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

1948–1949

Contents

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 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 fields 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.

DEGREES OFFERED

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

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 in Engineering (M.S. in Engineering), 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...Cornell University requires men of the Freshmen and Sophomore classes to take the Basic Course in Military Science and Tactics. That requirement is precisely defined, and exceptions and alternatives are clearly stated, in the *General Information* booklet, which should be consulted. See also page 129 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. in Engineering, 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.

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 cooper-

ation 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 79.)

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 Counselor of Students for men and his staff may be consulted by men students regarding their non-academic problems. There is also a Counselor of Students for women.

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 Cornell Cosmopolitan House, 301 Bryant Avenue, which has lodging and dining room accommodations for a group of foreign and American students. 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 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, 124 Roberts Place, Ithaca, New York.

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 December of their senior year. Servicemen may substitute the special aptitude tests for veterans if they have not taken the regular scholastic aptitude tests.

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. Application blanks and instructions are sent, about October 1 of each year, to the principals and headmasters of accredited schools for their use in recommending outstanding candidates who wish to enter the College of Engineering. An application blank will also 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 Financial Aid* should be consulted. This can be obtained by application to the Cornell University Official Publication, 124 Roberts Place.

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 Counselor of Students for 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, 124 Roberts Place. 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.
ROBERT FRANKLIN CHAMBERLAIN, M.E., (in E.E.), Assistant Dean of the College and Personnel Officer.
JEANETTE POOR, B.S., Librarian.

SCHOOL OF CIVIL ENGINEERING

WILLIAM LINDSAY MALCOLM, M.A., B.Sc., M.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.
HENRY NEELY OGDEN, C.E., Professor of Sanitary 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.
CHARLES LEOPOLD WALKER, C.E., Professor of Sanitary Engineering.

PROFESSORS

GILMORE DAVID CLARKE, B.S., Professor of Regional Planning and Dean of the College of Architecture.
HERBERT HENRY SCOFIELD, M.E., Professor of Testing Materials.
ROMEYN Y. THATCHER, C.E., Professor of Civil Engineering.
PAUL HALLADAY UNDERWOOD, C.E., Professor of Surveying.

ASSOCIATE PROFESSORS

DONALD J. BELCHER, B.S.C.E., M.S.E., Associate Professor of Highway Engineering.
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.
DAVID E. DONLEY, B.S. in C.E., C.E., Associate Professor of Hydraulic Engineering.
HOWARD MERRILL GIFFT, B.S., M.S., 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.
JOHN EDWIN PERRY, B.S. in C.E., Associate Professor of Railroad Engineering and Personnel Officer of the School of Civil Engineering.
LINCOLN REID, B.S., M.S., Associate Professor of Experimental Hydraulics.
GEORGE WINTER, C.E., Ph.D., Associate Professor of Civil Engineering.

ASSISTANT PROFESSORS

CHARLES M. ANTONI, B.S. in C.E., M.S. in C.E., Assistant Professor of Civil Engineering.
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TAYLOR LEWIS, B.S. in C.E., Assistant Professor of Civil Engineering.
ROBERT MAINS, B.S. in C.E., M.S. in C.E., Assistant Professor of Civil Engineering.
MELVILLE STANTON PRIEST, B.S., M.S., Assistant Professor of Civil Engineering.
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

JOSEPH D. GILFOYLE, B.S. in C.E., Marc Eidlitz Instructor in Civil Engineering.
MARIO LEON JUNCOSA, A.B., M.S., Instructor in Mechanics.

ASSISTANTS

HOWARD GOLUB, B.S. in C.E., Assistant in Route Surveying.
RAYMOND JOSEPH HODGE, B.C.E., Assistant in Surveying.
ALEXANDER B. HORVATH, B.S. in C.E., Assistant in Materials Laboratory.
HENRY JONES, B.C.E., Assistant in Drawing.
FREDERICK J. MALKMUS, B.C.E., Assistant in Route Surveying.
WILLIAM PANSIUS, Assistant in Drawing.
JOHN F. ROONEY, Assistant in Drawing.

SIBLEY SCHOOL OF MECHANICAL ENGINEERING

W. JULIAN KING, B.CH.E., M.E., Director of the School and Professor of Mechanical Engineering.
GEORGE RAYMOND HANSELMAN, M.E., M.S., Assistant Director of the School of Mechanical Engineering, Professor of Administrative Engineering, and Secretary of the Faculty of Mechanical Engineering.

EMERITUS PROFESSORS

CALVIN DODGE ALBERT, M.E., Professor of Machine Design, Emeritus.
DEXTER SIMPSON KIMBALL, A.B., M.E., D.Sc., D.Eng., LL.D., Professor of Mechanical Engineering, Emeritus.
WILL MILLER SAWDON, B.S. in M.E., M.M.E., Professor of Experimental Engineering, Emeritus.
ALBERT EDWARD WELLS, Sibley Professor of Mechanic Arts, Emeritus.

EDGAR HARPER WOOD, M.M.E., Professor of Mechanics of Engineering, Emeritus.

PROFESSORS

PAUL HOWARD BLACK, M.E., Professor of Machine Design.
ARTHUR HOUGHTON BURR, B.S. in M.E., M.S. in M.E., Ph.D., Professor of Machine Design.
STEPHEN FARRELL CLEARY, M.E., M.M.E., Professor of Engineering Drawing.
WALTER RODNEY CORNELL, B.S., C.E., Professor of Mechanics of Engineering.
FRANK OAKES ELLENWOOD, A.B., M.E., Professor of Heat-Power Engineering.
VICTOR RAYMOND GAGE, M.M.E., Professor of Mechanical Engineering.
DWIGHT FRANCIS GUNDER, B.S., M.S., Ph.D., Professor and Department Head of Mechanics.
JOSEPH OLMSTEAD JEFFREY, M.E., M.M.E., Professor of Engineering Materials.
HARRY JOHN LOBERG, M.E., M.S. in Eng., Professor of Industrial and Administrative Engineering.
CHARLES OSBORN MACKEY, M.E., Professor of Heat-Power Engineering.
CLYDE IRA MILLARD, E.E., Professor of Industrial and Engineering Administration.
JOHN ROBERT MOYNIHAN, M.E., M.M.E., Professor of Engineering Materials.
FRED STILLMAN ROGERS, B.S., M.E., Professor of Machine Design.
CLARENCE ELLSWORTH TOWNSEND, M.E., Professor 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.
H. D. CONWAY, M.E., M.M.E., Ph.D., Associate Professor of Mechanical Engineering.
DAVID DROPKIN, M.E., M.M.E., Ph.D., Associate Professor of Mechanical Engineering.
FREDERICK SEWARD ERDMAN, B.S., B.S. in M.E., M.M.E., Ph.D., Associate Professor of Mechanical Engineering.
HOWARD NEWTON FAIRCHILD, M.E., E.E., Associate Professor of Mechanical Engineering.
ROGER LOREN GEER, M.E., Associate Professor of Materials Processing.
ROLLAND THEODORE HINKLE, B.S. in M.E., M.S., Ph.D., Associate Professor of Mechanical Engineering.
WARREN HOWARD HOOK, M.E., Associate Professor of Heat-Power Engineering.
WILLIAM EMERSON MORDOFF, M.E., Associate Professor of Engineering Drawing.
LOUIS LESLIE OTTO, M.E., M.M.E., Associate Professor of Mechanical Engineering.
HAROLD CHARLES PERKINS, M.E., Associate Professor of Mechanics of Engineering.
ANDREW S. SCHULTZ, JR., M.S. in A.E., Ph.D., Associate Professor of Industrial and Engineering Administration.
EDWIN B. WATSON, B.S. in M.E., M.S. in Eng., Associate Professor of Mechanical Engineering.
KENDALL C. WHITE, E.E., Associate Professor of Industrial and Administrative Engineering.

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.

NORMAN RUSSELL GAY, B.S. in M.E., M.S. in Engineering, Assistant Professor of Heat-Power Engineering.
ISRAEL KATZ, B.S. in M.E., M.M.E., Associate Professor of Mechanical Engineering.
HAMILTON HORTH MABIE, B.S. in M.E., M.S. in Eng., Assistant Professor of Machine Design.
CLARENCE BERNARD MANSKY, B.S., in M.E., Assistant Professor of Mechanics of Engineering.
CHARLES RAYMOND OTTO, M.E., Assistant Professor of Engineering Materials.
WALTER JOSEPH PURCELL, C.E., Assistant Professor of Engineering Materials.
MARTIN WRIGHT SAMPSON, JR., B.S. in A.E., Assistant Professor of Industrial and Engineering Administration.
CHARLES RALPH SCOTT, JR., B.S. in A.E., M.S. in Eng., Assistant Professor of Industrial and Engineering Administration.
ROBERT HERMANN SIEGFRIED, M.E., Assistant Professor in Engineering Drawing.
THOMAS BROADHEAD TRACY, M.E., M.M.E., Assistant Professor of Mechanical Engineering.
EDGAR RAYMOND WATT, M.E., M.M.E., Assistant Professor of Mechanical Engineering.
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 Industrial and Engineering Administration.
OWEN JOSEPH BLACK, JR., B.S. in M.E., Instructor in Engineering Materials.
H. RUPERT CARPENTER, Instructor-Technician in Materials Processing.
HARRY NORMAN COTTER, JR., B.S. in M.E., Instructor in Machine Design.
HOWARD BENJAMIN CURTIS, Instructor-Technician in Materials Processing.
ANTHONY S. DISPENZA, Instructor-Technician in Materials Processing.
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FRANK A. SWINGLE, B.M.E., Instructor in Engineering Materials.
ROBERT H. UNDERWOOD, B.M.E., A.B., Instructor in Mechanics.
ERNEST S. YAWGER, Instructor-Technician in Materials Processing.
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SCHOOL OF ELECTRICAL ENGINEERING

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

EMERITUS PROFESSOR

VLADIMIR KARAPETOFF, C.E., M.M.E., D.Sc., Professor of Electrical Engineering, Emeritus.

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LAWRENCE ADAMS BURCKMYER, JR., B.S. (in E.E.), E.E., Professor of Electrical Engineering.

ROBERT FRANKLIN CHAMBERLAIN, M.E. (in E.E.), Professor of Electrical Engineering, and Personnel Officer.

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EDWARD WOODWORTH HAMLIN, B.S. in E.E.; M.S. in E.E., Ph.D., Professor of Electrical Engineering.

HENRY B. HANSTEEN, E.E., M.A., Ph.D., Professor of Electrical Engineering.

TRUE McLEAN, E.E., Professor of Electrical Engineering.

MICHEL GEORGE MALTI, A.B., B.S. in E.E., M.E.E., Ph.D., Professor of Electrical Engineering.

BURDETTE KIBBE NORTHROP, M.E. (in E.E.), Professor of Electrical Engineering.

HOWARD GODWIN SMITH, E.E., M.E.E., Ph.D., Professor of Electrical Engineering.

EVERETT MILTON STRONG, B.S. in E.E., Professor of Electrical Engineering.

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ASSOCIATE PROFESSORS

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NELSON HOWARD BRYANT, E.E., Instructor in Electrical Engineering.
ALFRED EMERYS DAVIES, B.S. in E.E., Instructor in Electrical Engineering.
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SIMPSON LINKE, B.S. in E.E., Instructor in Electrical Engineering.
HENRY S. McGAUGHAN, B.S.E. (in Phys.), Instructor in Electrical Engineering.
BENJAMIN NICHOLS, B.E.E., Instructor in Electrical Engineering.
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ROBERT LEE SCRAFFORD, B.E.E., Instructor in Electrical Engineering.
LAWRENCE B. SPENCER, E.E., Instructor in Electrical Engineering.
MOODY CHALMERS THOMPSON, B.E., Instructor in Electrical Engineering.
GORDON JAMES WATT, B.S. in M.E., Instructor in Electrical Engineering.
WILLIAM HENDERSON WILDER, B.E.E., Instructor in Electrical Engineering.
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SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

FRED HOFFMAN RHODES, A.B., Ph.D., Director of the School, Herbert Fisk Johnson Professor of Industrial Chemistry, Professor of Chemical Engineering, and Personnel Officer of the School.

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PETER EDWARD KYLE, M.E., M.S. (in M.E.), Professor of Metallurgy.
CLYDE WALTER MASON, A.B., Ph.D., Professor of Chemical Microscopy and Metallography.
CHARLES CALVERT WINDING, B.Chem.E., Ph.D., Professor of Chemical Engineering.

ASSISTANT PROFESSORS

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FRANK MASLAN, B.S. in Chem.E., M.S. in Chem.E., Ph.D., Assistant Professor of Chemical Engineering.
JULIAN C. SMITH, B.Chem.E., Assistant Professor of Chemical Engineering.

ROBERT L. VON BERG, B.S. in Chem.E., M.S. in Chem.E., Ph.D., Assistant Professor of Chemical Engineering.
HERBERT F. WIEGANDT, B.S. in Chem.E., M.S. in Chem.E., Ph.D., Assistant Professor of Chemical Engineering.

INSTRUCTOR-TECHNICIANS

MORRIS L. HARPER, Instructor-Technician in Metallurgy.
GERALD A. HILL, Instructor-Technician in Metallurgy.
DENNIS J. JOYCE, Instructor-Technician in Metallurgy.
CHARLES H. PATTERSON, Instructor-Technician in Metallurgy.

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JAMES GILLIN, B.Chem.E., Assistant in Chemical Engineering.
WILLIAM R. LEHRIAN, B.S. in Chem.E., Assistant in Chemical Engineering.
RAYMOND G. THORPE, B.S. in Chem.E., Assistant in Chemical Engineering.
ARTHUR A. VOGT, B.S. in Chem.E., Assistant in Chemical Engineering.

GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

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

ASSOCIATE PROFESSORS

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

ASSISTANT PROFESSORS

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

POST-DOCTORATE FELLOW

SHIH-I PAI, B.S., Ph.D., Professor of Aeronautical Engineering, National Central University, Nanking, China.

LECTURER

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

ASSISTANTS

E. EUGENIA McDONALD, B.A., Technical Assistant in Aeronautical Engineering.
WILLIAM S. MILLER, B.M.E., Assistant in Aeronautical Engineering.

FRANKLIN K. MOORE, B.M.E., Assistant in Aeronautical Engineering.
EDWIN L. RESLER, B.S. (Aero.E.), Assistant in Aeronautical Engineering.
HAO-SUNG TAN, B.S., Assistant in Aeronautical Engineering.

RESEARCH ASSOCIATE

ABRAHAM HERTZBERG, 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.

PROFESSORS

CHARLES RUSSELL BURROWS, Ph.D., Director of the School of Electrical Engineering and Professor of Electrical Engineering.
JACOB ROLAND COLLINS, Ph.D., Professor of Physics.
ALEXANDER BERRY CREDLE, Ph.D., Professor of Electrical Engineering.
GUY EVERETT GRANTHAM, Ph.D., Professor of Physics.
MARK KAC, Ph.D., Professor of Mathematics.
WILLIAM REES SEARS, Ph.D., Director of the Graduate School of Aeronautical Engineering and Professor of Aeronautical Engineering.

ASSOCIATE PROFESSORS

TREVOR RHYS CUYKENDALL, Ph.D., Associate Professor of Engineering Physics.
PAUL LEON HARTMAN, Ph.D., Associate Professor of Physics.
HENRI SAMUEL SACK, Sc.D., Associate Professor of Engineering Physics.

ASSISTANT PROFESSORS

WILFRID BARRETT WHALLEY, M.A.Sc., Assistant Professor of Engineering Physics.

OTHER MEMBERS OF THE STAFF

JEAN L. DAVIDSON, Secretary to the Dean.
LULU MARKELL, Clerk, Dean's Office.
DORIS L. CALDWELL, Secretary, Personnel and Employment Office.
MINA M. WILD, Secretary, Committee on Scholarships.
LUCILLE HUME, Secretary to the Director of the School of Civil Engineering.
LILLIAN H. LEHMANN, Secretary to the Director of the Sibley School of Mechanical Engineering.
LUCY B. PHILLIPS, Secretary to the Director of the School of Chemical and Metallurgical Engineering.
ELEANOR D. GEISSLER, Secretary to the Director of the School of Electrical Engineering.
KATHERINE HANDLEN, Secretary of the Electrical Engineering School.
ALICE ANTHONY, Secretary to the Director of the Graduate School of Aeronautical Engineering.
MARTHA C. HENNESSEY, Secretary to the Director of the Department of Engineering Physics.

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SOLOMON CADY HOLLISTER, B.S., C.E., D.Eng., Dean of the College.
J. PAUL LEINROTH, M.E., Representative of Cornell Society of Engineers.
OLIVER ELLSWORTH BUCKLEY, B.S., Ph.D., Sc.D., President Bell Telephone Laboratories.
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JAMES WENTWORTH PARKER, M.E., Vice-President, The Detroit Edison Company.
COLONEL FREDERICK WILLIAM SCHEIDENHELM, A.B., C.E., Consulting Engineer.
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JOHN CROSIER WILSON, M.E., The Cutler Hammer Mfg. Co.

COUNCIL OF THE ENGINEERING EXPERIMENT STATION

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W. JULIAN KING, M.E., in Charge of Research in Mechanical Engineering.
CHARLES RUSSEL BURROWS, B.S.E. (in E.E.), A.M., E.E., Ph.D., in Charge of Research in Electrical Engineering.
FRED HOFFMAN RHODES, A.B., Ph.D., in Charge of Research in Chemical Engineering and Metallurgical Engineering.
WILLIAM R. SEARS, B.Aero.E., Ph.D., in Charge of Research in Aeronautical Engineering.
LLOYD P. SMITH, B.S. in E.E., Ph.D., in Charge of Research in Engineering Physics.

School of Civil Engineering

THE COURSES OF STUDY

The courses of study offered by the School of Civil Engineering lead to the degrees of Bachelor of Civil Engineering and Bachelor of Science in Civil Engineering. The courses are all planned to provide fundamental instruction for the practice of the profession.

The degree of Bachelor of Civil Engineering is granted to those who successfully complete the five years' work covered by the ten-term curriculum or who having been registered previous to September 1946 successfully complete the eight-term curriculum. The degree of Bachelor of Science in Civil Engineering is granted to those students who having been V–12 or NROTC students, complete the outline covered by the Navy V–12 program or its equivalent or veterans who follow the eight-term curriculum after registration September 1, 1946, or February 1947. Information on the V–12 program may be obtained from the director.

In normal times, special options in Administrative Engineering, Sanitary Engineering, Structural Engineering, Hydraulic Engineering, Transportation Engineering, Geodetic Engineering are offered. Owing, however, to the necessity of giving practically all required courses every term, it is not possible for students to take such options. Faculty action has placed all options in abeyance. Thus, until this School resumes normal operations, electives will be selected from a comparatively few specialized courses. Lists of courses that can be used as electives will be issued at the end of each term and prior to new registration.

The junior inspection trip will be held in the spring term, and the summer survey camp, replaced by special work on the campus during the emergency, will be resumed in 1947.

EQUIPMENT

The principal building occupied by the School of Civil Engineering is Lincoln Hall, containing classrooms, drafting rooms, laboratories, and the working library. The library facilities include the Kuichling Memorial Library donated and endowed by Mrs. Sarah L. Kuichling

in memory of Emil Kuichling, A.B., C.E. The Irving Porter Church Fund, donated by former students of the school, aids in purchasing books.

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.

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 Laboratory of Applied Elasticity, equipped for experimentation by advanced students; the Sanitary Laboratory, with facilities for physical, chemical, bacteriological, and biological analyses of water and sewage; and the Soil Mechanics Laboratory, with all the facilities for performing standard tests on soil. Further investigations in soil mechanics may be carried on cooperatively by the School staff and the Army Engineers in another laboratory housed in a separate building constructed on the Campus by the Federal Government.

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 an average of 65 per cent or better, with at least half the credit hours with marks of 70 per cent or better, may be dropped from the University or placed on probation.

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

REGULAR COURSE

All students entering fall 1947 and thereafter

			CONTACT HOURS	
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 101 or 105, General Inorganic Chemistry	3	3	2½
	English 111, Reading and Writing	3	3	0
	Engineering 2001, Drawing	3	0	7½
	Engineering 2101, 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 102 or 106, General Inorganic Chemistry	3	3	2½
	English 112, Reading and Writing	3	3	0
	Engineering 2002, Drawing	3	0	7½
	Engineering 2102, Surveying	3	3	0
	Total	18		

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

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	History 165, Science in Western Civilization	3	3	0
	Engineering 2601, Route Surveying (or Construction Methods 2901)	3	1	5
	Geology 113, Engineering Geology (or Drawing 2003)	3	2	5
	Engineering 1131, Mechanics	3	3	0
	Total	18		
TERM 4	Physics 118, Electricity, Magnetism, and Light	3	3	2½
	History 166, Science in Western Civilization	3	3	0
	Engineering 2901, Construction Methods (or Route Surveying 2601)	3	3	0
	Engineering 1132, Mechanics	3	2	2½
	Engineering 1133, Mechanics	3	2	2½
	Engineering 2003, Drawing (or Geology 113)	3	0	7½
	Total	18		

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

	Engineering 2103, Summer Survey Camp	5		
TERM 5	Engineering 1134, Mechanics	3	2	2½
	Engineering 1211, Materials	3	3	0
	Engineering 2301, Fluid Mechanics	3	3	0
	Engineering 2401, Applied Hydrology (or Accounting 3231)	2	2	0
	Engineering 3241, Statistics (or Accounting 3231)	2	2	2½
	Economics 107, Introduction to Economics (or Public Speaking 101)	3	3	0
	Engineering 2501, Sanitary Engineering	3	3	0
	Total	19		
TERM 6	Engineering 2721, Mathematics	3	3	0
	Engineering 1212, Materials	3	0	5
	Engineering 2701, Stress Analysis	3	2	2½
	Engineering 2302, Hydraulics	3	2	2½
	Public Speaking 101 (or Economics 107)	3	3	0
	Engineering 3231, Accounting (or 2401 and 3241)	3	2	2½
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 7	Engineering 2702, Structural Design	3	0	7½
	Engineering 1213, Materials (or 2725)	3	3	0
	Engineering 2715, Concrete Construction (or 2903)	3	0	6
	Engineering 2703, Timber Design	2	0	5
	Engineering 2612, Transportation (or 2503)	3	3	0
	Engineering 2502, Water Supply and Treatment (or 2902)	3	2	2½
	Total	17		
TERM 8	Engineering 2725, Soil Mechanics (or 1213)	3	2	2½
	Engineering 2610, Highway Engineering	3	2	2½
	Engineering 2503, Sewerage and Sewage Treatment (or 2612)	3	2	2½
	Engineering 2902, Engineering Law (or 2502)	3	3	0
	Engineering 2903, Economics of Engineering (or 2715)	3	3	0
	Electives	3		
	Total	18		
TERM 9	Engineering 2704, Advanced Stress Analysis (or 2904)	3	3	0
	Engineering 4920, Electrical Equipment	3	2	3
	Engineering 2611, Highway Engineering	3	3	0
	Engineering 2720, Foundations (or 2402)	3	3	0
	Economics 201, Money and Banking (or 401)	3	3	0
	Electives	3		
	Total	18		
TERM 10	Engineering 3543, Heat-Power Engineering	3	2	2½
	Engineering 2402, Hydraulic Engineering (or 2720)	3	3	0
	Economics 401, Labor Conditions and Problems (or 201)	3	3	0
	Engineering 2904, Public Administration (or 2704)	3	3	0
	Electives	6		
	Total	18		

Total—185 hours, including camp

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

For those students who commenced their curricula prior to fall term 1946

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
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	19		
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	17		

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 (or English 111)	3	1	5
	Total	18		
TERM 4	English 111, Reading and Writing (or Surveying 2601)	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.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Engineering 2152, Surveying (or Concrete Construction 2715)	3	1	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	17		
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 ..... 141 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 different kinds of stress and heat treatment; 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 experience in engineering practice in the fields of Mechanical Engineering and Administrative Engineering as can be well 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.

Based upon the fundamental instruction given in the first two terms in mathematics, physics, chemistry, drawing, and materials processing, and that given in the next two terms in advanced physics, mechanics of engineering, advanced applied mathematics, materials of construction, kinematics, drawing, materials processing, machine construction, and industrial organization and management, the student in the fifth and sixth terms receives training in fluid mechanics (including hydraulics), machine design, economic organization, industrial accounting and cost finding, heat-power engineering, electrical engineering, and the testing of engineering materials. In the final terms, the student receives training in steam power-plant engineering, internal combustion engines, refrigeration and air conditioning, and mechanical engineering laboratory practice; also provision is normally made for some degree of specialization in one of the recognized fields of mechanical engineering.

To provide for this specialization, selected groups of courses, designated as Options, have been offered in the past in Power Plant Engineering, Heat Engineering (including fluid flow, heat transmission, refrigeration, and air-conditioning engineering), Industrial Engineering, Automotive Engineering, Aeronautical Engineering, Advanced Mechanics of Engineering, Metallurgical Engineering, Mechanical

Engineering Design, or in other fields allied to Mechanical Engineering; also opportunity was afforded to elect various other courses of an advanced nature. Under present circumstances, however, it is necessary to discontinue temporarily these Options, as such, although many of the courses in them are still available for election. As soon as conditions permit, the Options will be re-established; thus it is hoped that new matriculates and present lowerclassmen will find them again available when they are ready to take them.

The student in Administrative Engineering, in the field of Mechanical Engineering, pursues a curriculum which is basically one in Mechanical Engineering, but modified sufficiently to permit the incorporation of courses relating to business and industrial management.

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, automotive engineers, design engineers, fuel and combustion 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 an average of 65 per cent or better, with at least half the credit hours with marks of 70 per cent or better, may be dropped from the University or placed on probation.

CURRICULA

A former undergraduate student of Sibley School returning from war service to renew his studies may continue in his original four-year curriculum in Mechanical or Administrative Engineering, with such minor modifications as become necessary. Beginning with the fall of 1947 all new students will follow the five-year program.

FIVE-YEAR CURRICULUM IN MECHANICAL ENGINEERING (B.M.E.)

The 5-year curriculum in Mechanical Engineering is arranged to provide not only stronger technical instruction than is contained in the usual 4-year curriculum, but also to include additional training to develop leadership in this field. Accordingly, supplementing the technical courses, instruction is given in subjects related to management. Also because of the flexibility of the program, the student has an opportunity to elect other courses, liberal or otherwise, and to undertake some specialization of particular interest to him.

In his last year, the student will undertake an option consisting of a combination of advanced courses and a project in a technical, managerial, or related field for the purpose of applying to one or more broad 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.

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

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	English 111, Reading and Writing	3	3	0
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	3	3
	Engineering 3111, Drawing and Descriptive Geometry	3	1	5
	Engineering 6110, Casting Processes (or Pattern Shop 3401 and Machine Tools 3403)	2	1	2½
	Total	17		
TERM 2	English 112, Reading and Writing	3	3	0
	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
	Engineering 3112, Mechanical Drafting	3	1	5
	Engineering 3401, Pattern Shop ... or Casting Processes 6110	1	0	2½
	Engineering 3403, Fundamentals of Machine Tools ... or Casting Processes 6110	1	0	2½
	Total	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.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
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
	History 165, Science in Western Civilization	3	3	0
	Engineering 3235, Corporate and Industrial Organization (or Machine Tools 3404 and Gage Lab. 3405)	3	3	0
	Psychology 440 (or Economics 107)	3	3	0
	Public Speaking 105 (either third or fourth term)	2	2	0
	Total	19		
TERM 4	Engineering 1151, Mechanics	3	3	0
	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Introduction to Physical Chemistry	2	2	0
	History 166, Science in Western Civilization	3	3	0
	Engineering 3404, Production Machine Tools or Industrial Organization	2	0	5
	Engineering 3405, Gage Laboratory 3235	1	0	2½
	Economics 107, Introduction to Economics (or Psychology 440)	3	3	0
	Total	17		

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

TERM 5	Engineering 1152, Mechanics and Strength of Materials	3	3	0
	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3351, Kinematics	3	2	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 3250, Industrial Accounting and Cost Control	4	2	5
	Engineering 2331, Fluid Mechanics (or applied Mathematics 1155)	3	2	2½
	Total	19		
TERM 6	Engineering 1153, Mechanics and Strength of Materials	3	3	0
	Engineering 1222, Engineering Materials	3	3	0
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 1155, Applied Mathematics (or Fluid Mechanics 2331)	3	3	0
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 7	Engineering 1154, Advanced Mechanics and Strength of Materials	3	3	0
	Engineering 3353, Machine Design	3	3	0
	Engineering 1232, Engineering Materials Laboratory	3	1	2½
	Engineering 3535, Heat-Power Engineering	3	3	0
	Engineering 6113, Materials Processing	3	2	2½
	Engineering 4933, Electrical Engineering	3	2	2½
	Total	18		
TERM 8	Engineering 3354, Machine Design	3	1	5
	Engineering 3536, Heat-Power Engineering	3	3	0
	Engineering 3601, Mechanical Laboratory	3	0	5
	Engineering 4934, Electrical Engineering	3	2	2½
	Engineering 3261, Industrial Engineering	3	1	5
	Law (or Elective)	3	3	0
	Total	18		
TERM 9	Engineering 3581, Internal Combustion Engines	3	3	0
	Engineering 3602, Mechanical Engineering Laboratory	3	0	5
	Project (see pages 37, 38)	3		
	Courses related to project	3		
	Elective courses (or Law)	6		
	Total	18		
TERM 10	Engineering 3582, Steam Power Plants	3	3	0
	Engineering, 3603, Mechanical Engineering Laboratory	3	0	5
	Project (see pages 37, 38)	3		
	Courses related to project	3		
	Elective courses	6		
	Non-Resident Lecture	1		
	Total	19		
	Grand total for 10 terms	180		

FIFTH-YEAR PROJECTS

In his last year, the student will undertake an option consisting of a combination of advanced courses and a project in technical, managerial, or related field for the purpose of applying to one or more broad 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.

The choice of projects may be made by the student, subject to the advice and approval of his adviser and to the availability of necessary facilities and staff for its supervision; or if the student has no choice, he may be assigned a project. In order to acquire before the fifth year the preparation needed for some types of projects, it may be necessary to postpone until later terms some courses indicated by asterisks (*) in the outline of the curriculum and to substitute a sequence of preparatory courses; however, the adjustments of the program are to be subject to the advice and approval of the student's adviser.

INDUSTRIAL & ENGINEERING ADMINISTRATION OPTION

The elective hours available in the five-year curriculum will permit a student to select an option in the field of industrial and engineering administration. For the student who is interested in this area of study an integrated program of basic courses including Industrial Statistics, Labor Relations, Production Engineering, Industrial Marketing, Production Management, Methods Engineering, and Standard Costs is available. Having completed his basic work, the student will elect six hours of work related to his major interest, such as production, quality control for inspection, accounting, sales management, personnel, labor relations, industrial design, or teaching. The combination of basic courses and elective courses in a specialized field will be followed by a 6-hour project course in his last term. The project course will serve as a capstone to integrate all the training he has had in the previous nine terms.

In order to develop the proper sequence of course material, the student interested in this field must take his choice at the beginning of his third year. This will permit him to take all the work in proper order. In those cases where a specialized interest has been definitely established, some modification in the basic courses may be made to permit the student to take those courses which more completely meet his needs. This allows the student some latitude in the selection of

his courses under the guidance of the faculty so as to obtain from the various courses offered throughout the University a coordinated program of study in his chosen field.

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

War veterans who matriculated as freshmen prior to the fall of 1947 and who do not wish to conform to the five-year curriculum, may pursue the following four-year program, the successful completion of which leads to the degree of Bachelor of Mechanical Engineering.

			CONTACT HOURS	
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Same as Term 1 of the 5-year curriculum (page 35)			
TERM 2	Same as Term 2 of the 5-year curriculum (page 35)			
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	3	3	0
	Physics 118, Physical Electronics and Optics	3	3	2½
	Chemistry 402, Introduction to Physical Chemistry	2	2	0
	Engineering 3351, Kinematics	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		
TERM 5	Engineering 1152, Mechanics and Strength of Materials	3	3	0
	Engineering 3535, Heat-Power Engineering	3	3	0
	Engineering 1221, Engineering Materials, Lecture: Recitation	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	2	2½
	Electives	2		
	Total	20		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP
TERM 6	Engineering 1153, Mechanics and Strength of Materials	3	3	0
	Engineering 3536 Heat-Power Engineering	3	3	0
	Engineering 1222, Engineering Materials, Lecture: Recitation	3	3	0
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 1155, Applied Mathematics (either term)	3	3	0
	Electives	1		
	Total	19		
TERM 7	Engineering 1154, Advanced Mechanics and Strength of Materials	3	3	0
	Engineering 3353, Machine Design	3	3	0
	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	2½
	Total	18		
TERM 8	Engineering 3354, Machine Design	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, Materials Processing	3	2	2½
	Engineering 4934, Electrical Engineering	3	2	2½
	Total	18		
	Grand total for eight terms	146		

School of Electrical Engineering

EQUIPMENT

The School of Electrical Engineering occupies the greater portion of Franklin Hall, the second floor of Rand Hall, and the High-Voltage Research Laboratory. 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 High-Voltage Research Laboratory provides excellent facilities for demonstrations, tests, and research on insulators of all types and on high-voltage transmission lines, switchgear, transformers, and other apparatus. These facilities, which electrical manufacturers and public utilities find suitable for the testing of their equipment, are available for undergraduate and graduate instruction and research.

THE CURRICULUM

The curriculum leading to the degree of Bachelor of Electrical Engineering has recently been extended from four years to five years in order to permit restoration of a reasonable and desirable amount of non-technical and elective study which the pressure of expanding technical requirements had nearly eliminated. A considerable amount of managerial study previously offered in the curriculum leading to a degree in administrative engineering is now included.

The curriculum 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 popular specialties such as radar, television, radio, servomechanisms, or lightning phenomena which often initiate the student's interest in electrical engineering.

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 opportunities 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.

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 Engineering 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 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 70 per cent may be dropped or placed on probation.

FOUR-YEAR CURRICULUM

During the years of transition to the five-year curriculum, provision is being made whereby a student who matriculated when the four-year curriculum was in effect may follow the four-year curriculum to graduation, provided that the student is in a position to be graduated not later than June, 1950.

FIVE-YEAR CURRICULUM

Beginning in September, 1947, a student entering the College of Engineering without matriculation at Cornell or elsewhere prior to February, 1947, will follow a five-year curriculum. The curriculum leading to the degree of Bachelor of Electrical Engineering (B.E.E.) is outlined on pages 45–50. Before a student completes his seventh term, he should, in consultation with his Class Adviser, elect one of the six options.

Courses designated by four-digit numbers are offered by the College of Engineering. The first digit indicates the school or department offering that course, according to the following code:

1. General Engineering
2. Civil Engineering
3. Mechanical Engineering
4. Electrical Engineering
5. Chemical Engineering
6. Metallurgical Engineering
7. Aeronautical Engineering

Courses required in the curriculum but offered outside the College of Engineering are described on pages 129–138.

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, Metal Working and Casting	2	0	6
	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	Physics 118, Electricity, Magnetism, and Light	3	3	3
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1125, Mechanics	3	3	0
	Engineering, 3231 Accounting	3	2	3
	Engineering 4031, Engineering Mathematics	3	3	0
	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.

TERM 5	Engineering 1223, Engineering Materials	3	3	0
	Engineering 1226, 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, Survey of Psychology	3	3	0
	Total	19		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 6	Engineering 1127, Strength 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 201, Differential Equations	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	2	2	0
	Engineering 3532, Heat Power	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 50)	6		
	Total	18		
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 50)	9		
	Total	19		
	Grand total for 10 terms	180 hours		
	(not including Military Science and Tactics and Physical Training)			

POWER GENERATION AND DISTRIBUTION OPTION

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Engineering 3531, Heat Power	2	2	0
	Engineering 3532, Heat Power	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 50)	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 50)	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	2	2	0
	Engineering 3532, Heat Power	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		
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 50)	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 4492, Project	4		
	Option Electives	3		
	Electives (See page 50)	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	2	2	0
	Engineering 3532, Heat Power	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 50)	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	3		
	Electives (See page 50)	9		
	Total	18		

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

ILLUMINATION OPTION

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Engineering 3531, Heat Power	2	2	0
	Engineering 3532, Heat Power	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 50)	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 50)	9		
	Total	18		

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

PHYSICS OPTION

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Engineering 3531, Heat Power	2	2	0
	Engineering 3532, Heat Power	1	0	3
	Physics 210, Advanced Physics Laboratory	3	1	6
	Option Electives (See page 50)	3		
	Electives (See page 50)	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 50)	6		
	Electives (See page 50)	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 50)	4		
	Electives (See page 50)	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
Architecture
Astronomy
Biology
Botany
Dramatics
Economics
English
Fine Arts
Floriculture
Geology
Government
History
Language
Landscape Architecture
Meteorology
Music
Ornithology
Philosophy
Psychology
Sociology
Speech
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 106–120. 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

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.)

		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		

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

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	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 4031, Engineering Mathematics	3	3	0
	Engineering 4111, Basic Electrical Engineering	4	3	3
	Total	18		
TERM 5	Mathematics 201, Differential Equations	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*	2	2	0
	Engineering 3532, Heat Power*	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 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 50)	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*	2	2	0
	Engineering 3532, Heat Power*	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 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	2	2	0
	Engineering 3532, Heat Power	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	9		

		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 metal-

lurgical 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 pages 57, 58.)

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 engineering 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.)

			CONTACT HOURS	
		CREDIT HOURS	LEC. & REC.	LAB. & COMP.
TERM 1	Chemistry 111, Introductory Inorganic Chemistry	3	3	0
	Chemistry 115, Inorganic Chemistry Laboratory	3	1	5
	Mechanics 115, General Physics	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	Mathematics 201, Differential Equations	3	3	0
	Chemistry 308, Introductory Inorganic Chemistry	3	3	0
	Chemistry 312, Organic Chemistry Laboratory	3	0	7
	Engineering 5501, Chem. Eng. Stoichiometry	2	2	0
	Engineering 1125, 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 1126, 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 1127, 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 1231, Materials Testing Laboratory	3	1	3
	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Electives	3	–	–
	or			
	History 165, Science in Western Civilization	–	–	–
		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	–	–
	History 166 or (Elective) Science in Western Civilization	3	3	–
		19		
TERM 9	Engineering 4951, Electrical	4	3	3
	Engineering 5603, Chemical Equipment Design	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 or (Elective), Chemical Engineering Economics	3	2	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 Design	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 6110, Casting, Working, and Welding of Metals	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, 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.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
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
	Chemistry 220, Introductory Quantitative Analysis	3	3	0
	Chemistry 222, Quantitative Analysis Laboratory	3	0	7
	General Physics 117, Electricity and Magnetism	3	2	3
		18		
TERM 4	Mathematics 201, Differential Equations	3	3	0
	General Physics 118, Physical Electronics and Optics	3	2	3
	Engineering 1125, Mechanics	3	3	0
	History 166, Science in Western Civilization	3	3	0
	Minerals and Ores	2	2	0
	Economics 107, Introduction to Economics	3	3	0
	Public Speaking 101	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 1126, 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 1127, Strength of Materials	3	3	0
	Engineering 6811, Introductory Metallography	3	1	5
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Engineering 1256, Materials of Construction	3	0	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 of Metallurgy	3	1	2½
	Engineering 6302, Slag-Metal-Atmosphere Reactions	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 of Metallurgy	2	1	2½
	Engineering 3253, 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 Inspection	1	0	0
		20		
TERM 9	Engineering 6323, 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, Non-Ferrous Metallurgy	3	3	0
	Engineering 69 4, 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.

A special group of technical electives will be available, when needed, for some specialized work related to the foundry industry. These electives will include Foundry Metallurgy, Foundry Technology, Foundry Design and Layout, and Advanced Radiography. Courses in Welding Metallurgy, Powder Metallurgy, X-Ray Diffraction, and Electro-Metallurgy will be available.

Technical electives available in the Departments of Chemistry, Physics, and Engineering Physics include courses in crystallography, phase rule, theory of solids, physics of metals, applied electrochemistry, and atomic and molecular physics.

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 more scientific aspects of aeronautics. This training is intended especially to prepare the students to carry out research and development engineering of high quality 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. Throughout 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.

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 15 credit-hours a term. Required courses are indicated by an asterisk (*).

It should also be noted that the schedule is planned so that, at the end of the first year of graduate study, the student has completed an aeronautical curriculum that should qualify him for an engineering position in the aeronautical or related industries. It is anticipated that, should a student find it impossible to complete the second year of graduate study – for financial or other reasons – he could nevertheless be recommended for such an industrial position.

FIRST YEAR OF GRADUATE STUDY

FIRST TERM	CREDIT HOURS
Mathematics 611, Higher Calculus for Engineers and Physicists	3
* or	
Mathematics 621, Mathematical Methods in Physics	(3)
Engineering 7101, *Airplane Mechanics	4
Engineering 7201, *Gasdynamics	(3)
Engineering 7401, *Airplane Structures	3
Engineering 7403, *Airplane Design	1
Engineering 7901, Aeronautical Engineering Colloquium	1
	15

SECOND TERM	
Mathematics 612, Higher Calculus for Engineers and Physicists	3
* or	
Mathematics 622, Mathematical Methods in Physics	(3)
Engineering 7102, Airplane Mechanics	4
* or	
Engineering 7203, Aerodynamics of Power Plants	(3)
Engineering 7202, *Gasdynamics	3
Engineering 7402, *Airplane Structures	3
Engineering 7404, *Airplane Design	1
Engineering 7901, Aeronautical Engineering Colloquium	1
	15

*Required for the degree M.Aero.E.

SECOND YEAR OF GRADUATE STUDY

THIRD TERM	CREDIT HOURS
Engineering 1163, Applied Elasticity	3
* or	
Engineering 1162, Mechanics of Vibration	(3)
Engineering 7301, *Theoretical Aerodynamics I	3
Engineering 7203, Aerodynamics of Power Plants	3
or	
Approved Elective	(3)
Engineering 7303, *Theoretical Aerodynamics III	3
Engineering 7901, Aeronautical Engineering Colloquium	1
Engineering 7801, *Research in Aeronautical Engineering	3†
	16

*Required for the degree M.Aero.E.

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

FOURTH TERM	CREDIT HOURS
Engineering 1164, Applied Elasticity	3
* or	
Engineering 1165, Theory of Elastic Stability	(3)
Engineering 7302, *Theoretical Aerodynamics II	4
Engineering 7304, Theoretical Aerodynamics IV	3
or	
Engineering 7405, Aero-Elastic Problems	(3)
Engineering 7901, Aeronautical Engineering Colloquium	1
Engineering 7801, *Research in Aeronautical Engineering	5†
	16

*Required for the degree M.Aero.E.

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

B. Courses Leading to the Degree Ph.D.

Students will 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 Airplane Mechanics
Mathematics 611, 612 Higher Calculus for Engineers and Physicists
or
Mathematics 621, 622 Mathematical Methods in Physics
Engineering 7201, 7202 Gasdynamics

Engineering	7401, 7402	Airplane Structures
Engineering	7403, 7404	Airplane Design
Engineering	1163, 1164	Applied Elasticity
Engineering	1162	Mechanics of Vibration
Engineering	1165	Theory of Elastic Stability

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 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	1112, 1113	Strength of Materials
Engineering	1161	Advanced Engineering Mathematics
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, 17 hours of technical electives are provided which may be selected, with the permission of the student's adviser, from the following subjects: Physics, Mathematics, Chemistry, Physical Metallurgy, Advanced Mechanics and Elasticity, Fluid Mechanics, Aerodynamics, Ultra-high frequency. In addition to this, there are alternatives in mathematics, physics, and engineering, provided in the course schedule. The choice in these alternatives 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 15 hours required and 15 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,
(2) 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.

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
	Metal Processing 6110	2	1	2½
		19		

*See note.

TERM 4	Mathematics 201, Elementary Differential Equations	3	3	0
	Physics 118, Electricity, Magnetism, and Light	3	3	2½
	Chemistry 402	2	2	0
	Strength of Materials 1122	3	3	0
	Physical Mechanics and Properties of Matter	3	3	0
	Electric and Magnetic Circuits (Modified) 4111	3	3	2½
		17		

In addition to these courses, freshmen 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
	Electric and Magnetic Circuits (modified) 4112	3	3	2½
	Electric Circuit Laboratory 4116	3	1	3
	Engineering Materials 1221	3	3	0
	Thermodynamics and Kinetic Theory 8121	3	3	0
	Liberal Elective	3	3	0
		18		
TERM 6	Physics 226, Electricity and Magnetism	3	3	0
	Physics 242, Analytical Mechanics	3	3	0
	Mechanics of Vibrations 1162	3	3	0
	Engineering Materials 1222	3	3	0
	Thermodynamics and Kinetic Theory 8122	3	3	0
	Electronics 4121	3	3	0
		18		
TERM 7	Mathematics, Fourier Series and Transforms or Mathematics 501, Advanced Calculus	3	3	0
	Atomic Physics 243	3	3	0
	Engineering Materials 1231	3	1	2½
	Electrical Machinery	3		
	Electronics 4122	4	2	6
	Liberal Elective	3		
		19		
TERM 8	Physics 254, Electronic Properties of Matter	5	3	5
	Electrical Machinery	3		
	Radio and Communication Theory 4511 or Communication Networks 4513	3	2	3
	Mathematics 502, Advanced Calculus or Technical Elective	3	3	0
	Technical Electives	5		
		19		
TERM 9	Mathematics 621, Mathematical Methods or Mathematics 681, Differential Equations of Mathematical Physics	3	3	0
	Physics 215, Optics or Research Project	5	3	5
	English Composition	3	3	0
	Physics 380, Special Topics Laboratory	2	1	2½
	Technical Electives	6		
		19		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 10	Mathematics 622, Mathematical Methods			
	or	3	3	0
	Mathematics 682, Differential Equations of Mathematical Physics			
	Research Project	5		
	or			
	Physics 253, Wave Motion and Sound		3	5
	Technical Electives	6		
	Liberal Elective	3		
		17		

*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. General Engineering
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.

General Engineering

Courses described in this section are courses that fall outside the jurisdiction of any one of the schools of engineering, and courses given within certain schools that are basic to all branches of engineering.

MECHANICS OF ENGINEERING

IN CIVIL ENGINEERING, Messrs. ANTONI, CHENEY, and HOWELL.

IN MECHANICAL ENGINEERING, Messrs. CONWAY, CORNELL, GUNDER, MANSKY, and PERKINS.

1111. *THEORETICAL AND APPLIED MECHANICS.* Credit five hours. Five recitations a week. Prerequisites, Mathematics 162. Principles of Statics; forces and couples in a plane and in space; applications to structures and mechanisms. Principles of Dynamics; analysis of translational and rotational motion of particles and rigid bodies; velocity, acceleration, momentum, impulse, work and energy, with engineering applications.

1112. *STRENGTH OF MATERIALS.* Credit three hours. Prerequisite, course 1111. Stress, strain; strength and elastic properties of materials in tension, compression, and shearing; riveted joints; torsion of shafts; helical springs; shear, moment, safe loading, and deflection of simple beams; special beams; eccentric loads; columns; impact loads.

1113. *STRENGTH OF MATERIALS.* Credit two hours. Two recitations a week. A continuation of course 1112. Continuous beams; combined stresses; principal stresses; Mohr's circle of stress; theories of failure; thick-walled cylinders; curved bars; unsymmetrical bending.

1114. *APPLIED MATHEMATICS.* Credit three hours. Prerequisite, course 1111. Three recitations a week. Manipulation of data and reduction to empirical equations; elementary differential equations and applications to a variety of engineering problems, including free and forced vibration of the simpler mechanisms and structures.

1121. *STATICS AND STRENGTH OF MATERIALS.* Term 3. Three hours. Prerequisites, Mathematics 162, Physics 116. Three recitations a week. 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.* Term 4. Three hours. Prerequisites, 1121 and Physics 117. (A continuation of 1121.) Three recitations a week. Eccentric thrust in bars; buckling; continuous beams; combined stresses; principal stresses; theories of failure; thick-walled cylinders; curved bars; unsymmetrical bending; strain energy; Castigliano's theorem.

1125. *THEORETICAL AND APPLIED MECHANICS.* Credit three hours. Three recitations a week. Prerequisites, Mathematics 163. Statics in a plane and in space; dynamics of particles and rigid bodies; conditions of equilibrium of force systems, application to simple structures; friction; center of gravity; velocity and acceleration; Newtonian laws of motion; moments of inertia; translation and rotation of rigid bodies.

1126. *MECHANICS AND STRENGTH OF MATERIALS.* Credit three hours. Three recitations a week. Prerequisites, course 1125. General plane motion of rigid bodies; work and energy, linear and angular impulse and momentum, for particles and rigid bodies.

Analysis of stress and strain, statically indeterminate problems; riveted and welded joints; thin walled cylinders; combined stress; plane strain.

1127. *STRENGTH OF MATERIALS.* Credit three hours. Three recitations a week. Prerequisite, course 1126. Torsion, Shear and Moment Diagrams; Stress in beams; Deflections of beams by integration and area moment methods; Statically indetermi-

nate beams; Combination of direct stress, bending and torsion, Beams of two materials, Bending of curved bars, Columns; Strain Energy.

1131. *MECHANICS OF ENGINEERING—STATICS.* Required of all Civil Engineering students in the five-year curriculum. Credit three hours. Prerequisite, Mathematics 162. Statics of a material point and of rigid bodies and structures by algebraic and graphic methods of analysis, chains and cords, centers of gravity and moments of inertia. Three recitations a week. Textbook: *Analytical Mechanics for Engineers,* Seeley and Ensign.

1132. *MECHANICS OF ENGINEERING—DYNAMICS.* Required of all Civil Engineering students in the five-year curriculum. Credit three hours. Prerequisite 1131. Centrifugal and centripetal forces; dynamics of a particle and rigid bodies; pendulums; friction, work, and power; work and energy; impact, impulse, and momentum. Facility in the use of the slide rule is required. Two recitations and one computing period a week. Textbook: *Analytical Mechanics for Engineers,* Seeley and Ensign.

1133. *MECHANICS OF ENGINEERING—STRENGTH OF MATERIALS.* Required of all Civil Engineering students in the five-year curriculum. Credit three hours. Prerequisite, 1132. Mechanics of materials including stress and strain, tension, shearing, compression, torsion, flexure. Two recitations and one computing period a week. Textbook: *Mechanics of Materials,* George, Rettger, and Howell.

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

1136. *MECHANICS OF ENGINEERING.* Required of all Civil Engineering sophomores in the four-year curricula. Any term. Credit five hours. Prerequisite course, Mathematics 156. (See course 1137 below.) Statics of a material point and of rigid bodies and structures by algebraic and by graphic methods of analysis; chains and cords; centers of gravity; moments of inertia; kinetics and dynamics of a material particle; centrifugal and centripetal forces; dynamics of collections of material particles forming rigid bodies; pendulums; friction, work, power, measurement of power; the general theorem of work and energy applied to collections of rigid members forming machines; impact, impulse, and momentum. Emphasis is placed upon the theory as well as upon the use of consistent units and correct numerical work. Facility in the use of the slide rule is essential. Textbook: Seeley and Ensign, *Analytical Mechanics for Engineers.* Five recitations a week.

1137. *MECHANICS COMPUTATIONS.* Required of Civil Engineering sophomores in the four-year curricula. Any term. Credit one hour. To be taken with Course 1136. Devoted to the solution of problems related to the topics covered concurrently in Course 1136. One computation period of two and one-half hours a week under instruction.

1138. *MECHANICS OF ENGINEERING.* Required of Civil Engineering sophomores in the four-year curricula. Any term. Credit four hours. Continuation of Mechanics 1136. Prerequisite course, Mechanics 1136. Mechanics of materials including stress and strain, tension, sharing, compression, torsion, flexure; elastic curves; safe loads; columns; flexure of beams by semigraphic treatment. Review problems showing application of principles in Engineering Design. Textbook: George and Rettger, *Mechanics of Materials.* Four recitations a week.

1139. *MECHANICS COMPUTATIONS.* Required of Civil Engineering sophomores in the four-year curricula. Any term. Credit one hour. Courses 1138 and

1139 are closely correlated and should be taken concurrently. One 2½-hour period a week.

1140. *ADVANCED MECHANICS.* Elective. Seniors and graduates. Any term. Credit three hours. 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. Textbook: Seeley, *Advanced Mechanics of Materials.* Recitations, three hours a week.

1151. *MECHANICS.* Credit three hours. Prerequisites, Mathematics 163, Physics 117. Three recitations a week. The principles of statics and particle dynamics and their use in the solution of engineering problems of equilibrium and motion of machines and structures. Forces and couples in a plane and in space; friction; velocity and acceleration; particle motion under given forces.

1152. *MECHANICS AND STRENGTH OF MATERIALS.* Credit three hours. Prerequisite, course 1151. Three recitations a week. Dynamics of rigid bodies; motions of translation, rotation, and general motion, in two dimensions under given forces; impulse and momentum; work and energy. Stress and strain; tension, compression, and shear; analysis of riveted and welded joints; torsion of shafts; helical springs.

1153. *STRENGTH OF MATERIALS.* Credit three hours. Prerequisite, course 1152. Three recitations a week. Elementary theory of beams; bending moments and shear forces; deflections; combined tension or compression and bending; beams of non-uniform section; composite (including reinforced concrete) beams; buckling of compression members; elastic strain energy; stress due to sudden loading; beams on several supports; strain energy methods for the calculation of elastic deformations.

1154. *ADVANCED MECHANICS AND STRENGTH OF MATERIALS.* Credit three hours. Prerequisite, course 1153. Three recitations a week. General bending and twisting; bending of thick curved bars, principal stresses in two and three dimensions; theories of failure; stress in thick-walled cylinders.

Dynamics of jets, rockets, gyroscopes, and governors. Elements of dynamics in three dimensions.

1155. *APPLIED MATHEMATICS.* Credit three hours. Prerequisite, course 1111. Three recitations a week. The derivation and solution of ordinary differential equations arising in engineering problems of fluid flow, heat conduction, control mechanisms, jet propulsion, vibration in one degree of freedom.

1161. *ADVANCED ENGINEERING MATHEMATICS.* Elective for graduates and qualified undergraduates. Credit three hours. Prerequisite, 1114 or equivalent. Three recitations a week. An introduction to the mathematics used in the solution of advanced engineering problems. Partial differentiation; line and surface integrals, ordinary differential equations, power series solutions; Fourier series. Fourier integrals; partial differential equations.

1162. *MECHANICS OF VIBRATION.* Elective for graduates and qualified undergraduates. Credit three hours. 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.* Elective for graduates and qualified undergraduates. Continuing two terms. Credit three hours each term. General theorems of the elastic solid, reciprocal theorem, sudden loading; tension, flexure, and torsion of bars of arbitrary section; Castigliano's theorem with application to frames, rings loaded in and normal to plane, spiral and helical springs; stress in thick cylinders and discs due to pressure, heating, and rotation; beams on elastic foundations; symmetrical deformation of thin tubes; propagation of stress waves in bars; thermal stress; stress-analysis and deflection of plates and shells; vibration of beams.

1165. *THEORY OF ELASTIC STABILITY.* Elective for graduates and qualified undergraduates. Credit three hours. 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.

1166. *PHOTOELASTICITY.* Elective for graduates and qualified undergraduates. Credit two hours. One lecture and one laboratory-lecture period each week. Optics of photoelasticity; plane and circularly polarized light, monochromatic and white light, fringes, isochromatics and isoclinics; discussion of models, materials, and preparation. Elements of elasticity, including equilibrium and compatibility equations for plane stress, and stress functions; methods for determining principal stresses from photoelastic observations. In the laboratory, experiments on the calibration of color and fringe scales by tension, compression, and bending, are followed by tests on centrally loaded beams, the determination of stress concentration factors, and the separation of principal stresses.

1180. *SEMINAR IN APPLIED MECHANICS.* Elective for graduates (undergraduates by special permission). Credit, one hour each term. One discussion period each week. Current research papers in applied mechanics reported and discussed by members of the group.

MATERIALS OF CONSTRUCTION

IN CIVIL ENGINEERING. Mr. SCOFIELD.

ENGINEERING MATERIALS

MECHANICAL ENGINEERING. Messrs. EHRHART, JEFFREY, MOYNIHAN, OTTO, PURCELL, and YOUNG.

1211. *MATERIALS OF CONSTRUCTION.* Required of all third-year students in the five-year curriculum. Prerequisite courses, Mechanics 1133. Credit three hours. The materials studied are lime, cement, stone, brick, sand, timber, 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.

1212. *MATERIALS OF CONSTRUCTION.* Required of all third-year students in Civil Engineering in the five-year curriculum. Second term. Prerequisite courses, Mechanics 1134, and Materials 1211. Credit three hours. 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 observations; tests of concrete, concrete aggregate, plain concrete. One recitation and two laboratory periods a week.

1213. *MATERIALS OF CONSTRUCTION.* Required of all fourth-year students in Civil Engineering in the five-year curriculum. Either term. Credit three hours. Prerequisite courses, Mechanics 1134; Materials 1212; and must be taken with, or preceded by Structural Engineering Course 2715. More advanced tests of structural materials, with especial reference to stress and stress distribution in columns, beams, and slabs. Study of the effect of heat-treatment and welding is included. Two 2½-hour laboratory periods a week.

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. 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. Prerequisite, 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 1225. 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 observations; tests 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.

1227. *TESTING OF MATERIALS (LABORATORY).* Given especially for students in the College of Architecture. Any term. Credit one hour. A brief course in laboratory methods comprising tests of beams and columns in steel, wood, and concrete.

1231. *ENGINEERING MATERIALS LABORATORY—METALS AND ALLOYS.* Credit three hours. Prerequisites, 1221, 1222, 1153, but may be taken simultaneously with the latter course. A laboratory 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. Prerequisite, 1222 and 1231. A laboratory course dealing with materials testing and the properties, composition, selection and use of the following non-metallic materials: oils and lubricants, fuels (solid, liquid, and gaseous) and combustion, plastics, wood, cementing materials and concrete.

1251. *ENGINEERING MATERIALS RESEARCH.* Credit one hour for forty hours of work. Prerequisites, 1231, 1232. Open to a limited number of seniors and graduate students who have shown a proficiency in this field. Special problems and investigations are carried on under staff supervision.

1252. *APPLIED PHYSICAL METALLURGY.* Credit three hours. Elective. 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.* Any term. Credit variable. Open to graduate students by permission.

This course offers opportunity for individual research in the field of physical properties of engineering and applications 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 WINDING. 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.

1931, 1932. *ENGINEERING JOURNALISM.* Elective for Juniors 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. 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.

Civil Engineering

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

Astronomy 182. The Elements of Field Astronomy (p. 132)
Chemistry 101, 102, 105, 106. General Chemistry (p. 132)
Economics 107. Introduction to Economics (p. 135)
Economics 201. Money and Banking (p. 135)
Economics 401. Labor Conditions and Problems (p. 135)
English 111, 112. Reading and Writing (p. 135)
Geology 113. Engineering Geology (p. 135)
History 165, 166. Science in Western Civilization (p. 135)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (p. 136)
Physics 115. Mechanics (p. 136)
Physics 116. Wave Motion, Sound, and Heat (p. 136)
Physics 117. Electricity and Magnetism (p. 137)
Physics 118. Physical Electronics and Optics (p. 137)
Public Speaking 101 (p. 138)

Required courses in Mechanics and Materials of Construction given in the School of Civil Engineering are described on pages 75–78.

Courses in Regional and City Planning in cooperation with the College of Architecture are described on page 131.

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

DESCRIPTIVE GEOMETRY AND DRAWING

2001. *DRAWING.* Either 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," French. Messrs. JENKINS and others.

2002. *DRAWING.* Either term. Credit three hours. Prerequisite course 2001. In struction and drill in the fundamental conception of Descriptive Geometry, dealing with graphic solution of advanced space problems, both theoretical and practical. It is designed to develop the powers of visualization and analysis by the methods of revolution and auxiliary views. Problems involving the measurement of angles and distances are given consideration, after the use of exercises on the point, line, and plane. In addition, the course includes a study of intersections and the development

of surfaces, mining problems, graphic solutions of stresses, and other problems of a practical nature. Text: "Engineering Descriptive Geometry", Rowe. Messrs. JENKINS and others.

2003. *DRAWING.* Either term. Credit three hours. A continuation of courses 2001 and 2002. The objective of this course is to develop a more complete grasp of the principles of projection covered in the earlier courses, and to give further training in visualization. Emphasis is placed on sections, scale drawings, conventional signs, and pictorial representation. Practical civil engineering problems such as topographic mapping, structural drafting, and charts and graphs are included in the course. Messrs. JENKINS, THATCHER, 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.

2051. *DRAWING.* Second term in the four-year course. Credit three hours. Orthographic projection, sections, scale drawings, practical problems, tracing, blueprinting, conventional signs, topographic mapping, isometric drawing. Textbook: *Engineering Drawing,* French. Mr. JENKINS and assistants.

2052. *DRAWING.* Required of all sophomores in the four-year course in Civil Engineering. Fourth term. Credit two hours. Projections and intersections in practical problems; structural detailing and tracing; reading engineering drawings. Textbook: *Engineering Drawing,* French. Mr. JENKINS and assistants.

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 freshmen 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; elements 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 or 2151. 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.

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.

2243. *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.

THEORETICAL AND EXPERIMENTAL HYDRAULICS

2301. *ELEMENTARY FLUID MECHANICS.* Fifth term, five-year curriculum. Credit three hours. Prerequisite 1133. 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. REID, BOGEMA, and PRIEST.

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. Textbook: *Hydraulics,* Schoder and Dawson. Two recitations and one laboratory period a week. Messrs. REID, BOGEMA, PRIEST, and assistants.

2303. *ADVANCED HYDRAULICS.* Elective. Credit three hours. Prerequisite 2302. This course involves more detailed and extended theory and application than the first courses. Three lectures or 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, impulse wheel, reaction turbine selection and testing. 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. Messrs. REID, BOGEMA, and PRIEST.

2331. *FLUID MECHANICS.* Required for students in Mechanical and Electrical Engineering. Credit three hours. Either term. Prerequisite Mechanics 1151. Properties of fluids, gas laws, viscosity; static pressures, center of pressure on plane and curved surface; gages and manometers; buoyant force and equilibrium of floating and immersed bodies; dynamics of fluids, Bernoulli's theorem; impulse and momentum, open jets, vanes; flow in pipes, Reynolds' number, hydraulic gradient, divided flow; orifices, nozzles, weirs, and gates; open-channel flow; hydraulic similitude and dimensional analyses. Textbook: *Fluid Mechanics,* Cox and Germano. Two recitations and one laboratory period a week. Messrs. REID, BOGEMA, PRIEST, and WILLIS.

2342. *HYDRAULICS.* 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. REID, BOGEMA, and PRIEST.

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 1136 and 1138. 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; elementary power calculations in common pumping and fire protection problems; 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.

HYDRAULIC ENGINEERING

2401. *APPLIED HYDROLOGY.* Either term. Credit two hours. Prerequisite, course 2351. The term is devoted to the methods of making the preliminary investigations for a hydraulic development involving the use of a stream; general hydrology; water resources of a basin; methods of systematic stream gaging; stream characteristics; working up data; use of mass curves in storage studies; percolating waters; probably dependable draft, etc.; a study of the working conditions and fundamental data for designing conduits, distributing reservoirs. In the problems, applications of the text are made to particular localities, the topographic maps of drainage basins forming the bases of the problems. Students contemplating extensive election of courses in the hydraulics group should arrange to take this course the first term. Courses 2403, 2404, and 2405 are elaborations of details in this course. Textbooks: Turneaure & Russell, *Public Water Supplies;* Hoyt & Grover, *River Discharge.* Two recitations a week. Mr. DONLEY.

2402. *HYDRAULIC ENGINEERING.* Required in the five-year curriculum. Credit three hours. Prerequisite, 2401. An introductory course in Hydraulic Engineering. Three recitations a week. Mr. DONLEY.

2403. *HYDRAULIC CONSTRUCTION.* Elective for seniors and graduates. Second term. Credit three hours. This is a computing and designing course dealing with problems of water storage and the design and construction of dams by means of lengthy problems to be solved by graphical and analytical methods, and involving the economics of water storage at a given site; the design of a high masonry dam by Wegmann's Method and the tests for safety and stability of design, and the analysis of stresses and stability. Three design periods a week. Text: *Design of Dams.* Justin, Creager, and Hinds. Mr. DONLEY.

2404. *WATER POWER.* Elective. Seniors and graduates. Either term. Credit three hours. Prerequisites, courses 2401 and 2351, or the equivalent. The subject matter of the course covers the technique of hydraulic turbines, the analysis of test data, a study of the adaptation of turbine types to working conditions, unsteady flow and surging in long conduits, governing, and the analysis of the power available at a low head millsite. Textbook: Mead's *Water Power Engineering.* Three lectures and recitations a week and the working of three lengthy problems during the term. Mr. DONLEY.

2405. *HYDRAULIC ENGINEERING.* Elective. Seniors and graduates. First term. Credit three hours. The theory of percolating water; ground water development; recent developments in soil technology and the design and construction of earthen dams and levees; theory of design of gravity and arch masonry dams and distribution of stresses in such structures; spillway design; preparation of dam sites; construction methods and plants. Lectures, recitations, and abstracting of references. Mr. DONLEY.

2406. *CONSERVANCY AND RECLAMATION PROBLEMS.* Elective. Seniors and graduates. Any term. Credit three hours. Flood flow estimates; planning for and designing of flood protection structures, irrigation, and drainage works. Lectures, recitations, and abstracting of references. Mr. DONLEY.

2407. *WATER POWER AND PUMPING PLANTS.* Elective. Seniors and graduates. Second term. Credit three hours. This is a computing and designing course devoted to the problems of designing and detailing power and pumping plants. Prerequisites, courses 2401 and 2404. Mr. DONLEY.

2408. *HARBOR ENGINEERING.* Elective. Credit three hours. Study of wave action; currents, tides; shore protection, wharves, bulkhead, jetty design and construction; channel and revetment work; dredging and reclamation of land; cargo handling; transportation in dock areas; storage and warehouse facilities. Three recitations a week. Mr. DONLEY.

2441. *HYDRAULIC ENGINEERING DESIGN.* Any term. Prerequisite course 2351. For best results Hydraulic Engineering Design should be preceded by Course 2401 but the two may be taken concurrently. The purpose of the course is to go more into detail in selected phases of hydraulic engineering and is not to duplicate in large part work regularly given in the scheduled courses in hydraulic and structural engineering. Mr. DONLEY.

2443. *HYDRAULIC 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 hydraulic engineering field. Mr. DONLEY.

MUNICIPAL AND SANITARY ENGINEERING

2501. *SANITARY ENGINEERING.* Required of all students in the five-year curriculum. Credit three hours. Recitations and lectures. 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 bathnig beaches, domestic and industrial wastes, and to the interpretation of such examinations. Three recitations a week. Messrs. GIFFT and BOND.

2502. *WATER SUPPLY.* 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 and BOND.

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 and BOND.

2504. *SANITARY BIOLOGY.* Elective for Chemical Engineers and for juniors, seniors, and graduates in Civil Engineering. First term. Credit three hours. The course is designed to familiarize the student with the use of the microscope, preparation of media, bacteriological analyses of water, sewage, sewage effluents, and sewage sludge; the preparation and use of stains; disinfection of sewage and of swimming pools. Textbook: Buchanan's *Bacteriology.* One recitation and two laboratories a week. Mr. GIFFT.

2505. *SANITARY BIOLOGY.* Elective for Chemical Engineers and for juniors, seniors, and graduates in Civil Engineering. Second term. Credit two hours. The subject matter covered in the course includes the collection, identification, and control of the various forms of plant and animal life most prevalent in water supplies, and associated with sewage wastes and industrial waste-polluted streams. Consideration is given to the making of biological counts and to the use of biological forms of life as indices of pollution. Various references and texts are used in the course. One recitation or lecture and one laboratory a week.

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. Textbook: Metcalf and Eddy, *American Sewerage Practice, Vol. III, Disposal of Sewage.* Two recitations and one computation period a week. Mr. GIFFT.

2508. *TREATMENT OF 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 AND COMMUNITY SANITATION.* 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 two hours. A course dealing with general sanitation problems, primarily of rural areas such as trailer, construction, military, recreational and other camps, summer hotels, swimming pools and beaches, water and milk sheds. Lectures, reports, and recitations. Two 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. Testbooks: 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. Mr. GIFFT.

2512. *A LABORATORY COURSE FOR GRADUATES.* Hours to be arranged. A course devoted to some problem of water or sewage or trade waste, such as the operation of a water filtration plant, a sewage disposal plant, the detection, measurement, and treatment of trade wastes, the value of disinfection, etc. Mr. GIFFT.

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, trade 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.

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

2601. *ROUTE SURVEYING AND DRAWING.* Required of all Civil Engineering sophomores. Either term. Credit three hours. Prerequisite, Advanced Surveying 2102. 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 two field or drawing periods a week. Messrs. THATCHER, CRANDALL, PERRY, SPRY, and others.

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, 2601 and 2725. Design, construction, and maintenance of highways and city streets. Location, alignment, drainage, width, and capacity; soils and soil stabilization; earth, gravel, and macadam roads; city and rural pavements; grade separations; minor structures; construction in swamps; construction methods and equipment; traffic control; planning surveys, economics, financing, and administration. Two recitations and one computing period a week. Textbook: *Highway Design and Construction,* Bruce. Messrs. BELCHER and LEWIS.

2611. *HIGHWAY ENGINEERING.* Required of all seniors in the five-year curriculum. Credit three hours. Survey, sampling and testing of soils and aggregates; bituminous materials. Construction methods: Grading and paving; analysis and correction of characteristic pavement failures; rural and urban traffic problems. Limited access roads and freeways. Special structures and landscaping.

2612. *HIGHWAY LABORATORY.* Elective. Seniors and graduates. Either 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. *ADVANCED HIGHWAY LABORATORY.* Elective. Seniors and graduates. Either term. Credit three hours. Prerequisites, courses 2610 and 2611. 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. Mr. BELCHER.

2614. *ADVANCED HIGHWAY ENGINEERING.* Elective. Seniors and graduates. Second term. Credit three hours. The topics for assignment and discussion include the economics of highway engineering, highway finance, legislation, regulation, traffic, design, construction, and maintenance of highways, the latest research programs and reports, labor and plant organization for various kinds of highway contracts with especial emphasis on the economics of contracting, etc. This course is conducted as a seminar. Meetings are held once each week at hours to be arranged. Mr. BELCHER.

2615. *MODERN HIGHWAY PLANNING AND DESIGN.* Elective. Seniors and graduate students. Second term. Credit three hours. Prerequisite, course 2610 or its equivalent. Study of geographical, political, and economic divisions of communities with particular reference to highway transportation requirements; analysis of regional plans chiefly concerning the classification of roads and the selection of routes to be abandoned or improved, based upon their economic justification. Design of regional systems of highways, freeways, and parkways, including the consideration of

the economic, safety, and aesthetic aspects. Traffic studies, legislation, financing, and zoning. Design of intersections and grade separations. Problems and reports required. Mr. CLARKE.

2616. *CITY STREETS.* Elective. Seniors and graduate students. Credit two hours. Prerequisite 2610. The location and design of streets in cities and villages. One recitation and one long period a week. Mr. MALCOLM.

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. MALCOLM.

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 and 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. Design, construction, and maintenance of road mixes, plant mixes, etc. Messrs. MALCOLM and BELCHER.

2619. *BITUMINOUS PAVEMENTS.* Elective. Credit three hours. Prerequisite, 2610 and 2612. Part I: Properties of tars; base and liquid asphalts. Weathering and stripping of bituminous films; adhesion. Special uses and applications of individual materials. Part II: Theory and practice in design based on surface area, density, and loading and subgrade conditions. Part III: Design of surface treatment mixes, patches, sheet asphalt, bituminous concrete. Rock asphalt. Control and construction. Bituminous undersealing and maintenance. Mr. BELCHER.

2620. *TRAFFIC ENGINEERING.* Elective. Credit three hours. Prerequisite, 2610. City and highway traffic surveys. Traffic control and routing. Signs and markings. Regulation; truck and bus units as traffic elements. 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. 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.

2622. *ADVANCED ENGINEERING INTERPRETATION OF AERIAL PHOTOGRAPHS.* Elective. Credit three hours. Prerequisite, 2621. Engineering interpretation of aerial photographs with special emphasis on engineering construction problems in frozen ground (arctic), the analysis, mapping and estimating of tropical areas, and the special problems associated with arid regions. Particular emphasis is placed on the significance of vegetation in these three special climatic areas. Two recitations and one drawing room 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 materials and estimates of cost are usually required, also plant layouts and methods of executing work. Messrs. BELCHER and 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 2613. 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. *STRESS ANALYSIS.* Required of all students in the five-year curriculum. Credit three hours. Prerequisite: Course 1134. Fundamental principles of graphic statics applied to the analysis of beams and trusses. Analytical computation of stresses caused by dead load, moving live loads, impact, and wind load in the principal types of simple highway and railway truss bridges, and in girder bridges. Use of influence lines in the analysis of a three-hinged, spandrel-braced arch. Text: *Stresses in Simple Structures,* Urquhart and O'Rourke. Messrs. BURROWS, MAINS, ANTONI, and GILFOYLE.

2702. *STRUCTURAL DESIGN.* (Steel) Required of all students in Civil Engineering. Either term. Credit three hours. Prerequisite, course 2701. An elementary course in steel design. Principles of both riveted and welded connections. Complete designs and detail drawings of the steel skeleton of a small building, including trusses, and of a through plate girder bridge. Textbook: Grinter's *Design of Modern Steel Structures.* Three computation or drawing periods a week. Messrs. BURROWS and GILFOYLE.

2703. *TIMBER DESIGN.* Required of all students in the five-year curriculum. Credit two hours. Prerequisite 2701. Design of a timber roof truss of English type, using dimension timbers and framed joints. Design of a two-story industrial building; the second floor is of mill construction supported on interior and exterior columns, and the roof framing consists of flat-top trusses of the Pratt type with built-up members and timber-connector joints. Discussions of grading and preservation of timber. Text: *Modern Timber Design,* Hansen, and miscellaneous commercial data sheets. Two laboratory periods a week. Mr. BURROWS.

2704. *ADVANCED STRESS ANALYSIS.* Required of all Civil Engineering students in the five-year curriculum. Credit three hours. Prerequisites 2702 and 2715. Deflections of beams and statically indeterminate framed structures. Application of the principles of slope-deflection and moment distribution to the analysis of rigid

frames, including frames with sidesway and frames with members of varying cross section. Use of influence lines in the analysis of a two-hinged spandrel-braced arch. Text: *Analysis of Statically Indeterminate Structures,* Williams. Three recitations a week. Mr. MAINS.

2705. *ADVANCED STRUCTURAL ANALYSIS.* Elective for seniors and graduates and required of seniors in the Structural Engineering Options in Civil Engineering and of all graduate students majoring or minoring in structural engineering. Either term. Credit three hours. Prerequisite, course 2701. Stress analysis of continuous beams, framed bents, and rigid frames. Horizontal as well as vertical loading considered. Redundant structures including the braced two-hinged arch. Displacement diagrams for trusses and arches and analytical computation of deflections of such structures. Textbook: *Structural Theory,* Sutherland and Bowman. Three recitations a week. Mr. MAINS.

2706. *STEEL BUILDINGS.* Elective. Seniors and graduates. Any term. Credit three hours. Prerequisites, course 2702. This course comprises the design of the steel framework for buildings of the prevailing type used in power house or shop construction. Dead, snow, and wind stress diagrams are drawn for the roof trusses. Provision is made for an electric crane moving the full length of the building and the stresses in the frame work due to the movement of the crane are determined. The effect of the wind and the eccentric load due to the crane girder are considered in the design of the columns. Textbook: Ketchum's *Steel Mill Buildings.* Reports and drawings. Three two-hour periods a week. Mr. BURROWS.

2707. *BRIDGE DESIGN IN STEEL.* Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite, course 2702. Computations and drawings for the complete design of a railroad bridge of six or seven panels or a heavy highway bridge. The computations to determine the stresses and sections of all members, pins, pinplates, splices, deflection, camber, and other details as well as of connecting rivets are to be written up in the form of systematically arranged reports. The drawings consist of general detail plans showing the location of all rivets as well as the composition and relation of all members and connections. The final report is to give a full list of shapes and plates, and a classified analysis of weight for the span. Textbook: Johnson, Bryan & Turneaure, *Modern Framed Structures, Vol. III.* Computation and drawing, three two-hour periods a week. Mr. BURROWS.

2708. *INVESTIGATION OF EXISTING BRIDGES.* Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite, course 2702. Inspection of existing structures for the determination of sizes and conditions of plates and shapes. After full data have been obtained in the field, computations will be made to determine either the unit stresses under a specified load, or the safe load or rating according to standard specifications. Hours as assigned. Mr. BURROWS.

2709. *RIGID FRAMES.* Credit three hours. Prerequisite, 2705. Review of fundamental theorems and principles used in the solution of indeterminate structures. Comparative analyses of various types of ridged frames by different methods. Members of variable cross-section by column analogy and Newmark's method. Stresses in building and bridge frames. Secondary stresses in trusses. The Vierendeel truss. Use of influence lines for preliminary design studies and for determination of effects of temperature, shrinkage, rib shortening, and foundation settlement. Shear-distortion effects. Design problems in indeterminate structures. *Statically Indeterminate Structures,* Maugh. Mr. MAINS.

2710. *STRENGTH OF STRUCTURES.* Elective. Credit three hours. Prerequisite, 2705 (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, hysteressis, 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. Credit three hours. Prerequisite, 2710 and 2721. (2753 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. Credit three hours. Prerequisite, 2704 and 2721 or equivalent. Analysis and design of domes, tanks, reservoirs, bunkers, and bins in reinforced concrete (plain and prestressed) and steel. Methods of analysis include theory of plates and shells, advanced beam theory, hipped plate construction. Three recitations a week. Mr. WINTER.

2715. *CONCRETE CONSTRUCTION.* Required of all Civil Engineering students. Either term. Credit three hours. Prerequisite, 1134 or 1138. (Preferably taken concurrently with or preceded by course 1225.) Properties of plain concrete, elementary theory of reinforced concrete as applied to rectangular beams, slabs, T-beams, beams reinforced for compression, columns, and footings. Shear, diagonal tension, and direct stress combined with flexure. Computations in the forms of reports on the design of a typical beam and girder floor panel and of a retaining wall. Detail sketches of sections and reinforcement required. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures.* Six hours a week. Messrs. WINTER, GRISET, ANTONI, and MAINS.

2716. *REINFORCED CONCRETE DESIGN.* Elective for seniors and graduates. Either term. Credit three hours. Prerequisite, course 2715. Comparative design of retaining walls. Design of mutiple footings. Design of bins and tanks, flatslab construction both subsurface and on towers. Three two and one-half hour periods a week.

2717. *REINFORCED CONCRETE HIGHWAY BRIDGES.* Elective for seniors and graduates. Credit three hours. Prerequisite 2701 and 2715. Design of short span slab and girder bridges and their abutments. Theory of fixed and hinged arches. Influence lines. Effect of temperature, plastic flow, and its deformation. Design of reinforced concrete arch. Three two and one-half hour periods a week.

2719. *REINFORCED CONCRETE BUILDING DESIGN.* Elective. Seniors and graduates. Either term. Credit three hours. Prerequisites, course 2715. Design of a reinforced concrete flat-slab building and investigation of various other types of floor systems for commercial buildings. Complete detail design for one building, including stairway, elevator shafts, penthouses, etc. Working drawings and steel schedules. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures.* Seven and one-half hours a week.

2720. *FOUNDATIONS.* Required of all Civil Engineering juniors or seniors. Either term. Credit three hours. Prerequisite, course 2725. Subterranean explorations; application of soil mechanics to the determination of safe loads and of expected settlement. Piles and pile driving, including timber, concrete, tubular and sheet piles; cofferdams; box and open caissons, pneumatic caissons for bridges and buildings, caisson sinking, and physiological effects of compressed air; pier foundations in open wells; freezing process; hydraulic caissons; ordinary bridge piers; cylinders and pivot-piers; bridge abutments; spread footings for building foun-

dations; underpinning buildings. Textbook: Jacoby and Davis's *Foundations of Bridges and Buildings*. Recitations, collateral reading in engineering periodicals, and illustrated reports. Three hours a week. Messrs. WINTER and MAINS.

2721. *APPLIED ENGINEERING MATHEMATICS*. Credit three hours. Prerequisite, Mathematics 60c and Mechanics 1134. Elementary differential equations and applications to engineering problems in the Civil Engineering fields.

2723. *SUSPENSION BRIDGE THEORY*. Credit three hours. Prerequisites, 2704 and 2721 (or equivalent). The elastic theory; stresses in cables, moments and shears in stiffening trusses, temperature effects, and deflections. Fundamental principles of the deflection theory. Three recitations a week.

2725. *SOIL MECHANICS*. Required of all students in Civil Engineering. Either term. Credit three hours. Prerequisite, 1134 or 1138. A comprehensive study of the properties of soil, presenting a conception of its behavior as an engineering material. Theory of soil classification, soil structure, pressure distribution, compressibility, cohesion, elasticity, plasticity, and permeability. Laboratory tests for identification of soils; mechanical analysis, determination of water content, specific gravity, density, permeability, etc. Tests for physical properties of soils. Two lectures and one laboratory period a week. Mr. HOUGH.

2726. *APPLIED SOIL MECHANICS*. Elective for seniors and graduate students. Second term. Credit three hours. Prerequisite, course 2725. Advanced application of soil mechanics, based on the principles and physical studies of course 2725. The plastic flow theory; the consolidation theory; stability of earth slopes; flow of water through earth structures; theories of earth pressure on retaining walls, caissons, and tunnels. Review of modern soil mechanics research. Mr. HOUGH.

2731. *ELEMENTS OF STRUCTURAL ENGINEERING*. Elective. Seniors in Electrical Engineering. Any term. Credit two hours. Analysis and design of beams of steel, timber, and concrete, columns, footings, and retaining walls. Textbook: Urquhart & O'Rourke's *Elementary Structural Engineering*. One lecture and one computing period a week. Mr. ANTONI.

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 of steel, (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. BURROWS and others.

2742. *STRUCTURAL ENGINEERING RESEARCH*. Any term. Students wishing to pursue one particular branch of bridge 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. BURROWS, WINTER, MAINS, and others.

2743. *STRUCTURAL 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 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 maxi-

mum 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 ANTONI.

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 widge range of topics, is given out for solution. Computations and reports. Five hours a week. Messrs. HOWELL, ANTONI, and CHENEY.

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.

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): 0, 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 of Engineering, Materials Processing, Mechanics of Engineering, Mechanical Engineering Laboratory.

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

Chemistry 105, 106. General Chemistry (p. 132)
Chemistry 301. Introduction to Organic Chemistry (p. 134)
Chemistry 402. Introduction to Physical Chemistry (p. 134)
Economics 107. Introduction to Economics (p. 135)
English 111, 112. Introductory Course in Reading and Writing (p. 135)
History 165, 166. Science in Western Civilization (p. 135)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (p. 135)
Physics 115. Mechanics (p. 136)
Physics 116. Wave Motion, Sound, and Heat (p. 136)
Physics 117. Electricity and Magnetism (p. 137)
Physics 118. Physical Electronics and Optics (p. 137)
Psychology 440. Psychology for Engineering Students (p. 138)
Public Speaking 105 (p. 138)

Required courses in Mechanics of Engineering, Strength of Materials, and Engineering Materials are described on pages 74–79.

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 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.* Required of freshmen in Electrical and Mechanical Engineering. First term. Credit three hours. One recitation and two drawing periods a week. Studies in subject matter prerequisite to professional applications of Mechanical Drafting. Lettering, delineation, Mongean descriptive geometry and pictorial representation.

3112. *BASIC MECHANICAL DRAFTING.* Required of freshmen in Electrical and Mechanical Engineering. Second term. Credit three hours. 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.* Required of freshmen in Chemical Engineering. First term. Credit two hours. 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.* Required of freshmen in Chemical Engineering. Second term. Credit two hours. 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.* Elective. Credit two hours. 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.* Required of freshmen in Engineering Physics. First term. Credit two hours. Two drawing periods, including lectures, a week. Content similar to 3114.

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

3131. *MECHANICAL DRAFTING RESEARCH AND DEVELOPMENT.* Elective any term for limited number of qualified seniors and graduates. Credit to depend

upon hours of actual work. Special problems and investigations in the subject matter, tools, materials, and processes of Mechanical Drafting.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

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

3231. *PRINCIPLES OF INDUSTRIAL ACCOUNTING AND COST FINDING.* 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. 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. *CORPORATE AND INDUSTRIAL ORGANIZATION.* Credit three hours. Two lectures and one recitation 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.

3241. *ELEMENTARY INDUSTRIAL STATISTICS.* Credit three hours. Two recitations and one computing period a week. Required of students who elect the Industrial and Engineering Administration Option. The elementary technique of statistical analysis as applied to engineering and industrial problems.

3242. *STATISTICAL QUALITY CONTROL.* Credit three hours. 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 1947–1948.

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. Required of students who elect the Industrial and Engineering Administration Option. 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. Required of all students in Mechanical Engineering, except those who elect the Industrial and Engineering Administration Option. 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. Required of students who elect the Industrial and Engineering Administration option. 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. Prerequisite, 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 1947–1948.

3270. *INDUSTRIAL MARKETING.* Credit three hours. Three recitations a week. Prerequisites, 3235, 3250, 3241. Required of students who elect the Industrial and Engineering Administration Option. 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.

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. 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, HINKLE, MABIE, NOTHMANN, and ROGERS.

3325. *KINEMATICS, RECITATIONS.* Credit three hours. Prerequisite courses, Mechanical Drafting 3112, and Mathematics 162. Three recitations a week throughout the term on the theory of motion; the transmission of motion; the instant-center method of determining linear and angular velocities; cams; rolling curves and friction gearing; gears and gear cutting; linkwork and miscellaneous mechanisms; belt, rope, and chain drives; and trains of mechanism.

3326. *KINEMATICS, DRAWING.* Credit two hours. Must be taken with course 3325. Two drawing periods a week throughout the term devoted to drawingboard applications of the theory and principles of course 3325.

3327. *KINEMATICS, RECITATIONS.* Credit two hours. Prerequisite courses, Mechanical Drafting 3112, Mathematics 162. A study of linkages; cams; spur, bevel, helical, and worm gearing; intermittent motion; trains of mechanism.

3337. *MACHINE DESIGN, RECITATIONS.* Credit three hours. Prerequisite courses, 3325, 1222, 3423, and 1112. Three recitations a week throughout the term on the theoretical and practical applications of kinematics, materials, mechanics, and technology to the design of machines and machine elements with due regard to considerations as suitability of materials, safety, lubrication, construction, etc.

3338. *MACHINE DESIGN.* Credit two hours. Prerequisite course, 3337. Two design periods a week throughout the term. The student for the first time undertakes the design of machine parts and assemblies, and makes all the necessary calculations and drawings. Systematic calculations and such layout and detail drawings are made as are found necessary to complete each problem.

3351. *KINEMATICS.* Credit three hours. Two recitations and one design-room period a week. Prerequisite courses, Descriptive Geometry 3111, Mechanical Drafting 3112, Mathematics 162. A study of linkages; cams; spur, bevel, helical, and worm gearing; gear cutting; intermittent motion, and trains of mechanism.

3352. *DYNAMICS OF MACHINERY.* Credit three hours. Two recitations and one design-room period a week. Prerequisite courses, Kinematics 3351, and Mechanics 1151. Graphical and analytical treatment of velocities, accelerations, inertia forces, static forces, and total forces; turning-effort, pin-pressure diagrams, and balancing of engines, and critical speeds.

3353. *MACHINE DESIGN.* Credit three hours. Prerequisite courses, Strength of Materials 1153, Engineering Materials, Materials Processing, Dynamics of Machinery 3352. Three recitation periods a week throughout the term on the theoretical con-

siderations and practical applications of kinematics, materials, mechanics and mechanical processes to the design of machines with due regard to selection of materials, construction, lubrication, safety, and cost.

3354. *MACHINE DESIGN.* Credit three hours. Prerequisite course, 3353. Two design periods and one recitation period a week throughout the term. The student undertakes to apply to practice the basic knowledge acquired in earlier courses. The course provides for the design of machine parts and assemblies involving the necessary calculations and such layout and detail drawings as are required for a complete solution.

3361. *ADVANCED MACHINE DESIGN.* Elective for qualified undergraduate and graduate students. Credit three hours. Three lecture-discussion periods a week. Advanced problems in analysis of machine and structural members including consideration of fatigue, creep, stress concentration, vibration, and lubrication. Special problems.

3370. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN.* Credit as arranged. Opportunity is offered to qualified students, individually or in small groups, to pursue, under direction, special investigations in machine design and related fields.

MATERIALS PROCESSING

Mr. GEER.

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 article to be cast. Operation of hand and power tools used in the modern pattern shop.

3402. *MACHINE TOOLS.* Credit two hours. Two laboratory periods 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. Two laboratory periods 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 in calibration of measuring standards.

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

3423. *MACHINE TOOL PROCESSES.* Credit two hours. Two laboratory periods a week. Fundamentals of machine tools and cutting tools. Study of machine tool design as related to modern tools and methods. Demonstrations and practice of the basic operations including gear cutting methods. Operation of jigs and fixtures.

3424. *MEASURING INSTRUMENTS.* Credit one hour. One laboratory period a week. Must be taken with or after 3423. Study of types of gages and measuring instruments and their applications; jigs, fixtures, and demonstrations of their use. Laboratory practice in handling precision gages and comparators.

HEAT-POWER ENGINEERING

Messrs. CLARK, ELLENWOOD, GAY, HOOK, and WATT.

3530. *THERMODYNAMICS.* Three recitations a week. Credit three hours. Prerequisites, Physics and Mechanics. The fundamental concepts and principles involved in the release, transfer, and conversion of thermal energy. Energy concepts and units; energy equations. Properties of gases, vapors, and mixtures. Expansion and compression of fluids. The use of Thermodynamic tables and charts.

3531. *HEAT-POWER ENGINEERING.* Credit two hours. Two recitations a week. Prerequisite, 3530 or its equivalent. Fuels, combustion, steam-generating units, steam turbines, condensers, internal combustion engines, and performances of complete power plants. Messrs. GAY and WATT.

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

3535. *HEAT-POWER ENGINEERING.* Credit three hours. Prerequisites, 3325, 3326, 1111, and 1112, or their equivalent. Three recitations a week. Basic thermodynamics of gases and vapors; ideal cycles and their application in air compressors, internal combustion engines, steam engines, and turbines; efficiencies and performances.

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

3543. *HEAT-POWER ENGINEERING.* Required of all seniors in Civil Engineering. Credit three hours. Not open to students in Mechanical or Electrical Engineering. Prerequisite courses, Physics (or the equivalent), Chemistry, and Mechanics. 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.

3544, 3545. *STEAM AND OIL ENGINE POWER PLANTS.* Two lectures a week. Two terms. Credit two hours a term. Prerequisite courses, 3337, 3332, 3535, and 3536; must be accompanied by courses 3546 and 3547, and accompanied or preceded by courses 3581 and 3582. Performance characteristics and design features of steam prime movers, steam generators, condensers, feedwater heaters, evaporators, deaerators, oil engines, pumps, fans, and cooling towers; power-plant piping; automatic control; power-plant instruments, fuel-burning equipment; coal- and ash-handling equipment. (Temporarily discontinued.)

3546, 3547. *POWER PLANT COMPUTING AND DESIGN.* Two computing periods a week. Credit two hours a term. Must be accompanied by 3544 and 3545. Energy balances; plant layouts; piping layouts; selection of equipment for central stations and industrial power plants. (Temporarily discontinued.)

3548. *HEATING, VENTILATING, AND AIR CONDITIONING.* Credit three hours. Principles and practice in the conditioning of air, including cooling, heating, dehumidifying, and ventilating. (Temporarily discontinued.)

3550. *POWER PLANT ECONOMICS: EQUIPMENT SELECTION.* Elective for seniors. Credit two hours. Prerequisite courses 3535, 3536. Two lectures a week. Cost of equipment and plants; energy costs; load curves, station factors; determining

characteristics of equipment: selection of working pressures and temperatures and cycles; proper load distribution; economic number and sizes of units; selection of equipment based on these and other determining considerations; economic operations. Application to central stations and to industrial power and heating plants. Other similar topics. (Temporarily discontinued.)

3551. *STEAM TURBINES.* Elective for seniors. Alternate terms. Credit two hours. Prerequisite, courses 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.

3557, 3558. *HEAT ENGINEERING.* Throughout the year. Credit four hours a term. Must be accompanied or preceded by 3582. Properties of mixtures, dimensional analysis, fluid flow, heat transmission, selection of fans and pumps, and refrigeration; applications to problems in air conditioning. (Temporarily discontinued.)

3563. *ADVANCED THERMODYNAMICS.* Elective for advanced students. Credit two hours. Two recitations a week. Prerequisites, 3535 and 3536. 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.

3570. *ADVANCED HEAT-POWER ENGINEERING RESEARCH.* Elective for graduate students and others qualified for advanced study in this field. Work and credit as arranged with Mr. ELLENWOOD and others of the department.

3581. *INTERNAL COMBUSTION ENGINES.* Three recitations a week. Credit three hours. Prerequisites, 3535 and 3536, or their 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. Prerequisites, 3535, 3536, or their 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.* Two recitations and one laboratory period a week. Credit three hours. Prerequisites, 3535, 3536, or their 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. 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.

MECHANICAL ENGINEERING LABORATORY

Messrs. ANDRAE, DROPKIN, ERDMAN, FAIRCHILD, GAGE, KATZ, MACKEY, OTTO, TRACY, and WATSON.

3601. *MECHANICAL ENGINEERING LABORATORY.* Second term. Credit

three hours. Regularly taken by five-year students in their eighth term. Two laboratory periods a week. Prerequisite, 3535. A laboratory study of instruments and methods used in measurement and control of variables important in mechanical and thermal processes. Measurement of pressure, temperature, speed, torque, power, flow rate, and humidity. Automatic controllers.

3602. *MECHANICAL ENGINEERING LABORATORY.* First term. Credit three hours. Regularly taken by five-year students in their ninth term. Two laboratory periods a week. Prerequisites, 3601, 3536. Laboratory instruction in the performance, testing, operation, and maintenance of internal combustion engines and engine accessories.

3603. *MECHANICAL ENGINEERING LABORATORY.* Second term. Credit three hours. Regularly taken by five-year students in their tenth term. Two laboratory periods a week. Prerequisites, 3601, 3536. Must be preceded by or taken with 3582. Laboratory instruction in the performance, testing, operation, and maintenance of complete steam and gas power plants and plant units.

3620. *INTRODUCTORY MECHANICAL LABORATORY.* Each term. Credit four hours. Prerequisites, 3535 and 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.* Each term. Credit four hours. Laboratory instruction on steam power plants and power plant auxiliaries, internal combustion engines and accessories, hydraulic machinery, and pneumatic machinery.

3651. *EXPERIMENTAL ENGINEERING.* Elective. Any term. 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. Each term. Credit two hours. One lecture and one laboratory period each 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.* Each term. Credit one hour. Elective for Juniors and Seniors. One lecture-recitation period a week. Dimensions of physical units. Use of dimensional analysis. Deviation 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. (Not given in 1947–1948.)

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

3670. *AUTOMATIC CONTROL ENGINEERING.* Elective. Each term. 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 ENGINES.* Elective. Each term. Credit three hours. Prerequisite, 3581. Two lecture-recitation periods, one laboratory period a week. An elementary course covering engine construction, diesel fuel characteristics, combustion phenomena in diesel engines, combustion chambers, fuel injection systems, and engine performance characteristics. A study will also be made of induction systems, scavenging, and supercharging of diesel engines.

AUTOMOTIVE ENGINEERING

3741. *AUTOMOTIVE LECTURES.* Seniors and graduates. Credit three hours. Three lectures a week. Prerequisite, course 3337. The automobile, and the power required for its operation, but not including the power plant. Analysis is made of the relations of the car to the road; functions of steering, driving, braking; mechanical efficiency of chassis; springing for comfort of riding; wind resistance; layout of parts for balanced design.

3743. *AUTOMOTIVE COMPUTATIONS.* Credit two hours; two computing periods a week. Must be accompanied by course 3741, which it parallels, but with more 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 accompanied by 3581, which it parallels, but with more detailed studies in operation and design. (Temporarily discontinued.)

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

Electrical Engineering

COURSES BY GROUPS. . . Within the School of Electrical Engineering the courses are numbered in groups with each course designated by a four-digit number. The second digit denotes the group in which the course is listed and the last digit the type of course.

The index of course descriptions follows:

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4216 Electrical Machinery Laboratory (p. 111)
4221 Alternating Current Machinery (p. 111)
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4341 Motor Control (p. 113)
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4343 Aircraft and Marine Electric Power Control Systems (p. 113)
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4361 Power Systems (p. 114)
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4364 Protection and Relaying on Power Circuits (p. 114)
4365 Symmetrical Components (p. 114)
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COURSES IN INDUSTRIAL ELECTRONICS

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*4451 High Frequency Heating (p. 116)
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*One of these to be chosen as Option Elective in Industrial Electronics Option.

COURSES IN RADIO AND COMMUNICATIONS

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4517 Radio and Communication Laboratory (p. 117)
*4521 Radio Broadcasting (p. 117)
*4522 Telephone and Telegraph Systems (p. 117)
*4526 Design and Construction of Vacuum Tubes (p. 117)
*4531 Television Systems (p. 118)
*4541 Applied Acoustics (p. 118)
*4551 Radio Aids to Navigation (p. 118)
4561 Ultra High Frequency Systems (p. 118)
4565 Electromagnetic Waves (p. 119)
4566 Electromagnetic Waves (p. 119)
4591 Project (p. 119)
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*At least three hours to be chosen from these for Option Elective in Radio and Communication Option.

COURSES IN ILLUMINATION

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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.

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.

4031. *ENGINEERING MATHEMATICS.* Term 4. Required. Credit three hours. Three recitations each week. Prerequisite, Mathematics 161. Text: *Engineering Mathematics,* SOHON.

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 determinants, complex numbers, hyperbolic functions, Fourier series, methods of interpolation, theory of equations, probability and least squares, vector algebra, vector calculus, and dimensional analysis.

4035, 4036. *OPERATIONAL ANALYSIS.* Terms 9 and 10. Elective. Credit three hours each term. Two recitations and one computing period each week. Prerequisite, 4311.

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. The course concludes with 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.

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.

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, Math 163; Physics 117; Chemistry 102 or 106. Text: *Electrical Engineering,* STRONG.

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 combinaiton 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. Three recitations and one computing period each week. Prerequisites, 4111 and 4031. Text: *Alternating-Current Circuits,* KERCHNER and CORCORAN.

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; introduction to filters.

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.

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. Three lecture-recitations each week. Prerequisite, 4112. Must be accompanied by course 4126. Text: *Applied Electronics,* M.I.T. staff; and supplementary notes.

This is the first of a group of courses which present and expand the fundamental laws of electronic 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 lecture-laboratory, and one computing period each week. Prerequisites, 4121 and 4126. Text: *Applied Electronics,* M.I.T. staff; and supplementary notes.

This course continues the study of electron tubes and circuits begun in courses 4121 and 4126. It deals with: amplifiers including transformer coupling; power amplifiers; push-pull operation of class A, B, and C amplifiers; analysis of single-tube oscillators with effects of feed-back; theory of amplitude and of angular modulation and detection with simple circuits; thermionic gas-filled triodes, with methods of control and with application to full-wave rectifiers and motor control; and inverter circuits, with analysis of their operation.

4126. *ELECTRONICS LABORATORY.* Term 6. Required. Credit two hours. One lecture-laboratory and one computing period each week. Prerequisite, 4112. Must be accompanied by course 4121. Text: *Applied Electronics,* M.I.T. Staff; and supplementary notes.

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.

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 are 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. One lecture and one lecture-laboratory period each week. Prerequisites, 4121 and 4126. Must be preceded or accompanied by 4122.

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. Inspection trips are included in the course.

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.

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.

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.

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.

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 Math 201.

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*, LAWRENCE; supplementary notes.

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 4311. Text: mimeographed notes.

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.

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.

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.

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.

Characteristics of motors and requirements of typical loads are analyzed and correlated so that the motor selected for the load is of the proper type and rating. 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.

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.

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 recitations and one computing period each week. Prerequisite, 4221. Text: *Electric Power Equipment,* TARBOUX.

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 recitations and one computing period each week. Prerequisite, 4311 and 4361. Text: *Introduction to Electric Power Systems,* TARBOUX.

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.

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.* Term 10. Elective. Credit two hours. Two lectures each week. Must be preceded or accompanied by 4371. Text: mimeographed notes supplemented by manufacturer's bulletins.

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 10. Elective. Credit three hours. Three lectures and three recitation periods each week. Prerequisites, 4311, 4321, and 4361. Text: *Applications of the Method of Symmetrical Components,* LYON.

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-laboratory period each week. Prerequisite, 4362. Text: mimeographed notes.

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.

A considerable portion of the laboratory work is done in the High Voltage Research Laboratory, located in East Ithaca.

4391 and 4392. *PROJECT.* Terms 9 and 10. Required in Power Utilization and in Power Generation and Distribution Options. Credit two hours for the first term and four hours for the second term.

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, 4122 and 4131. Text: mimeographed notes.

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 the subjects of laboratory experiments are timing circuits, welder controls, motor controls, voltage regulators, frequency-varying circuits, and frequency-discriminating circuits.

4415. *ADVANCED ELECTRONIC CONTROLS.* Term 10. Elective. Credit three hours. Two recitations and one computing period each week. Prerequisite, 4421. Text: References and mimeographed notes.

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.

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, 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.

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.

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.

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 COMMUNICATIONS

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. Prerequisites, 4112 and 4122. Texts: *Applied Electronics,* M.I.T. Staff; supplementary notes.

Intensive studies of the various components of radio receivers, broadcast studios, and broadcast transmitters constitute the course. The topics studied are: amplifiers with compensation, feed-back, and of class C; double-tuned transformer circuits; oscillators; modulation and detection; frequency modulation; microphones; and loud speakers.

4512. *RADIO AND COMMUNICATION THEORY.* Term 9. Required in Radio and Communication Option. Credit three hours. Two lectures and one recitation or computing period each week. Must be preceded or accompanied by 4511. Texts: *Radio Engineering Handbook,* TERMAN; *Ultra-High Frequency Technique,* BRAINARD et al; supplementary notes.

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 4511. Texts: *Transmission Networks and Wave Filters,* T. E. SHEA; supplementary notes.

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 lecture-laboratory or computing period each week. Must be preceded or accompanied by 4511. Texts: *Applied Electronics,* M.I.T. Staff; supplementary notes.

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 lecture-laboratory or computing period each week. Must be preceded or accompanied by 4512. Texts: *Radio Engineering Handbook,* TERMAN; *Ultra-high Frequency Technology,* BRAINARD et al; supplementary notes.

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

4521. *RADIO BROADCASTING.* Elecitve. 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.

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.

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.

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 recitations and one computing period each week. Text: *Principles of Television Engineering,* FINK.

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 studios, transmitters, and receivers.

Basic work in optics, illumination, cathode-ray tubes, vacuum-tube amplifiers, pulse shaping, modulation, and antenna characteristics, serves as a background for further study of television problems. In addition, such problems as 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.

A review of the laws of ideal gases, the thermo-dynamic 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. Two recitations each week. Prerequisite, 4131. Text: *Principles of Aeronautical Radio Engineering,* SANDRETTO, and selected references.

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.

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.

4565. *ELECTROMAGNETIC WAVES.* Term 10. Elective. Credit three hours. Three lecture-recitations each week. Prerequisites, 4512 and 4517.

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.

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

4591 and 4592. *PROJECT.* Terms 9 and 10. Required in Radio and Communication Option. Credit three hours each term.

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: *Electrical Illumination,* KRAEHENBUEHL.

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.

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.

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.

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.

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.

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

4920. *ELECTRICAL EQUIPMENT.* Required of seventh- or eighth-term, four-year students, and ninth- or tenth-term, five-year students in Civil Engineering.

Credit three hours. Two lectures and one laboratory or computing period each week. Prerequisites, Physics 11 and 12, or Physics 115, 116, and 117, and Mechanics.

A study of the fundamental physical principles of electrical engineering and their application in the common types of electrical equipment is made to enable the student to select the proper type of apparatus for the services met in ordinary practice.

4931, 4932, 4933, 4934. *ELECTRICAL ENGINEERING.* Required respectively, of fifth-, sixth-, seventh-, and eighth-term, five-year students in Mechanical Engineering. Credit three hours each course. Two lecture-recitations and one laboratory or computing period a week. Prerequisites, Math. 161, 162, and 163; Physics 115, 116, and 117, and Mechanics.

This sequence of four courses is designed to provide the student in Mechanical Engineering with the basic knowledge of electrical principles and equipment which may be most applicable in his field. The study treats of electric and magnetic circuits, electronic fundamentals, rectifiers and transformers, rotating machinery, control instruments and methods, electric heating and lighting, and the application of these to industrial machinery.

(Not available until fall semester 1948)

4935. *FUNDAMENTALS OF ELECTRICAL ENGINEERING.* Required of fifth-term, four-year students in Mechanical Engineering. Credit three hours. Two lectures and one recitation-computing period each week. Prerequisites, Math. 161, 162, and 163; Physics 118 or equivalent, and Mechanics. Text: *Electrical Engineering,* COOK.

This course presents the fundamentals of d-c electric and magnetic circuits and their application to d-c machinery and equipment.

4936. *FUNDAMENTALS OF ELECTRICAL ENGINEERING.* Required of fifth-term, four-year students in Mechanical Engineering. Credit one hour. One laboratory period each week. Must be preceded or accompanied by 4935. Text: *Electrical Engineering,* COOK; *mimeographed notes.*

This course is a laboratory study of the material in 4935.

4937. *FUNDAMENTALS OF ELECTRICAL ENGINEERING.* Required of sixth-term, four-year students in Mechanical Engineering. Credit three hours. Two lectures and one recitation-computing period each week. Prerequisite, 4935. Text: *Electrical Engineering,* COOK.

This course is a continuation of 4935. The principles of a-c electric and magnetic circuits are studied, with emphasis upon their application in a-c machinery and equipment.

4938. *FUNDAMENTALS OF ELECTRICAL ENGINEERING.* Required of sixth-term, four-year students in Mechanical Engineering. Credit one hour. One laboratory period each week. Prerequisite, 4936. Must be preceded or accompanied by 4937. Texts: *Electrical Engineering,* COOK; mimeographed notes.

This course is a laboratory study of the material in 4937.

4951. *ELECTRICAL ENGINEERING.* Required of ninth-term students in Chemical Engineering. Credit four hours. Three lecture-recitations and one laboratory or computing period each week. Prerequisites, Math 161, 162, and 163; Physics 115, 116, and 117. Text: mimeographed notes.

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.* Required of tenth term students in Chemi-

cal Engineering. Credit four hours. Three lecture-recitations and one laboratory or computing period each week. Prerequisite, 4951. Text: *mimeographed notes.*

This 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. 133)
115. Introductory Inorganic Laboratory (p. 133)
212. Introductory Qualitative Analysis (p. 133)
220. Introductory Quantitative Analysis (p. 133)
222. Introductory Quantitative Laboratory (p. 133)
240. Special Methods of Quantitative Analysis (p. 134)
307, 308. Introductory Organic Chemistry (p. 134)
311. Introductory Organic Laboratory (p. 134)
312. Intermediate Organic Laboratory (p. 134)
403, 404. Introductory Physical Chemistry (p. 134)
411, 412. Introductory Physical Laboratory (p. 135)
English 111, 112. Introductory course in Reading and Writing (p. 135)
Electrical Engineering 4951, 4952 (p. 121)
History 165, 166. Science in Western Civilization (p. 135)
Mathematics 161, 162, 163. Analytical Geometry and Calculus (p. 135)
201. Elementary Differential Equations (p. 136)
Mechanics and Materials of Engineering (p. 74–79)
Mechanical Engineering Courses (p. 97–106)
Physics 115. Mechanics (p. 136)
116. Wave Motion, Sound, and Heat (p 136)
117. Electricity and Magnetism (p. 137)
118. Physical Electronics and Optics (p. 137)
Public Speaking 101 (p. 138)

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 application to their applications to chemical engineering processes.

5104. *CHEMICAL ENGINEERING THERMODYNAMICS.* Spring term. Credit two hours a term. Prerequisite course, Chemical Engineering 5103. Messrs. RHODES and VON BERG.

Lectures. Continuation of course 5103.

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

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 405b and Chemical 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, Chemical 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, Chemical Engineering 5304. Mr. WINDING.

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

5505. *ADVANCED PROBLEMS IN HEAT TRANSFER.* Fall term. Credit three hours. Prerequisite courses 5503 and 5504, or equivalent. Messrs. RHODES, WINDING, and SMITH.

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. Messrs. RHODES, WINDING, and SMITH.

Conferences and lectures. Advanced topics in distillation, gas absorption, liquid-liquid extraction, and drying. Primarily for graduate students.

5603, 5604. *CHEMICAL ENGINEERING EQUIPMENT DESIGN.* Credit two hours a term. Prerequisite course, Chemical Engineering 5304. Messrs. SMITH and VON BERG.

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, WEIGANDT, and MASLAN.

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 5304. Mr. WINDING. Three lectures a week. Processes employed in petroleum refining.

5742. *SYNTHETIC RESINS AND PLASTICS.* Alternate terms. Credit three hours. Prerequisite or parallel course, Chemical 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. The lectures for the Fall Term of 1947–1948 will deal with instrumentation, with special reference to instrumentation in the chemical industries.

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. Two laboratory periods.

Lectures and laboratory practice. 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, Chemical 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, Chemical 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. Not given in 1947.

5859. *ADVANCED CHEMICAL MICROSCOPY.* Either term. Credit one or more hours. Prerequisite course, Chemical 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, Chemical Engineering 5304. Messrs. RHODES, MASON, WINDING, SMITH, VON BERG, WEIGANDT, and MASLAN.

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, HILL, JOYCE, and PATTERSON. One lecture and one laboratory period each week.

An elementary course covering the important industrial processes used in the casting, hot working, cold forming, heat treating, and welding of metals.

6113. *CASTING, WORKING, AND WELDING OF METALS.* Fall term. Credit three hours. Prerequisite course, Engineering 6110. Mr. 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. (Not offered in 1947–1948.)

6114. *CASTING, WORKING, AND WELDING OF METALS.* Spring term. Credit three hours. Prerequisite course, Engineering 6110 and Introductory Metallography, Engineering 6811. Messrs. KYLE, BURTON, and assistants. Two lectures and one laboratory period each week.

An advanced course for students in Metallurgical Engineering. (Not offered in 1947–1948.)

6203. *SLAG-METAL-ATMOSPHERE REACTIONS.* Fall term. Credit three hours. Prerequisite courses, Engineering 1256, Chemistry 404, and Metallurgical Calculations, Engineering 6501. Lectures.

Theory of the reactions involved in the reduction and refining of metals, carburization and decarburization, slag control, furnace-atmosphere generation, and related topics. (Not offered in 1947–1948.)

6253. *UNIT PROCESSES IN METALLURGY.* Fall term. Credit three hours. Prerequisite or parallel course Slag-Metal-Atmosphere Reactions, Engineering 6203. 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 electrode position. (Not offered in 1947–1948.)

6254. *UNIT PROCESSES IN METALLURGY.* Spring term. Credit two hours. Prerequisite course, Unit Processes in Metallurgy, Engineering 6253. One lecture and one laboratory period each week with reports. Continuation of course 6253. (Not offered in 1947–1948.)

6311. *PHYSICAL METALLURGY.* Fall term. Credit three hours. Prerequisite course, Introductory Metallography, 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. (Not offered in 1947–1948.)

6323. *ADVANCED FERROUS METALLURGY.* Fall term. Credit three hours. Prerequisite course, Physical Metallurgy, Engineering 6311. Lectures.

Discussion, at an advanced level, of alloy steels, cast irons and heat treatment. (Not offered in 1947–1948.)

6324. *ADVANCED NON-FERROUS METALLURGY.* Spring term. Credit three hours. Prerequisite course, Physical Metallurgy, Engineering 6311. Lectures.

Detailed discussions of advanced topics in non-ferrous metallurgy. (Not offered in 1947–1948.)

6351. *PHYSICAL METALLURGY LABORATORY.* Fall term. Credit three hours. Parallel course Physical Metallurgy, 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. (Not offered in 1947–1948.)

6501. *METALLURGICAL CALCULATIONS.* Fall term. Credit two hours. Prerequisite or parallel course, Engineering 1255. 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. (Not offered in 1947–1948.)

6602. *METALLURGICAL DESIGN.* Spring term. Credit three hours. Prerequisite course, Physical Metallurgy, Engineering 6311, or special permission. Lectures.

The application of metallurgical principles to the study of the performance of metal parts in service. Includes metallurgical considerations in the choice of metals for various types of service, factory 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 1947–1948.)

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. (Not offered in 1947–1948.)

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, Unit Processes in Metallurgy, Engineering 6254.

Research on an original problem in Metallurgical Engineering. (Not offered in 1947–1948.)

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. Mr. OCVIRK.

GRADUATE COURSES

7101. *AIRPLANE MECHANICS.* 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. *AIRPLANE MECHANICS.* 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. Not given in 1947–1948.

7104. *MECHANICS OF ROTARY-WING AIRCRAFT.* Credit 3 hours. Fundamentals of propeller theory. Rotor in veritcal 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. Spring term. Mr. FLAX.

7201. *GASDYNAMICS.* Credit three hours. Thermodynamics and kinetic theory in relation to fluid dynamics. One-dimensional steady flow of a compressible fluid;

addition of heat. Prerequisite, Physics, Integral Calculus. Fall term. Mr. KANTROWITZ.

7202. *GASDYNAMICS.* Credit three hours. Propagation of finite waves in compressible fluid; stationary and non-stationary shock waves. Nozzle and channel flow with shock waves. Prandtl-Meyer flow. Method of characteristics for stationary and non-stationary channel flow. Experimental methods. Prerequisite, 7201. Spring term. Mr. KANTROWITZ.

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, 7201, Physics. Each term. Mr. WILD.

7301. *THEORETICAL AERODYNAMICS I.* Credit three hours. Introduction to theoretical hydrodynamics; the theory of ideal fluids; potential flows; conformal transformation. Prerequisites, Advanced Engineering Mathematics, Differential Equations, Engineering Mechanics or Introduction to Theoretical Physics. Fall term. Mr. SEARS.

7302. *THEORETICAL AERODYNAMICS II.* Credit four 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. Prerequisites, same as for 7301, plus 7201, 7202, and enrollment in 7301. 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. OCVIRK.

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. Mr. OCVIRK.

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. Not given in 1947–1948.

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 University courses that fall outside the jurisdiction of any college and courses in the College of Arts and Sciences prescribed for students in Engineering.

CLINICAL AND PREVENTIVE MEDICINE

These courses may be counted among the thirty hours of non-Arts courses allowed to students in the College of Arts and Sciences.

1. *HEALTH PROBLEMS, PERSONAL AND COMMUNITY.* Either term. Credit three hours. Not open to freshmen. M W F 11. Dr. SHOWACRE and members of the medical staff.

Discussion and analysis of common health problems of the individual and the community.

4. *ADVANCED FIRST AID.* Either term. Credit two hours. Enrollment limited. Prerequisite, consent of the instructor. Lecture, F 9. Laboratory, T 7–9 P.M. Dr. SHOWACRE and members of the medical staff.

MILITARY SCIENCE AND TACTICS

(Students who have been enrolled in the Armed Services are exempted from the requirement in Military Science by reason of such service).

1. *ELEMENTARY COURSE.* Throughout the year. This course, conducted throughout the year, is required (with the exception of those specified above) of all able-bodied first-year and second-year male students who are American citizens and candidates for a baccalaureate degree. The requirements of Military Science and Tactics must be completed in the first two years of residence. Otherwise, the student will have to obtain consent of the Faculty to register again in the University. Three hours a week on any afternoon from Monday through Friday, commencing at 1:40 P.M.

Basic instruction in Leadership, Rifle Marksmanship, The World Military Situation, Evolution of Warfare, and a study of maps and aerial photographs are the major subjects offered in this course. Further details may be obtained at Barton Hall, or in the Announcement of the Department of Military Science and Tactics.

2. *ADVANCED COURSE.* Throughout the year. Credit three hours a term. This course appeals to those students who are aware of the country's need for specially trained men in the event of a national emergency, and to those potential leaders who desire advanced training in leadership. Students who have completed the Elementary Course or have had one year of service with any of the Armed Forces, are eligible for enrollment. Six months with the Armed Forces credits a student with one year of the Elementary Course toward Advanced ROTC requirements. By taking a second year of the Elementary Course, he may complete this requirement. Five hours a week are required.

Tactics and Technique is taught in four of the arms and services including Field Artillery, Ordance, Signal Corps, and Quartermaster Corps; and the attendance at one summer camp for six or eight weeks is required. Instruction is also provided in

such general subjects as Military Problems of the United States; Psychological Warfare; Combined and Joint Operations; Military Leadership, Psychology and Personnel Management; Occupied Territories, Command and Staff Functions, by specialists in these fields, including lectures from other departments, schools, and colleges of the University.

During the course, the student receives a substantial government allowance and a regulation officer's uniform. The complete course covers two years.

Completion of the Advanced Course qualifies students for commissions as Second Lieutenants of the Officers Reserve Corps, U. S. Army.

NAVAL RESERVE OFFICERS TRAINING CORPS

The Bureau of Naval Personnel has established at Cornell University a permanent Naval Reserve Officers Training Corps unit. Properly prepared students who register in the Schools of this College under the Navy Plan will be able to qualify for appropriate degrees and fulfill naval requirements also by carefully scheduling their courses. Present credit allowances for the separate schools are explained later in this section.

The course in Naval Science is four years in length, and normally requires three class room hours a week plus certain laboratory periods of approximately two hours a week in each term, in addition to summer cruises. In the case of students pursuing five-year courses the Naval Science courses may be taken during either the first or the last four years, except that students must begin their Naval Science courses in the year for which they are designated by the Bureau of Personnel. Undergraduates in the NROTC may take any university course leading to a baccalaureate degree, and will not be held for the Basic Course in Military Science and Tactics. Students are entered in either of two categories, Regular and Contract, for both of which academic and laboratory requirements are identical.

Regular Students gain admission to the NROTC unit through nation wide examinations conducted for the Navy by the Naval Examination Section of the College Entrance Examination Board and special boards in each State. Tuition, books, and usual fees are paid by the Navy, and in addition, students are paid $600 a year. They are required to serve approximately two years as Ensigns in the Regular Navy or Second Lieutenants in the Marine Corps, upon graduation. Thereafter, they may elect to make the Navy a career, or be placed on inactive duty with corresponding rank in the Reserve Corps.

Contract Students are selected by the Professor of Naval Science from applicants who have already been admitted to the College of Engineering, and who require four or five years of work before graduation. They are paid approximately $20 a month during the third and fourth years of their Naval Science courses, and are commissioned in the Naval Reserve or the Marine Corps Reserve, and placed on inactive duty, upon graduation.

Candidates for regular and contract status must have attained the age of seventeen years before July 1 and September 1 respectively of the year of enrollment, and must not have attained the age of twenty-five years before the first of July of the year in which they are due to be commissioned.

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 NS 302, 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	—	12 hours
School of Electrical Engineering	—	13 hours
School of Chemical Engineering	—	10 hours
School of Civil Engineering	—	4 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

(By cooperation of the School of Civil Engineering)

710. *PRINCIPLES OF REGIONAL AND CITY PLANNING.* Elective. Registration limited to 50. Open to graduates and upperclassmen in all colleges of the University. First 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. M W F 12. *White* 201. Messrs. CLARKE and MACKESEY.

711. *CITY PLANNING PRACTICE.* Elective. Second 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. M W F 12. *White* 201. Messrs. CLARKE and MACKESEY of the College of Architecture.

712. *REGIONAL PLANNING PRACTICE.* Elective. Open to graduates and upperclassmen in all colleges of the University. Second term. Credit three hours. Prerequisite Course 710. A study of the principles involved in county, regional, state, and

national planning. Includes discussion of following factors involved: land use, water resources, recreation, transportation, public services, and public works. Occasional lectures will be given by members of other faculties and outside lecturers. Lectures, assigned reading, reports, and examinations. Hours to be arranged. Mr. CLARKE and Mr. MACKESEY of the College of Architecture.

713. *HOUSING.* Elective. Registration limited. First 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. Students in the College of Architecture will take one or more design programs having some phase of housing as subject. These problems will be substituted for a regular problem in courses 113 or 151, and values, as earned, will be awarded in those courses. Lectures, assigned reading, and reports. Hours to be arranged. *White* 210. Mr. CLARKE and Mr. MACKESEY of the College of Architecture.

714. *SEMINAR IN REGIONAL AND CITY PLANNING.* Elective. Throughout the year. Credit one hour each term. This course should accompany or follow course 710. Registration limited. Open to students in all colleges of the University, by permission. Investigation of assigned topics on particular aspects of the subject with emphasis on either urban or regional planning. Hours to be arranged. *White, Architectural Seminar Room.* Mr. CLARKE and Mr. MACKESEY of the College of Architecture.

715. *SEMINAR IN PARK PLANNING.* Elective. Registration limited. Open to upperclassmen and graduates in the Colleges of Architecture and Engineering and others by special permission. First term. Credit two hours. Specific problems relating to the design of city, state, and national parks with a study of examples. T 8–10. *White* B–15. Mr. CLARKE. (Not given in 1947–1948).

716. *SEMINAR IN PARKWAY, FREEWAY, AND HIGHWAY PLANNING.* Elective. Registration limited. Open to upperclassmen and graduates in the Colleges of Architecture and Engineering. Second term. Credit two hours. Specific problems relating to the design of the modern parkway, freeway, and highway with a study of examples. T 8–10. *White* B–15. Mr. CLARKE.

717. *ZONING PRINCIPLES AND PRACTICE.* Open to graduates and upperclassmen in all colleges of the University. Second term. Credit two hours. Prerequisite, course 710. Technical and legal aspects of drafting and administering zoning regulations. Hours to be arranged. Mr. MACKESEY.

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, Fall term: M F 10, 12, or 3. Spring term: M F 10, 11, or 3. Laboratory, M T W Th or F 8–11, 10–1, or 1:40–4:30, or S 8–11. Conference, one hour a week to be arranged. Mr. WOOD 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, T Th 8. Laboratory, M T W Th or F 1:40–4:30, or S 8–11. Conference, one hour a week to be arranged. Mr. CASHIN and assistants.

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, T Th 10, 12, or 3. Laboratory, M T W Th or F 8–11, 10–1, or 1:40–4:30, or S 8–11. Conference, one hour a week to be arranged. 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, Fall term, M W F 8; Spring term, W F 8. Mr. LAUBENGAYER.

115. *INTRODUCTORY INORGANIC LABORATORY.* Fall term. Credit three hours. Must be taken with Chemistry 111. Laboratory, T Th 8–11, W F 10–1, or S 8–1. Conference, one hour a week to be arranged. Mr. LAUBENGAYER 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, M S 8. Recitation, one hour a week, to be arranged. Laboratory, T Th or W F 1:40–4:30. 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, M W 10. Recitation, one hour a week, to be arranged. Mr. NICHOLS 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. Labora-

tory, T Th 9–12:30 (fall term only) or F 2–4:30 and S 8–12:30. Mr. NICHOLS 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, T 11. Laboratory, M T or Th F 2–4:30, or W 2–4:30 and Th 10–12:30. 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, electrolytric, 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 degrees of B. Chem. Eng. and A.B. with a major in Chemistry, and recommended for pre-medical students who desire the longer course. Students who have completed Chemistry 303 and 305 may register for Chemistry 308 and receive two hours' credit. (See Chemistry 303 and 305). Lectures, M W F 9. 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, and recommended for pre-medical students who desire the longer course. (See Chemistry 303 and 305.) Laboratory, T Th 9–12:30, T Th 1–4:30, or F 2–4:30 and S 8–12:30. 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 and pre-medical students who desire the longer course. (See Chemistry 303 and 305). Laboratory, T Th 9–12:30, T Th 1–4:30, or F 2–4:30 and S 8–12:30. 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, M W F 9. 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, M T or Th F 2–4:30, or W 2–4:30 and Th 10–12:30, or S 8–1. 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. M W F 12. Mr. ————.

401. *LABOR CONDITIONS AND PROBLEMS.* Fall term. Credit three hours. Prerequisite, Economics 101, or the equivalent. M W F 10. 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. M W F 8, 9, 10, 11, 12, 1, 2, or 3; T Th S 8, 9, 10, 11, or 12. 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, M W 11. Laboratory, M W or T Th 2–4:30. 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.

HISTORY

165–166. *SCIENCE IN WESTERN CIVILIZATION.* Throughout the year. Credit three hours a term. M W F 11. 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. For students in the College of Arts and Sciences, the prerequisites for Mathematics 161 are the same as those stated below for Mathematics 171. Time to be announced later.

201. *ELEMENTARY DIFFERENTIAL EQUATIONS.* Either term. Credit three hours. Prerequisite, Mathematics 163, or the equivalent. Time to be announced later.

501–502. *ADVANCED CALCULUS.* Throughout the year. Credit three hours a term. Prerequisite, Mathematics 163, or the equivalent. M W F 11.

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.

611–612. *HIGHER CALCULUS FOR ENGINEERS AND PHYSICISTS.* Throughout the year. Credit three hours a term. Prerequisite, some familiarity with ordinary differential equations. T Th S 10.

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 163, or the equivalent, and at least two years of general physics. M W F 12.

Lectures and problem work designed to give the students 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. M W F 11.

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 171. Entrance physics is desirable but not required. Lectures, Th 9or 11. Recitations, M F 9. Laboratory, M 2–4:30. 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 171. Lecture, T 9 or 11, Recitations, M F 9, Laboratory, M 2–4:30. 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 huors. Prerequisites, Physics 115, 116, Calculus, or simultaneous registration in Mathematics 173. Lectures, T 8 or 11, Recitations, T Th 10, Laboratory, M 2–4:30. 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, and electromagnetic waves.

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, Th 9 or 11, Recitations, T Th 10, Laboratory, M 2–4:30. 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 T W Th F 1:40–4:30 (two periods required). One discussion period to be arranged. Messrs. COLLINS, HARTMAN, and PARRATT.

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.

215. *OPTICS.* Fall term. Credit three or five hours. Prerequisites, Physics 205 and 206, or the equivalent, and the Calculus. Lectures, M W F 8. Laboratory, T W or Th F 1:40–4:30. Mr. COLLINS.

Geometrical optics, lens systems, Gauss points, aberrations, stops, photometry of optical systems, interference, application of various forms of interferometers; Fresnel and Fraunhofer diffraction patterns and their applications to optical instruments; polarized light, production, detection, measurements and applications of plane and elliptically polarized light.

225. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hours. Prerequisite, Physics 117, or 63, or 206. Lectures, T Th S 9, 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.

242. *ANALYTICAL MECHANICS.* Spring term. Credit three hours. Prerequisites, Physics 205 and Mathematics 201, or the equivalent. M W F 9. 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.

243. *ATOMIC AND MOLECULAR PHYSICS.* Fall term. Credit three hours. Prerequisite, Physics 225. T Th S 9. Mr. MORRISON.

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.

[253. *WAVE MOTION AND SOUND.* Fall term. Credit three or five hours. Prerequisite, Physics 242, or the equivalent; Physics 236 is desirable. Lectures, M W F 8. Laboratory, T W or Th F 1:40–4:30. Not offered in 1947–1948.]

254. *ELECTRONIC PROPERTIES OF SOLIDS AND LIQUIDS.* Spring term. Credit three or five hours. Prerequisite, Physics 243. Lectures, T Th S 9. 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. M W F 3. 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. M W F 11. Mr. LIDDELL.

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. M W F 10. Mr. PRICE.

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. M W F 8, 9, 10, 11, 12, or 2; T Th S 8, 9, 10, or 11. Messrs. WAGNER, WICHELNS, ARNOLD, GARBUTT, and assistants.

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.

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