discussed. The structure of atoms is correlated with their properties, their classification, and the nature of their compounds. The more common elements and compounds are considered, and organic chemistry is studied briefly. The application of the scientific method is stressed, and abundant lecture demonstrations supplement the experience which the student acquires in the laboratory.

102. *GENERAL CHEMISTRY.* Fall term. Credit three hours. Prerequisite, Chemistry 101, 105, or the first half of a satisfactory course in General Chemistry. Lectures, laboratory, and conference each week.

For description see Chemistry 101–102.

105–106. *GENERAL CHEMISTRY.* Throughout the year. Credit three hours a term. Chemistry 105 is prerequisite to Chemistry 106. Open to those students who have offered high school chemistry for entrance. Lectures, laboratory, and conference each week. Mr. VAN ARTSDALEN and assistants.

For description see Chemistry 101–102.

111–112. *INTRODUCTORY INORGANIC CHEMISTRY.* Throughout the year. Credit, Chemistry 111 three hours, Chemistry 112 two hours. Chemistry 111 is prerequisite to Chemistry 112. Chemistry 115 must be taken with Chemistry 111, except by consent of the instructor. Open to those students who have offered high school chemistry for entrance. Required of candidates for the degree of B. Chem. Eng. and recommended for candidates for the degree of A.B. with a major in Chemistry. Lectures. Mr. LAUBENGAYER and Mr. SIENKO.

115. *INTRODUCTORY INORGANIC LABORATORY.* Fall term. Credit three hours. Must be taken with Chemistry 111. Laboratory. Conference, one hour a week to be arranged. Mr. LAUBENGAYER, Mr. SIENKO, and assistants.

212. *INTRODUCTORY QUALITATIVE ANALYSIS.* Spring term. Credit five hours. Prerequisite, Chemistry 111 and 115. Must be taken with Chemistry 112. Required of candidates for the degree of B. Chem Eng. and recommended for candidates for the degree of A.B. with a major in Chemistry. Lectures. Recitation, one hour a week, to be arranged. Laboratory. Mr. BAUER, Mr. LONG, and assistants.

A study of the application of the theories of general chemistry, and the properties and reactions of the common elements and acid radicals to their systematic separation and detection, and their detection in various solutions and solids.

220. *INTRODUCTORY QUANTITATIVE ANALYSIS.* Either term. Credit three hours. Prerequisite, Chemistry 201, 205 and 207, or 212. Chemistry 222 must be taken with Chemistry 220. Required of candidates for the degree of B. Chem Eng. and recommended for candidates for the degree of A.B. with a major in Chemistry. Lectures. Recitation, one hour a week, to be ararnged. Mr. NICHOLS, Mr. SCHERAGA, and assistants.

A study of the fundamental principles of gravimetric and volumetric analysis with practice in stoichiometry.

222. *INTRODUCTORY QUANTITATIVE LABORATORY.* Either term. Credit three hours. Prerequisite, Chemistry 201, 205 and 207, or 212. Must be taken with Chemistry 220. Required of candidates for the degree of B. Chem. Eng. and recommended for candidates for the degree of A. B. with a major in Chemistry. Laboratory. Mr. NICHOLS, Mr. SCHERAGA, and assistants.

Laboratory practice in the preparation and standardization of various volumetric solutions and the analysis of a variety of substances by volumetric and gravimetric methods.

240. *SPECIAL METHODS OF QUANTITATIVE ANALYSIS.* Either term. Credit three hours. Prerequisite, Chemistry 220 and 222, or consent of the instructor. Primarily for candidates for the degree of B. Chem. Eng. Lecture and laboratory. Mr. NICHOLS and assistants.

The complete analysis of coal gas, the analysis of coal, the determination of the heating value of gaseous and solid fuels, and gas evolution methods. The application of instrumental methods to quantitative analysis including nephelometric, refractometric, colorimetric, electrolytic, combustion, conductometric, and potentiometric methods.

301. *INTRODUCTION TO ORGANIC CHEMISTRY.* Fall term. Credit two hours. Prerequisite, Chemistry 101–102, or 105–106. For students in Engineering. Mr. BLOMQUIST.

A brief survey of the principal classes of organic compounds, their industrial sources, manufacture, and utilization.

307–308. *INTRODUCTORY ORGANIC CHEMISTRY.* Throughout the year. Credit three hours a term. Prerequisite, Chemistry 201, 205 and 207, or 212. Open to those who are taking Chemistry 215 or 220 and 222. Chemistry 311 must be taken with Chemistry 307. Required of candidates for the degree of B. Chem. Eng. and A.B. with a major in Chemistry. Lectures. Mr. BLOMQUIST and Mr. JOHNSON.

A study of the more important compounds of carbon, their occurrence, methods of preparation, relations, and uses.

311. *INTRODUCTORY ORGANIC LABORATORY.* Fall term. Credit three hours. Must be taken with Chemistry 307. Required of candidates for the degrees of B. Chem. Eng. and A.B. with a major in chemistry. Laboratory. Mr. DeTAR and assistants.

The student prepares typical compounds of carbon and familiarizes himself with their properties, reactions, and relations.

312. *INTERMEDIATE ORGANIC LABORATORY.* Spring term. Credit three hours. Prerequisite, Chemistry 311, parallel course Chemistry 308. Required of candidates for the degree of B. Chem. Eng., and recommended for candidates for the degree of A.B. with a major in Chemistry. Laboratory. Mr. DeTAR, Mr. MILLER, and assistants.

A continuation of Chemistry 311.

402. *INTRODUCTION TO PHYSICAL CHEMISTRY.* Spring term. Credit two hours. Prerequisite, Chemistry 301, Mathematics 156 or 163, and Physics 117. For students in Engineering. Mr. LONG.

A brief survey of Physical Chemistry with emphasis on topics of interest to students in Engineering.

403–404. *INTRODUCTORY PHYSICAL CHEMISTRY.* Throughout the year. Credit three hours a term. Prerequisite, Chemistry 307–308, Mathematics 161–162–163, and Physics 107 and 108 (or their substantial equivalent). Required of candidates for the degree of B. Chem. Eng. Lectures. Mr. BRIGGS.

A systematic presentation of the principles of physical chemistry. The topics include: the properties of gases, liquids, and solids; physical and chemical equilibrium in homogeneous and heterogeneous systems; the mass law, theorem of Le Chatelier, and the phase rule; thermochemistry and elementary thermodynamics; the theory of solutions; ionic equilibria; chemical kinetics; problems in physical chemistry.

411–412. *INTRODUCTORY PHYSICAL LABORATORY.* Throughout the year. Credit three hours a term. Prerequisite or parallel course, Chemistry 403–404, or 407–408. Enrollment may be limited. Laboratory. Mr. BRIGGS, Mr. HOARD, and assistants.

Qualitative and quantitative experiments illustrating the principles of physical chemistry, and practice in performing typical physico-chemical measurements.

ECONOMICS

107. *INTRODUCTION TO ECONOMICS.* Either term. For students in Engineering. Credit three hours. Hours to be arranged.

An introduction to the more essential economic features of contemporary American Society.

201. *MONEY AND BANKING.* Either term. Credit three hours.

A general survey of the nature and functions of money and credit, and of the operation of the banking system.

401. *LABOR CONDITIONS AND PROBLEMS.* Fall term. Credit three hours. Prerequisite, Economics 101, or the equivalent. Mr. MONTGOMERY.

An introduction to the field of Labor Economics and a survey of the more basic labor problems growing out of modern economic arrangements.

ENGLISH

111–112. *INTRODUCTORY COURSE IN READING AND WRITING.* Throughout the year. Credit three hours a term. Open to freshmen. English 111 is prerequisite to 112. Mr. SALE and others.

The aim of this course is to increase the student's ability to communicate his own thought and to understand the thought of others.

ENGLISH FOR FOREIGNERS. (See English 101, 102, 103. Division of Modern Languages).

GEOLOGY

113. *ENGINEERING GEOLOGY.* Either term. Credit three hours only. Students who have had Geology 101–102 or 115 may take 113 for one hour credit. Lectures and laboratory. Mr. ANDERSON.

The purpose of the course is to provide a geologic background so that the engineer will be competent to adapt his work to conform with the limitations imposed by geologic conditions.

712. *METALLURGICAL RAW MATERIALS.* Spring term. Credit two hours. For students in Metallurgical Engineering. M W 10. Mr. ANDERSON.

Source, occurrence, association, distribution, and economic aspects of the important ore and fluxing materials that enter metallurgical operations.

HISTORY

165–166. *SCIENCE IN WESTERN CIVILIZATION.* Throughout the year. Credit three hours a term. Mr. GUERLAC.

MATHEMATICS

161–162–163. *ANALYTIC GEOMETRY AND CALCULUS.* Three terms; each course is offered each term. Credit three hours a term. Primarily for students in the College of Engineering; the prerequisites for such students are Mathematics 133 and Mathematics 129 or 131, or the equivalent.

201. *ELEMENTARY DIFFERENTIAL EQUATIONS.* Either term. Credit three hours. Prerequisite, Mathematics 163, or the equivalent.

501–502. *ADVANCED CALCULUS.* Throughout the year. Credit three hours a term. Prerequisite, Mathematics 163, or the equivalent.

A careful study of limits, continuity, derivatives and Riemann integrals. Functions of several variables. Multiple and line integrals. The course is designed to furnish necessary preparation for advanced work in analysis and applied mathematics. Emphasis is placed on the logical development of the calculus, rather than on a wide range of formal applications.

607. *APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS.* Term 4. Required. Credit three hours. Three recitations each week. Prerequisite, Mathematics 163. Text: *Applied Mathematics for Engineers and Physicists,* PIPES. Spring term only.

The purpose of this course is to develop an understanding of certain mathematical concepts and processes which are of wide utility in the solution of engineering problems. The topics include infinite series, complex numbers and hyperbolic functions, determinants, Fourier analysis, approximate solutions of equations, probability and least squares, and dimensional analysis.

608. *DIFFERENTIAL EQUATIONS FOR ELECTRICAL ENGINEERS.* Term 7. Required. Credit three hours. Three recitations each week. Prerequisite, Mathematics 163. Text: *Differential Equations,* FORD. Fall term only.

Special emphasis is placed upon means of solving differential equations of the types frequently encountered in electrical engineering problems. Separation of variables, Laplace transforms, and solutions by series are considered.

611–612. *HIGHER CALCULUS FOR ENGINEERS AND PHYSICISTS.* Throughout the year. Credit three hours a term. Prerequisite, Mathematics 163, or the equivalent.

Infinite series, partial differentiation, multiple and line integrals, Fourier series, partial differential equations, vector analysis, complex variables, orthogonal expansions, calculus of variations, Laplace and Fourier transforms with applications. Emphasis is placed on a wide range of formal applications of the calculus, rather than on the logical development. The second term will be accepted as prerequisite to Complex Variables.

621–622. *MATHEMATICAL METHODS IN PHYSICS.* Throughout the year. Credit three hours a term. Prerequisite, Mathematics 201, or the equivalent, and at least two years of general physics.

Lectures and problem work designed to give the student a working knowledge of the principal mathematical methods used in advanced physics.

681–682. *DIFFERENTIAL EQUATIONS OF MATHEMATICAL PHYSICS.* Throughout the year. Credit three hours a term. Prerequisite, Mathematics 502.

The derivation of the differential equations, with appropriate boundary conditions, which arise in certain problems of mathematical physics; the mathematical properties of solutions, and the physical meanings of these properties.

PHYSICS

Note: Physics 115, 116, 117 and 118 form a sequence in a two-year continuous course in General Physics required of all students of engineering who are candidates for the degrees of B. Chem. E., B.C.E., B.E.E., B. Eng. Phys., and B.M.E. Demonstrations, theory, experiments, and problem drill. One lecture, two recitations, and one laboratory period a week, as assigned.

115. *MECHANICS.* Fall term. Credit three hours. Prerequisite, Calculus, or simultaneous registration in Mathematics 161. Entrance physics is desirable but not required. Mr. GRANTHAM, Mr. NEWHALL, and assistants.

Kinetics, statics, elasticity, liquids, and mechanics of gases.

The laboratory work consists of measurements of length, acceleration, velocity, elasticity, harmonic motion, moment of inertia, mass, centripetal force, and density.

116. *WAVE MOTION, SOUND, AND HEAT.* Spring term. Credit three hours. Prerequisites, Physics 115, Calculus, or simultaneous registration in Mathematics 162. Mr. GRANTHAM, Mr. NEWHALL, and assistants.

Wave motion, sound, acoustic measurements, temperature, calorimetry, changes of state, liquefaction of gases, heat transfer, and elementary thermodynamics.

The laboratory work consists of measurements of temperature, properties of gases, calorimetry, mechanical equivalent of heat, change of state, sound production, wave motion, speed of sound, and resonant phenomena.

117. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hours. Prerequisites, Physics 115, 116, Calculus, or simultaneous registration in Mathematics 163. Mr. TOMBOULIAN, Mr. NEWHALL, and assistants.

Introductory study of the fundamental laws of electric and magnetic fields and their applications to elementary circuit problems. Electrostatic fields and potential; steady currents, induced emfs, inductance, dielectrics, capacitance, magnetic properties of matter, simple transients, alternating currents.

The laboratory work consists of basic measurements in direct current circuits.

118. *PHYSICAL ELECTRONICS AND OPTICS.* Spring term. Credit three hours. Prerequisite, Physics 117. Lectures, recitations, and laboratory. Mr. TOMBOULIAN, Mr. NEWHALL, and assistants.

Selected topics in thermionics, photoelectricity, gaseous conduction, motion of ions in electric and magnetic fields, introductory geometrical optics; physical optics, including interference, diffraction and polarization, radiation, and simple spectra.

The laboratory work consists of measurements in electronics such as the determination of work function, characteristics of photo cells, cut-off curves of magnetrons, simple lenses, dispersion, diffraction, resolving power, polarized light, and photometry.

210. *ADVANCED LABORATORY.* Either term. Credit three hours. Prerequisites, Physics 205 and 206, or the equivalents. Laboratory (two periods required). One discussion period to be arranged.

Experimental work in a wide variety of fields is offered to meet the needs of the individual student. Considerable time may be spent on a relatively few topics, or many experiments may be performed to gain acquaintance in several fields. The laboratory work is individual, and stress is laid on independent work on the part of the student. Among the topics for which facilities are available are mechanics, acoustics, optics, spectroscopy, electrical circuits, electronics and ionics, heat and temperature measurements, x-rays, cosmic rays, and nuclear physics.

215. *PHYSICAL OPTICS.* Fall term. Credit three or five hours. Prerequisites, Physics 206, or equivalent, and Calculus. Lectures and laboratory. Mr. HARTMAN.

Huygens and Fermat's principles, Fresnel and Fraunhofer diffraction, polarization of light, double refraction, optical activity, electromagnetic character of light, velocity of light, dispersion and reflection.

225. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hours. Prerequisite, Physics 117 or 206. Lectures, and one optional problem period to be arranged. Mr. MURDOCK.

Electrostatic and electromagnetic fields, polarization of dielectrics and magnetic media, displacement current, plane electromagnetic waves, the Poynting vector.

236. *ELECTRICITY AND MAGNETISM.* Spring term. Credit three or five hours as arranged. Prerequisites, Physics 225 and Differential Equations. Lectures, T Th S 9. Laboratory T W 1:40–4:30, also Th F 1:40 if a second section is warranted. Mr. TOMBOULIAN.

The formulation of circuit theory from the standpoint of the electromagnetic field. Validity and limitations of circuit concepts. Steady-current circuits and networks, transients, alternating-current circuits and networks, frequency characteristics of networks, circuits with distributed parameters, non-linear elements.

242. *ANALYTICAL MECHANICS.* Spring term. Credit three hours. Prerequisites, Physics 205 and Mathematics 201, or the equivalent. Mr. SPROULL.

Analytical mechanics of material particles, systems of particles, and rigid bodies; oscillations and forced vibrations; planetary motion; stability of orbits; Euler's equations; gyroscopic motion; Lagrange's equations.

243. *ATOMIC AND MOLECULAR PHYSICS.* Fall term. Credit three hours. Prerequisite, Physics 225.

The fundamental particles; statistical physics; the concepts of quantum mechanics; atomic structure and spectra; the periodic table; molecular structure and the chemical bond; fundamentals of nuclear physics.

254. *ELECTRONIC PROPERTIES OF SOLIDS AND LIQUIDS.* Spring term. Credit three or five hours. Prerequisite, Physics 243. Lectures. Two laboratory periods as arranged. Mr. SACK.

Lattice structure of solids; magnetic, dielectric, and thermal properties of solids; electrical and optical properties of metals, semi-conductors, and ionic crystals; electron emission and barrier layer effect; relaxation phenomena in liquids and solids.

PSYCHOLOGY

211. *PHYSIOLOGICAL PSYCHOLOGY OF THE SENSES.* Fall term. Credit three hours. Prerequisites, Psychology 101 and 102. Mr. DALLENBACH.

Lectures and demonstrations on the experimental psychology of the special senses together with a study of the nervous structures involved.

404. *PSYCHOBIOLOGY.* Spring term. Credit three hours. Prerequisite, junior standing.

The principal biological mechanisms of behavior with special reference to man.

440. *PSYCHOLOGY FOR ENGINEERING STUDENTS.* Either term. Credit three hours. Open by permission to students in Arts and Sciences.

A survey of some of the basic concepts of psychology including such topics as the scientific method, learning and thinking, individual differences, vocational guidance, and certain aspects of applied psychology.

PUBLIC SPEAKING

101. *PUBLIC SPEAKING.* Either term. Credit three hours. Not open to freshmen.

Practice in speaking on subjects of current interest; methods of preparation and delivery; various types of speech experience, such as exposition, advocacy, reading aloud, discussion, and chairmanship; study of principles and of noted examples; conferences.

Foreign students and others whose pronunciation of English falls below the normal standard, and students with special vocal problems, are advised to confer with Mr. THOMAS before registering.

105. *PUBLIC SPEAKING.* Fall term. Credit two hours. For third-term students in Mechanical Engineering under the five-year curriculum. Mr. WAGNER and staff.

Practice in speaking, on subjects of current interest; methods of preparation and delivery; various types of speech experience, such as exposition, advocacy, reading aloud, discussion, and chairmanship; study of principles and of examples; conferences.

Foreign students and others whose pronunciation of English falls below the normal standard, and students with special vocal problems, are advised to confer with Mr. THOMAS before registering.

ENGINEERING JOURNALISM

Instruction in these courses is given in the College of Engineering.

1931, 1932. *ENGINEERING JOURNALISM.* Elective for Juniors who are members of the staff of *The Cornell Engineer.* Enrollment for credit must be with the ap-

proval of the class adviser. Throughout the year. Credit, two hours. Practical training in magazine editing and business management, including the writing of technical articles, copy reading, proof reading, makeup, and other editorial procedures; also accounting, advertising, the handling of circulation problems, and other phases of business management as related to publishing. Group meetings and individual conferences at hours to be arranged. Messrs. THATCHER and SAMPSON.

1941, 1942. *ENGINEERING JOURNALISM.* A continuation of 1931, 1932. Elective for Seniors who are members of the staff of *The Cornell Engineer.* Enrollment for credit must be with the approval of the class adviser. Throughout the year. Credit two hours.

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