Announcement of the

College of Engineering

including

THE SCHOOL OF CIVIL ENGINEERING

THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

THE SCHOOL OF ELECTRICAL ENGINEERING

THE SCHOOL OF CHEMICAL ENGINEERING

THE COURSES IN ADMINISTRATIVE ENGINEERING

for 1939-40

The University Calendar for 1939-40

1939		FIRST TERM
Sept.	18, *Monday*,	Entrance examinations begin.
Sept.	25, *Monday*,	Registration and assignment, new students.
Sept.	26, *Tuesday*,	Registration and assignment, old students.
Sept.	28, *Thursday*,	Instruction begins at 8 A.M.
Oct.	19, *Thursday*,	Last day for the payment of tuition for the first term.
Nov.	29, *Wednesday*,	Instruction suspended at 4 P.M. (*Thanksgiving Recess*)
Dec.	4, *Monday*,	Instruction resumed at 8 A.M.
Dec.	20, *Wednesday*,	Instruction suspended at 4 P.M. (*Christmas Recess*)
1940		
Jan.	4, *Thursday*,	Instruction resumed at 8 A.M.
Jan.	11, *Thursday*,	Founder's Day.
Jan.	29, *Monday*,	Final examinations begin.
Feb.	7, *Wednesday*,	Final examinations end.
Feb.	8, *Thursday*,	A holiday.
		SECOND TERM
Feb.	9, *Friday*,	Registration of all students.
Feb.	12, *Monday*,	Instruction begins at 8 A.M.
March	4, *Monday*,	Last day for the payment of tuition for the second term.
March	30, *Saturday*,	Instruction suspended at 12:50 P.M. (*Spring Recess*)
April	8, *Monday*,	Instruction resumed at 8 A.M.
May	—, *Saturday*,	Spring Day: a holiday.
June	3, *Monday*,	Final examinations begin.
June	11, *Tuesday*,	Final examinations end.
June	17, *Monday*,	COMMENCEMENT.

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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 as the College of Civil Engineering, has also retained its identity to the present day.

In 1883 Cornell opened the first 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.

The College of Engineering organized a five-year course leading to the degree of Chemical Engineer in 1931, and more recently four-year courses leading to the degree of Bachelor of Science in Administrative

Engineering in civil, mechanical, and electrical engineering. The School of Chemical Engineering was established in 1938 and to it was transferred supervision of the curriculum leading to the degree of Bachelor of Chemical Engineering.

Students in engineering at Cornell use the facilities of Sibley Hall, which houses the Sibley School of Mechanical Engineering; Lincoln Hall, which houses the School of Civil Engineering; Franklin Hall, which houses the School of Electrical Engineering; Rand Hall, which contains the machine shop, pattern shop, and electrical laboratory; the Hydraulic Laboratory on Beebe Lake above Triphammer Falls; and part of the Baker Chemical Laboratory, a building given to the University in 1922 by George F. Baker. For various preparatory and elective courses they also use the facilities 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 extra-curricular 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 comprises the School of Civil Engineering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering, and the School of Chemical Engineering. Courses in Administrative Engineering are given in the first three of these Schools. 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 a general field is

essential to success in any of the narrower specialties, 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 senior options, rather than rigidly differentiated courses of study in narrow fields.

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 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. Where it is feasible, that is to say, in the Schools of Civil, Mechanical, and Electrical Engineering, the freshman program has been made nearly uniform, so that, if necessary, the student may have an additional year after his admission to discover in what general field his best work can be accomplished. In all the schools, specialization has been postponed until late in the course and 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 are courses of instruction designed to teach the fundamental principles, theoretical and practical, that underlie the various branches of engineering. Classroom instruction and laboratory experiment are supplemented by experience with the operation of various kinds of apparatus in the College laboratories and shops and by trips to inspect manufacturing plants, public works, and other places of interest in the industrial centers of the East. The student thus becomes familiar with problems encountered in modern engineering and with practical methods for their solution.

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

THE ORGANIZATION FOR INSTRUCTION

It has been said that engineering has more major divisions than any other profession; and each of these main divisions has many special branches. For effective instruction, the College of Engineering is divided into schools representing the four main divisions, Civil, Mechanical, Electrical, and Chemical Engineering, each with a director and a separate faculty. Administrative Engineering, designed to train men in the fundamentals of business and finance, is offered in special groups of courses in the schools of civil, mechanical, and electrical engineering.

The faculties of the schools are further divided into departments with staffs of specialists in their respective branches. Since the character of all instruction depends primarily on the qualifications of the teaching staff and on the efficiency with which they impart

knowledge to their students, careful consideration has been given to the type of men chosen for the faculty, to their number in relation to student enrollment, and to the facilities needed to make their instruction most effective.

Faculty members are selected for their scientific training, their teaching ability, and their practical knowledge of and close contact with modern engineering problems and procedures. For many years the college has maintained a ratio between staff members and students of approximately one to ten, so that instruction may be given in small groups. The college is large enough to permit each course to be taught by specialists, and yet not so large that the student fails to receive the personal attention of his instructors. The extensive laboratories and other facilities for instruction, both fundamental and advanced, are described elsewhere in this Announcement.

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

By fulfilling additional requirements (see page 12) graduates become eligible for the professional degrees of Civil Engineer (C.E.), Mechanical Engineer (M.E.), Electrical Engineer (E.E.), and Chemical Engineer (Chem. E.).

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 Science in Engineering (M.S. in Engineering), and Doctor of Philosophy (Ph.D.) are granted by the University on the recommendation of the Faculty of the Graduate School. (See page 13).

GENERAL PLAN OF STUDIES As already stated, the course of preparatory and professional studies has been planned with a view to laying a substantial foundation for the general and technical knowledge needed by practitioners in Civil, Mechanical, Electrical, Chemical, and Administrative Engineering, so that the graduates, guided by their theoretical education, and as much of engineering practice as can well be taught in schools, may develop into useful

investigators, designers, constructors, operators, and administrators.

All students entering upon the work of the first year in the College of Engineering, except in the five-year course in Chemical Engineering, take practically the same courses during that year, it being recognized that the fundamental instruction should be substantially the same for all engineers. In general, the work of the first year comprises fundamental training in mathematics, physics, chemistry, drawing, surveying, and shop work.

Upon entering, the student is registered in one of the schools of the college and follows one of the courses of study designated therein.

FOUR-YEAR COURSES Three schools of the college offer four-year courses leading to the degree of B.C.E., B.M.E., B.E.E., or B.S. in A.E. The curriculum of the first year is given on page 56 under the head of The Freshman Year. Further on in this Announcement there will be found, under the appropriate head, particular statements of the courses of study of the last three years in each school. In the last year of each course, certain options or electives are offered, so that each student may have a certain amount of freedom in placing the main emphasis of his work upon branches of the profession in which he may be most interested. These options and the elective courses are clearly defined in the announcement of each school on subsequent pages.

FIVE-YEAR COURSES The course of study leading to the degree of Bachelor of Chemical Engineering outlines an integrated five-year course. Provision is made for a considerable amount of elective work.

Five-year courses leading to the single degree of B.C.E., B.M.E., B.E.E., or B.S. in A.E. consist of the four-year engineering courses of study modified by the introduction of the equivalent of one year of broadening training. Students must fulfill the entrance requirements of any one of the four-year courses. There are no regular schedules for these five-year courses, the student being referred to the director of the school concerned for the arrangement of studies at the beginning of each term.

In civil engineering, the A.B. degree and the degree of Bachelor of Civil Engineering may be obtained in five years plus two summer sessions. The entrance requirements for this course must correspond to those for the first degree taken.

In administrative engineering it is possible so to arrange the work of the five-year course that the degree of B.C.E., B.M.E. or B.E.E. is obtained at the end of the first four years and the degree of Bachelor of Science in Administrative Engineering at the end of the fifth year. Declaration of intention to take these five-year combinations should be made not later than the end of the second year.

It is possible to rearrange the required work in the respective four-year courses of study in mechanical and electrical engineering so that both the B.M.E. and B.E.E. degrees may be obtained in a five-year period of study. The necessary adjustment of work for this purpose must be made with the directors of the Schools of Mechanical Engineering and Electrical Engineering before the beginning of the student's second year.

SIX-YEAR COURSES The six-year courses leading to the degrees of A.B. and B.C.E., or A.B. and B.M.E., or A.B. and B.E.E., or A.B. and B.S. in A.E., require admission to the College of Arts and Sciences, in which college the student is registered during the first four years. In order to make it possible to obtain the B.C.E., B.M.E., B.E.E., or B.S. in A.E. degree at the end of the sixth year, the student must complete the freshman engineering subjects before the beginning of his fourth year, and must complete the list of sophomore subjects in civil engineering, mechanical engineering, or electrical engineering before the beginning of his fifth year. Advice and assistance in arranging such a course may be obtained by applying to the director of the school concerned.

THE REQUIREMENTS FOR GRADUATION The degrees of B.C.E., B.M.E., B.E.E., B.S. in A.E., or B. Chem.E., 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), in Hygiene, 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, including 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 Univer-

sity or elsewhere, must conform to the requirements of the class with which he graduates.

UNIVERSITY REQUIREMENTS

MILITARY SCIENCE Cornell University requires men of the Freshman and Sophomore classes to take the Basic Course in Military Science and Tactics. That requirement is precisely defined in the *General Information Number*, which should be consulted. (The Schools of Civil and Mechanical Engineering permit qualified students to elect for credit certain advanced courses in Military Science and Tactics.)

HYGIENE

The University requires all members of the Freshman class to take a course of one hour a week in Hygiene and Preventive Medicine, and requires every student to take a physical examination in the Freshman and again in the Senior year. See the *General Information Number*.

PROFESSIONAL DEGREES The degrees of Civil Engineer, Mechanical Engineer, Electrical Engineer, and Chemical Engineer, which were formerly conferred at the end of undergraduate courses, are now designated as professional degrees and hereafter will be conferred only on graduates who have been successful in the actual practice of their profession and who meet certain other requirements.* The deferred professional degrees of C.E., M.E., E.E., and Chem.E., may be awarded under the following regulations:

(a) Applicants must hold baccalaureate degrees given by this college. Applications for these degrees should be sent to the dean of the college at least one year before the time the degree is desired.

(b) Each applicant for one of these professional degrees must have had after baccalaureate graduation four years of acceptable professional experience in the field of the degree sought. Each year of graduate residence credit in this field at Cornell or at some other accredited Graduate School, or each year of teaching in that field at Cornell or in any college of comparable rank may be counted as one year towards satisfying the requirement of professional experience. Detailed statements regarding his professional experience must be submitted by persons, firms, or colleges, under whom the experience was acquired.

(c) The applicant must write and present an original thesis of a type which would be accepted as a technical paper by one of the professional engineering societies. Detailed information regarding the proposed thesis must be submitted, in duplicate, preferably before the writing of the thesis is undertaken. The thesis must be submitted in triplicate to the Dean of the Engineering College three months prior to the June Commencement, and must conform to the requirements of the Graduate School relating to theses.

*Undergraduates who matriculated before February 15, 1937, have the choice between the degrees of B.C.E., B.M.E., or B.E.E., and the degrees of C.E., M.E., or E.E., appropriate to the course of study pursued by any of them. Undergraduates who matriculated in the five-year course in Chemical Engineering before June 1, 1938, have the choice between the degree of Chemical Engineer and the degree of B.Chem.E.

(d) The applicant must present himself at the University for an examination by a Faculty Committee. Such examination may be written, or oral, or both, and cover both the subject matter of the thesis and the professional experience. The candidate must pay such fees as may be required by the Treasurer of the University.

REQUIREMENTS CHANGEABLE The College of Engineering reserves the right to modify its general courses of study 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.

ONE DEGREE IN ANY YEAR In case a person has satisfied the requirements for any baccalaureate degree he may not be recommended for any other baccalaureate degree until he has completed at least one year of further residence and of work acceptable to the faculty on whose recommendation the second baccalaureate degree is to be conferred.

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.S. in Engineering, 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.

PERSONNEL SYSTEM The College of Engineering operates a personnel system to aid the student in deciding the nature of the work for which he is best suited. It endeavors to point out his desirable as well as his undesirable characteristics with a view to correcting the latter if possible. During the first and second years the student is rated by his instructors. In the third and fourth years he is rated by a committee of five members of the faculty and five members of his own class whom he has selected as being especially capable of giving him an accurate rating. The complete rating is compiled by the personnel officer and given to the student for his guidance. By this system there is available to every student information that he could not obtain otherwise and which should be of great value to him in laying part of the foundation for a successful career. In each of the four Schools a member of the faculty has been assigned as personnel officer. The personnel officer acquaints himself with the desirable and undesirable traits of each student as indicated by the composite rating; points out to the student the

advantages of carefully developing his desirable traits; and advises the student which of the undesirable traits may be changed. With such advice the student is in a position during the highly formative period of his life, to develop the characteristics which will aid him materially in later life. During the senior year each student is interviewed and an analysis of his aptitudes is made in order that he may intelligently interview representatives of business and industry.

EMPLOYMENT PROGRAM A systematic effort is made by the College of Engineering to help every graduate find congenial employment after graduation. Each School maintains an employment bureau under the supervision of the Director. These bureaus are coordinated through the office of the Dean and are also in close touch with the University's own placement bureau.

A Five-Year Service Plan for graduates consists of circularizing the class at the beginning of each year for five years after graduation to learn of their work, success, and desires as to change in position. After that period, those desiring changes in employment are urged to keep in touch with the Employment Bureaus in their respective Schools. Graduates frequently are enabled to make desirable connections through having up-to-date information regarding themselves on file.

EXPERIMENT STATION The Engineering Experiment Station was established for the purpose of conducting scientific and technical research of importance to the engineering profession and to industries. The station affords opportunities for members of the faculty, graduate scholars, and selected undergraduates to use for that purpose not only the college's own facilities but also those of other departments of the University. The investigations may consist of analytical studies to develop new theories, laws, or concepts, or to interpret and make more useful information and data already available; they may consist of the design and construction of new and useful forms of apparatus; or they may be experimental investigations of materials and their properties or of structures, instruments, apparatus, machines, prime movers, air-conditioning equipment, heat-transfer apparatus, etc. New equipment is bought or constructed as needed.

In laboring to advance the science or the art of engineering the experiment station gives the members of the teaching staff a ready means of keeping abreast of the times and serves also as a stimulus to

inquiring students. All members of the Faculty are encouraged to use the station's facilities in their own research or in supervising that of the John McMullen Graduate Scholars and other advanced students.

The Dean of the College is director of the experiment station and chairman of a managing council which includes the Directors of the four Schools and a committee on research assisting each of the four. The station publishes bulletins giving reports of completed investigations.

Funds for the experiment station's work are derived from direct appropriation by the University and also from the income of special endowments. The *Harold I. Bell Research Fund* of $5,000 was established in 1922 by Mrs. Ellen Foster Bell in memory of her husband, a member of the Class of 1905, for the promotion of research in hydraulic engineering and related fields. The income of the *Henry Herman Westinghouse Endowment Fund* of $500,000, given by the late H. H. Westinghouse of the Class of 1872 and established in 1933, is devoted, in accordance with the donor's wish, to the advancement of the science of engineering by means of research.

In addition to the investigations permitted by the experiment station's own funds the station or the college conducts *cooperative research*. This is done for companies or associations in trade or industry or for government bureaus. It involves experimental work for which there are facilities here and which is financed, at least in part, by those sponsoring the work.

MISCELLANEOUS INFORMATION

Other Facilities. In addition to the various school and departmental libraries of the college, the Cornell University Library is available to engineering students. This library contains one of the largest collections of its kind in the country. Mathematics is taught in White Hall, adjacent to the Engineering College buildings. Instruction in physics is given in nearby Rockefeller Hall, a large and well equipped building used solely for work in this field. This building also houses the library of the Department of Physics. Many other University buildings are used by students taking elective courses, or required courses in English, economics, and other non-technical subjects.

Nonresident Lecturers. Supplementing the regular class-room instruction, lectures are delivered from time to time by non-resident specialists in the profession on various subjects related to the many branches of engineering. Students may attend also the many public scientific

lectures given in other departments of the University by local or non-resident lecturers.

Inspection Trips. At appropriate times during their course the students of the various schools are taken on supervised inspection trips for the purpose of studying commercial, industrial, and engineering applications of the principles inculcated in the classroom, and affording them opportunities to observe typical engineering projects in the actual processes of development, as well as important ones that have been completed.

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. 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 hours for work on this magazine are given by the Schools of Civil, Mechanical, and Electrical Engineering.

Many 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, 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.

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, who makes a public announcement of the names of those students at an event known as

"honors night" which the college holds in the spring of each year. The honor students comprise approximately the highest tenth of all the students enrolled in the college.

School of Civil Engineering

EQUIPMENT The principal building occupied by the School of Civil Engineering is Lincoln Hall, containing classrooms, drafting rooms, laboratories, museums, 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 Laboratory is housed in a separate building and is 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. Experimental work is now being carried on at the laboratory by the United States Soil Conservation Service as a part of its national program of control of soil erosion.

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 Mechanics Laboratory, equipped for demonstration and experimentation in connection with the undergraduate instruction in mechanics; 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 are 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. (For outlines of courses of study, see pages 62–72.)

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.

Following is a brief outline of the scope and purposes of instruction in the various departments of the School of Civil Engineering:

Drawing and Descriptive Geometry. Engineering drawing is the graphic language of the industrial and professional world, and is used by engineers because of its exactness of expression. It is very important that the engineering student understand the basic principles of this universal language as well as obtain facility in the art of drawing. The elementary courses offered give practice in the handling and use

of instruments as well as training in accuracy, neatness, and speed. Descriptive geometry strengthens the power and habit of logical and exact thinking, and increases the ability to visualize in space. The advanced courses emphasize the use of theory in professional practice and provide knowledge and skill in making engineering drawings. The technical training acquired by the student engineer in these courses is important and necessary for his design courses, laboratory work, and later, his professional service.

Surveying. An important branch of civil engineering is the making of surveys for the accurate location of properties, for the purpose of mapping, and for the control of engineering works. Instruction is given in this department in the use of surveying instruments, in precise leveling and measuring, and in making topographic, hydrographic, subterranean, and geodetic surveys. The student is taught the elements of field astronomy, and makes astronomical observations in relation to survey control. Instruction is given in the principles and present practices in photographic and aerial surveying. An important feature of the instruction in this department is the work done by all students in the school at the Summer Survey Camp near Cayuta Lake, New York. Field practice is here given in topographic surveying, hydrographic surveying, and in precise leveling. Railroad and highway location surveying practice is also provided for the students. They become familiar with field organization, and hold the various positions in field and office parties.

Mechanics of Materials. In this department classroom and laboratory instruction is given to the student in the principles of mechanics as the fundamental basis for the design of engineering structures and works. An important feature of instruction in this department is the work done by the student in the laboratory, where he observes dynamical actions and the behavior of structural members under load. Demonstration and verification of the behaviors studied in the classroom are here developed. Opportunity is afforded the advanced student in mechanics for analytical and experimental work in the theory of elasticity, in photo-elasticity, in the application of analogies, and in the use of models as they apply to engineering analysis and design.

Materials of Construction. The purpose of the work in the department is to acquaint the student with the processes of manufacture of the materials of construction, and the properties of these materials which are important in their behavior in engineering structures. In the laboratory the student is afforded opportunity to observe the actual behavior of materials under load and other service conditions. It is not the purpose of this instruction to develop laboratory techni-

cians, but rather to provide the student with physical experience and concepts of the behavior of materials of engineering.

Hydraulics and Hydraulic Engineering. The work in this department begins with the fundamental behavior of fluids and continues into the design and operation of hydraulic works. In the Hydraulic Laboratory the student is instructed in the principles of hydraulic flow and measurement. The advanced student is afforded opportunity for study in hydrodynamics, experimental study in channel flow, pipe lines, weirs, spillways, and other hydraulic units. In water power engineering the student is given instruction in the methods of developing hydraulic power, the principles underlying the design and use of hydraulic machines, and in hydroelectric development. Instruction is given in the development and operation of public water supplies, reclamation, canalization, and river and harbor development.

Municipal and Sanitary Engineering. The object of the instruction in this department is to provide the student with the principles underlying sewer systems, the treatment of sewage, water supply and distribution, purification of water, operation of sanitary works, and trade wastes, and their treatments. Fundamental instruction in classroom and laboratory is given in sanitary biology and chemistry underlying the biological processes utilized in the purification of water and the treatment of sewage.

Transportation Engineering. The work in this department relates to the location, construction, operation, maintenance, and economics of various agencies of transportation. Instruction begins in the economic location and construction of railways and highways, and continues with study covering maintenance-of-way and the operation and management of railroads and highways. A feature of the work in highway engineering is the laboratory instruction giving students experience in the study and testing of soils of highway subgrades, and in the testing of materials used in road construction.

Structural Engineering. In this department the student receives instruction in the design of bridges, buildings, and other structures of timber, masonry, concrete, steel, and other materials. Instruction is also offered in more advanced forms of bridge and building design and in the principles underlying their analysis. The student is also given instruction in the principles and methods involved in foundation work for bridges, buildings, and other land and waterfront structures. The new and growing field of soil mechanics is being developed as a part of the work of this department.

Regional and City Planning. Instruction in regional planning is given by the Colleges of Engineering and Architecture in cooperation. The

work does not recognize regional or town planning as a separate profession, and hence no attempt is made to give the student technical proficiency in planning, nor even any large array of factual information. The courses deal in a broad way with the adaptation of man's environment to his needs and desires. A study is made of past and possible future achievement in the field of planned and controlled developments of public and private properties as the necessary basis for better living. Emphasis is placed on the fact that historically and logically the problems presented by large-scale planning are so difficult that no one professional group is competent to comprehend them, much less to solve them. It is shown that actual achievement must finally rest on the united efforts of groups composed of people of diverse interests and widely varying training. The courses offered are therefore open to upperclassmen and graduates in all colleges of the University.

Administrative Engineering. See page 38.

Research. Undergraduates who have shown the requisite proficiency and have available the necessary time may conduct special investigations under expert guidance. Such special work may consist of an analytical study or discussion of data, reports, and other engineering information already available, or it may be devoted to a design or construction or both of technical importance, or it may be an original investigation—analytical or experimental or both. In case the investigation or research is sufficiently extended, the student is encouraged to embody the work in a thesis. A limited number of seniors who have shown special ability for investigation may substitute research for some of the usual senior electives. See Course 297. Arrangements for research and thesis should be made with the Director of the School and the department concerned, preferably during the junior year.

EMPLOYMENT AFTER GRADUATION

Civil Engineering graduates find employment in both technical and general business enterprises. In the technical field they are employed in surveying operations of all kinds, including land surveying, construction surveys, aerial surveys, and in the geological and geodetic surveys of the U. S. Government; in the design and construction of irrigation, reclamation, river and flood control, harbor improvement, and hydroelectric projects; in designing and constructing water supply systems, sewerage systems, filtration and purification plants; in the location, maintenance, construction, and operation of railroads; in all classes of highway work; in the design and construction of steel and

reinforced concrete bridges and also of steel frame and reinforced concrete buildings; and in examining and testing the properties of materials. There is a growing field of service for the civil engineer in city and regional planning and in city management. Many civil engineers are also engaged in contracting. In the field of general business, experience clearly indicates increased opportunity in many business enterprises for the graduate in civil engineering because the training in analysis and precision are assets of value in the fields of finance, valuations, and real estate, and in other kindred activities of the business world.

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 large 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, for determination of the physical properties of engineering materials under different kinds of stress and heat treatment; the Photo-Elastic Laboratory, for instruction and research in photo-elastic 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. Hydraulic 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 Cement Laboratory, for the testing of cement and concrete; the Fuel Testing Laboratory, for determination of the composition and calorific value of all types of fuel; the Belt Testing Laboratory, for measurement of belt tension, power transmitted, and slip; the Micro-Motion Laboratory, for time and motion study; the Introductory Engineering Laboratory, for demonstrating the principal operations in forging, welding, soldering, braz-

ing, etc.; the Heat Transfer, Heating, Ventilating, Air Conditioning Laboratories; a series of Research Laboratories; the Forge Shop, Woodworking and Pattern Shop, Machine Shop, Foundry, and Boiler 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 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, boilers and power plant auxiliaries, gas and oil 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.

Based upon the fundamental instruction of the freshman year, and that given in the sophomore year in the mechanics of engineering, advanced applied mathematics, materials of construction, kinematics and drawing, economics, and machine construction, the junior student in mechanical engineering receives training in fluid mechanics (including hydraulics), machine design, shop processes, industrial organization, accounting, heat-power engineering, experimental engineering, and electrical engineering. In the senior year the student receives further training in the last three subjects and in heating, ventilating, and refrigeration, and also takes the courses outlined in one of the Senior Options. The respective Options provide for some degree of specialization in Steam Power Plant Engineering, Heat Engineering (including fluid flow, heat transmission, refrigeration, and air conditioning), Industrial Engineering, Automotive Engineering, Aeronautical Engineering, Water Power Engineering, Metallurgical Engineering, or in some other field allied to Mechanical En-

gineering; and, they also offer opportunity to elect various other courses of an advanced nature, such as those listed on page 108. The special work in these Options (A to H incl.) is described on pages 98–105. (For complete outlines of the four-year, five-year, and six-year courses in Mechanical Engineering see pages 97–108.)

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

Mechanics of Engineering. In this department instruction is given in theoretical and applied mechanics, hydraulics, fluid mechanics, and applied mathematics beginning with a course for sophomores in the fundamental principles of statics, kinetics, strength of materials, and hydraulics. An effort is made to teach students to think rather than to memorize. With this in view the free-body method is used in the solution of problems involving forces, and students are required to work from fundamental definitions and principles rather than from formulas. For seniors elective courses on hydraulic power plants are offered. While the theory of turbines is outlined, stress is laid upon the practical side of the subject, the object being to make the course of definite value for those expecting to take up hydroelectric work. The laboratory instruction in hydraulics is given in the Department of Experimental Engineering. Advanced courses in photoelasticity and applied elasticity are also offered.

Machine Design. In this department instruction is given in kinematics and machine design to sophomores and juniors in mechanical, electrical, and administrative engineering. Instruction in machine design is also given to seniors in chemical engineering. The department also offers elective courses open to sophomores, juniors, seniors, and graduates. Instruction is given by means of recitations and work over the drawing board. Kinematics is studied and applied to the solution of cam, gear, linkage, instant center, velocity, and acceleration problems. The courses in kinematics are followed by recitation and drawing room instruction in general machine design. The theory and principles developed are applied to the solution of many short problems in the class room and to the solution of longer problems in the drawing room for which computations and drawings are made. Only such problems as lend themselves to rational analysis to the greatest degree are selected. The calculations are regarded as an important part of the work and the student's design is criticized from the standpoint of appearance, cost, convenience, and economy of shop

operations, lubrication, accessibility, ease of assembly, economy of upkeep, etc.

Heat-Power Engineering. Instruction in this department is given to all juniors and seniors in mechanical engineering, juniors in electrical and administrative engineering, and seniors in civil engineering, with the object of training them to solve problems involving the theory, design, performance, selection, and economics of steam, internal-combustion and other heat engines, refrigerating machines, gas compressors, and related auxiliary equipment, considered both separately and in combination in power plants. This instruction in fundamentals begins with lectures and recitations on the elements of heat-power engineering, including the study of the thermodynamic properties and processes of gases, vapors, and mixtures; ideal and actual gas and vapor cycles; air compressors; internal combustion engines; and steam engines. This is followed by a study of steam turbines, fuels, combustion, heat transmission, flow of gases and vapors, furnaces, steam-generating units, draft apparatus, condensers and other heat exchangers, refrigeration, the utilization of waste heat, and other related topics. Two senior options are offered by this department, one in Steam Power Plants, and the other in Fluid Flow, Heat Transmission, Refrigeration, and Air Conditioning. Elective courses are also offered on steam turbines, power plant economics, steam generating equipment, internal combustion engines, refrigeration, and graphical computations.

Mechanical Experimental Engineering. Instruction in this department begins in the sophomore year with the study of materials of engineering, their manufacture, properties, and uses. Throughout the junior and senior years the student receives instruction in the completely equipped mechanical laboratories not only to familiarize himself with the various types of testing apparatus and to give him skill in their use, but also to teach him the best methods of research. Briefly, the courses include: the testing of engineering materials, with determination of influences of composition and heat treatment; the calibration and use of indicators, gauges, thermometers, dynamometers, etc.; tests of lubricants; fuel calorimetry; steam calorimetry; tests of boilers, steam engines, turbines, pumps, heaters, condensers, injectors, and other steam apparatus; tests of heat transfer; tests of fans, air compressors, and refrigerating machines; tests of internal combustion gas and oil engines; and tests of hydraulic machinery.

Industrial Engineering. All seniors in administrative engineering and seniors in mechanical engineering who elect the Industrial Option

receive in this department instruction in the principles and present problems of Industrial Engineering. The principles governing manufacturing methods are studied and a layout made for a modern manufacturing industry. Methods of production and materials control are studied as well as organization and engineering economy. The subject of time and motion study is presented, including micro-motion study and the principles of motion economy. The department conducts a micro-motion laboratory equipped with the necessary motion picture apparatus. The course in Advanced Industrial Relations includes a consideration of the human problems of management, which are studied by the case method. In the course in Industrial Auditing, the theory and practice of auditing pertaining to industrial concerns are studied.

Automotive Engineering. Since automotive engineering is merely a branch of the general field of mechanical engineering and is dependent on the basic preparation covered in the first three years of the regular curriculum, the special instruction of the Automotive Option is deferred until the senior year. This special work covers the wide variety of theoretical and practical problems in design and operation which are of great importance in the industry; applies the fundamental principles that have been studied in the previous years; reviews the topics that are usually covered by books on the subject; and makes a special study of current developments. The instruction is given by means of lectures and computing courses. The lectures may be elected by seniors in other options. Provision is made also for conducting experimental investigations in this field.

Aeronautical Engineering. In this field the College does not offer a complete four-year course, for the main reason that, under the Guggenheim Foundation, there are at the present time six or eight schools of engineering in the country offering such courses, and the number of graduates annually turned out is more than sufficient to supply the field. In accordance with the recommendation of the Foundation, therefore, this College is offering only a few courses in Aeronautics, beginning with the junior year and including an option in such work in the senior year. This amount of training constitutes a good foundation upon which to base advanced work in the same field in any one of the schools offering complete courses of study in Aeronautics.

Hydraulic Power Plant Engineering. The work of the water-power engineer includes a combination of civil, mechanical, and electrical engineering. Hence the special courses offered in this field are designed to cover all those topics which are essential to an intelligent co-

operation among all classes of engineers, whether engaged in the design, construction, or operation of water-power developments or in the transmission and distribution of the energy. The work of the option in this field is confined to the senior year. It gives special emphasis to the financial and economic phases, including the elements of design and construction which affect economical operation. Included in the option is a course in electrical engineering which covers the electrical power plant, transmission, and distribution. The object of the instruction is to present a complete picture of the problem, from the water in the stream to the sale of energy to the ultimate consumer. Arrangements are made, as opportunities occur, for inspection trips to waterpower plants under construction or completed, and students in this option have the privilege of joining in any such trip if they wish to do so. Those students who can spend five years are urged to combine this option with the course in electrical engineering; elective courses in the Department of Heat-Power Engineering ought also to be included, because the present-day power system usually includes thermal plants. In the five-year period the B.M.E. and the B.E.E. degree may both be obtained. For the details of this combination the student should consult the Directors of the Schools of Mechanical and Electrical Engineering as early as possible, preferably before beginning the second year.

Metallurgical Engineering. As the iron and steel and other metal producing or fabricating industries employ a larger percentage of graduates in mechanical engineering than other industries do, a metallurgical option is offered for students interested in this field of engineering. The courses in the option do not, however, constitute a complete curriculum in Metallurgy, for such a curriculum would require greater specialization in Physical Chemistry, Metallography, and Metallurgy than can be included in a course primarily devoted to mechanical engineering. The option does, however, give the student a good start in this branch. The special work begins in the junior year with a course in Introductory Metallography, and Analytical Chemistry. This is followed in the senior year by courses in Physical Chemistry, Applied Metallography, and Furnace Metallurgy.

Mechanic Arts. The object of the instruction in this department is not only to familiarize the student with modern shop operations and processes, and with the workability of materials used in engineering construction, but more particularly to give him instruction in the principles of manufacturing and duplication of parts, and in the selection and arrangement of shop equipment.

The work of the freshman year in the shops is given in a laboratory course and in the wood shop. The laboratory course is designed to familiarize the student with current engineering terms and common engineering appliances. This course also includes some work in the forge shop illustrating the principal operations, like welding, hot working, gas and electric welding.

Instruction in wood-working is given with the object not only of familiarizing the student with wood-working tools and machines and their use, but more especially to teach him pattern and core-box making. Instruction is also given in large pattern work and sweep-work.

In the sophomore year the student receives instruction in the foundry in molding, core making, mixing of metals, operation of cupola, the uses of moulding machines, etc., with consideration given to the methods and appliances for sweep-work, large work, and production in quantities.

In the junior year the principles of manufacturing are taught, supplemented by work of an illustrative character in the machine shop, where carefully graded instruction is given in the use of measuring instruments, hand tools, and machine tools, including semi-automatic and automatic machines, and in the use of jigs and special fixtures for manufacturing in large quantities. The administration of this shop in particular is intended to illustrate as far as possible approved methods of shop management and operation, and to give the students a general idea of time keeping, piece work, premium plan, and other wage systems. The instruction is given to a great extent in connection with the construction of commercial machines.

Engineering Research. Undergraduates who have shown the requisite proficiency and have available the necessary time may aid in the investigations conducted by the Engineering Experiment Station (see page 14) or conduct special investigations of their own under expert guidance. Such special work may consist of an analytical study or discussion of data, reports and other engineering information already available, or it may be devoted to a design or construction or both of technical importance, or it may be an original investigation—analytical or experimental or both. When occasion offers, qualified students may assist in commercial tests, made at the University or elsewhere, of materials, prime movers, machines, power plants, air conditioning equipment, etc. In case the investigation or research is sufficiently extended, the student is encouraged to embody the work in a Thesis.

A limited number of seniors who have shown special ability for investigation may substitute Research (or Thesis) for some of the usual senior electives or for courses in an option.

Arrangements for Research or Thesis should be made with the director of the school and the department concerned, preferably during the junior year.

EMPLOYMENT AFTER GRADUATION Mechanical Engineering applies to nearly all branches of industries; hence, it is called upon for the design, construction, operation, and testing of prime movers and other machinery, and of complete plants of many kinds, not only in its own immediate province but in the various other fields of engineering. Mechanical engineers serve also as planners of new projects and processes, and as power plant engineers, industrial engineers, fuel and combustion engineers, automotive engineers, aeronautical engineers, refrigeration engineers, air-conditioning engineers, and water-power engineers—to mention but a few of the many special fields open to them. Their training often serves also as an important foundation for employment in various branches of business connected directly or indirectly with engineering.

School of Electrical Engineering

EQUIPMENT The School of Electrical Engineering is housed in Franklin Hall, in a portion of Rand Hall, and at the Broadcasting Station and Studios. The school's library, which is housed in Franklin Hall, is the Alexander Gray Memorial Library, so called because it originated in a generous gift of the McGraw-Hill Book Company in memory of Professor Gray, a former teacher here. Laboratories and demonstration facilities of the school include the Lecture Room, with provision for experimental demonstrations to accompany the earlier lectures in electrical principles and applications; the Electrical Machinery Laboratories, with a great variety of both direct and alternating-current machines; the Electronic Laboratory, equipped for a wide variety of tests; the Standardizing Laboratory, for checking of secondary standards and meters; the Electrical Communication Laboratory, well provided with apparatus to illustrate modern electrical communication; and the Broadcasting Station and Studios, from which numerous University programs are broadcast, and which are available for instruction and research.

OUTLINE OF THE INSTRUCTION The four-year course in electrical engineering provides a strong fundamental training in the

analytical study of scientific subjects common to all branches of professional engineering. On this foundation is built a broad introduction to the basic work in the several branches of general engineering technology, economics, and administration, together with a major study of electrical engineering principles and their application in various fields.

In the last three years of the course students receive a thorough training in electrical engineering, in addition to training in applied mechanics, machine design, thermodynamics and heat power, and mechanical laboratory. The instruction in electrical engineering is of a distinctly scientific character and requires analytical ability of a high type. Instruction is given in the theory of electricity and magnetism, electrical machinery, radio tubes, rectifiers, electrical circuit analysis, mathematical applications, and the theory and practice of electrical engineering. Laboratory work serves to amplify, and is given in parallel with the theory. Opportunity is offered seniors to specialize to a limited extent in such subjects as application of electricity to transportation problems, electric power generation, transmission, and distribution, electric lighting, communication engineering, and research. Opportunity is also offered to those students who have a special liking for physics or chemistry to specialize in those subjects. (For courses of study see page 129.)

A large proportion of the work in mechanical engineering is also taken by those who elect electrical engineering, so that the student is not limited in his outlook or in his choice of work after graduation. For those desiring a still broader training, which shall include more of the liberal arts, a six-year course leading to the degrees of A.B. and B.E.E., is offered. (See page 130.)

The study in electrical engineering proper is begun in the sophomore year, as soon as the student is sufficiently advanced in the fundamental sciences, and gradually becomes the major study. In the senior year the student is given considerable opportunity to study in the field which most interests him, although with no neglect of the more advanced study of basic electrical engineering principles.

The instruction in mathematics, physics, chemistry, and English is given in the College of Arts and Sciences. All other subjects in the regular curriculum are given in the various departments of the Sibley School of Mechanical Engineering, the School of Civil Engineering, and the School of Electrical Engineering.

Following is a brief outline of the scope and purposes of instruction in the various departments of the School of Electrical Engineering:

Fundamentals of Electrical Engineering. Beginning with the second

term of the sophomore year, instruction is given in fundamental electrical phenomena and relations, in the characteristics of electric, magnetic, and electrostatic circuits, and in the characteristics of direct current generators, motors, and allied equipment. The work is carefully arranged in sequence and difficulty to promote efficient study and effective understanding. The physical phenomena are expounded and demonstrated in the lecture room together with their mathematical analysis. Study of lecture material and text is assigned for home work and applied to the solution of simple problems. More difficult problems are solved in the computing room under the supervision of the instructor, and recitation periods are provided for the prompt clarification of common difficulties in concept, analysis, application, or computation.

Care is exercised, not only to build in the student's mind an orderly fund of factual information in which he may find continued confidence, but also to teach him to apply his information effectively and to develop his judgment, sense of proportion, and accuracy.

In the junior year instruction is given in alternating current fundamentals, in characteristics of *ac* circuits, and in *ac* machinery and equipment. The work is conducted in manner similar to that pursued in the sophomore year.

The work given to mechanical and administrative engineering students is no less fundamental than that given to electrical engineering students but is necessarily less extensive and is selected and presented in sympathy with their probable needs and point of view. Instruction is conducted, as for the electrical students, by lecture, home work, computation, and recitation in a carefully coordinated sequence of study.

Advanced Electrical Engineering Theory and Practice. The object of the instruction in this department is to train the student in the principal quantitative methods and mathematical tools used in electrical engineering. First a bit of theory is taken up at a lecture or a recitation and a few simple numerical problems are solved by the student at home; then at least one practical application of the same theory is discussed, and finally a more elaborate practical layout is analyzed in the computing room. It is aimed to teach the theory and practice side by side, except in the junior year where some mathematical topics are taught in anticipation of their use during the senior year.

From the point of view of electrical engineering, the course consists of four main divisions: the electric circuit, the magnetic circuit, dielectrics, and gaseous conduction of electricity. From the point of view of mathematics, in addition to the usual analytic geometry and

calculus, the following topics are taught and made use of: determinants, complex quantities, vectors, Fourier series, differential equations, hyperbolic functions, and probabilities.

A separate elective course in Engineering Mathematics is given to those seniors who wish to pursue a special mathematical topic, or who are interested in one of the foregoing topics beyond their required scope.

Circuit Analysis. The term circuit is here used in its most general sense to cover electric, magnetic, and dielectric circuits. The instruction is planned to include power and communication networks in both the steady and transient states and to furnish a critical analysis of the design and operating features of electric machines.

In the second term of the junior year a study of circuit analysis is undertaken. This covers such mathematical tools as determinants, complex numbers, vectors, sine functions, dimensional analysis, and Fourier's series. Application of these tools to circuits and networks possessing constant as well as variable characteristics is then given.

In the first term of the senior year further applications are treated which cover the transient as well as the steady state phenomena in circuits possessing lumped and distributed characteristics.

The second term of the senior year is devoted to the study of electric machines and covers the design and operating features of transformers, synchronous, induction, and commutating machines.

Students interested in advanced circuit analysis are offered a course in Heaviside's Operational Analysis as an elective. This deals with the Laplacian Transform solutions of the transient and steady states in networks comprising lumped and distributed properties.

Other courses offered in this department include studies of the properties of magnetic and dielectric materials, and a seminar in Circuit Analysis.

Experimental Electrical Engineering. Throughout the junior and senior years the student receives instruction in the electrical laboratories which closely parallels and is coordinated with the theoretical instruction. The laboratory work is carried on with the purpose of developing in the student a scientific attitude of research as well as to teach him the characteristics of the equipment and the methods of testing. In the first term of the junior year the student prepares experiments on direct-current circuits, generators, motors, and controllers and alternating-current circuits and measurements. The second term is devoted entirely to electronics with experiments on vacuum tubes, gas conducting devices, mercury vapor rectifier, and inverters. In the senior year the student gets a more advanced course in electrical

machinery, covering the operation of generators in parallel, synchronous generators and motors, converters, transformers, and a study of the properties of magnetic and dielectric materials. This work is planned to afford constant original application of principles previously covered in the theory courses.

Electrical Communication Engineering. In the courses in Communication Engineering the problems of radio, telephony, and telegraphy are treated. The student in the second term of the junior year is given a course on the fundamentals of electronic devices, and studies their characteristics and theory of operation. While the course in electronics is not specifically limited to apparatus designed for communication purposes, it does treat of the fundamentals of electron tubes and similar apparatus, and serves as a basis for the more advanced instruction during the senior year. The work of the first term, senior year, is devoted to a study of communication apparatus and circuits, with special emphasis on the application of thermionic tubes to the art. The work of the second term is a continuation of the first term, and treats of the more advanced aspects of electrical communications, such as transmission theory over wires and through the ether, radiations systems, and associated circuits. In two auxiliary courses offered during the second term, the student is given an opportunity to specialize to a limited degree either in advanced circuit theory or practical operation.

Electrical Design. The object of this course is to set forth the fundamental principles upon which the design of electrical apparatus, such as generators, motors, and transformers, is based. Instruction is given both by recitation and computation of typical machines. This course is particularly recommended to those students who anticipate employment by electrical manufacturing companies.

Power Generation, Transmission, and Distribution. These subjects are studied not only from a technical viewpoint but also from the economic viewpoint as well. While it is recognized that a thorough understanding of the technical problems arising in power generation, transmission, and distribution is essential, it is also recognized that the economic problems arising in this field are no less important.

Economics of Public Utilities. As the name implies, this course is a study of the economic questions arising in the conduct of public utilities, particularly electric utilities. The importance of such a study is hardly open to question.

Electrical Applications and Control. Courses are given in this department covering the principles of electric railway practice and industrial applications and control.

Illumination. The development of lighting equipment and its application are very live and promising fields for the engineer. The electrical engineering student who is fortunate enough to combine strong artistic sensibility with his engineering proficiency is equipped for outstanding achievement in illumination. Courses in the engineering principles involved are regularly given and special work may be taken by arrangement.

Electrical Engineering Research. Undergraduates who have shown the requisite proficiency and have available the necessary time may conduct special investigations under expert guidance. Such special work may consist of an analytical study or discussion of data, reports, and other engineering information already available, or it may be devoted to a design or construction, or both, of technical importance, or it may be an original investigation—analytical or experimental or both. In case the investigation or research is sufficiently extended, the student is encouraged to embody the work in a thesis.

Undergraduates who have shown proficiency in the conduct of research will be permitted (at the option of the faculty) to substitute research for some of the senior electives.

EMPLOYMENT AFTER GRADUATION

Graduates in Electrical Engineering find employment with manufacturing companies in connection with the design, construction, testing, and application of electrical equipment; with public utilities in connection with the generation, transmission, and distribution of electrical energy, and in the sale of the same to the consumer. They are also employed to determine the costs involved, and the utilization of electricity and the rates charged for this service.

With the continued increase in use of electricity in industry, electrical engineers are needed in all industrial plants to select and install new equipment for motor drives, electric heating processes, electric welding, transportation, electro-chemical and electro-metallurgical processes, etc.

In the communication field many graduates are employed in connection with the design and manufacture of radio receiving sets, broadcasting equipment and the design and operation of broadcasting stations, as well as in the telephone and telegraph industries.

Men gifted with originality and scientific imagination find opportunities for employment in research and in the development of new applications for electric power.

The analytical and practical training provided in the course in

electrical engineering is of great value in the field of general business, and many graduates are so employed.

School of Chemical Engineering

EQUIPMENT The specialized training in Chemical Engineering and the general instruction in Chemistry for all students are given in the Baker Laboratory of Chemistry, which is adjacent to the engineering buildings. Students in Chemical Engineering thus have convenient access to extensive stocks of chemical supplies and apparatus and to the combined library for Chemistry and Chemical Engineering, which is unusually well supplied with reference books and journals dealing with these subjects.

The large laboratory for Unit Operations of Chemical Engineering is provided with experimental and semi-plant scale equipment for the study of fluid flow, heat transfer, evaporation, fractional distillation, gas absorption, filtration, drying, grinding, liquid extraction, and other operations. A 21-plate fractionating column is available for use both for batch distillation and for continuous distillation. The double-effect vacuum evaporator is provided with one horizontal unit and one vertical unit. Many of the pieces of equipment in this laboratory have been designed here, especially for use in experimental work.

Laboratory space and shop facilities for research in Chemical Engineering are also available.

Laboratories for metallography, chemical microscopy, and other special fields in Chemical Engineering and Chemistry provide useful adjuncts for instruction and research on materials and processes.

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 field of chemical engineering. In the required curriculum a certain amount of work in cultural subjects is included. By providing for a certain amount of 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.

Students receive during the first two years a thorough training in the fundamental subjects upon which their specific professional work

is based: mathematics, physics, introductory, analytical, and organic chemistry, English, and German. The third and fourth years include more strictly technical and more advanced courses in engineering and in chemistry, and the fundamental courses in the specific field of chemical engineering. The fifth year includes the more advanced work in engineering and in the specialized field. (For an outline of the course of study see page 138.)

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 connection with the selling of chemical products and chemical engineering equipment. A relatively large number of the graduates in Chemical Engineering continue their specialized training as graduate students in Chemical Engineering or in Chemistry and eventually receive industrial positions as research chemists or research chemical engineers.

Administrative Engineering

PURPOSE OF THE INSTRUCTION The large number of engineering graduates who hold administrative positions is evidence of the usefulness of a training for these positions. Engineering methods are finding increased application in problems of executive management. This is due in part to the increasing scientific development underlying the operation of works and processes, and in part to the nature of the training of the engineer in fact gathering and analytical study.

Students of Administrative Engineering in three Schools of Engineering (C.E., M.E., E.E.) receive substantially the same basic training in mathematics, physics, chemistry, geology, economics, mechanics, surveying, shopwork, materials, etc., as the other engineering students. In the more specialized technological subjects covered in the latter part of the regular courses in civil, mechanical, or electrical engineering the work is shortened by not quite one half to provide place for a coordinated group of courses in Business Organization and Management, Accounting, Money and Banking, Statistical Theory and Practice, Marketing, and Business Law, together with English, Technical Writing, and Public Speaking. The aim of these

courses is to preserve the basic content and spirit of the engineering training but to incorporate with it training in the fundamentals of business management.

IN MECHANICAL ENGINEERING It is recognized that the four functions of business and industry are marketing (including selling and advertising), production, finance, and accounting. Accordingly, the Department of Administrative Engineering in the School of Mechanical Engineering gives a basic course in Business and Industrial Management in the sophomore year to orient the student in commercial thinking. This course is paralleled by one in basic economics. Upon these two courses are built a series of carefully coordinated courses in English, Technical Writing, Accounting, Cost Accounting, Corporation Finance, Public Speaking, Industrial Relations, Statistics, Business Law, Industrial Engineering, Production Management, and Marketing. To supply the even closer contact with the outside world, a series of special lectures is given by business leaders who appear weekly before the senior classes.

In the special course in Administrative Engineering for mechanical engineers, the freshman year is the same as that given to other engineering students. During the next two years all students are required to take a balanced group of technical and economic courses. In the senior year a certain degree of specialization is permissible.

About 68 per cent of the course content, as given to the students in the Sibley School of Mechanical Engineering, is devoted to regular engineering subjects. This gives the course a substantial groundwork in fundamental engineering, a prime requisite for the principles of scientific management. These principles have spread to almost every phase of human endeavor but their background is still engineering. The remaining 32 per cent of the course is made up of subjects devoted to business and economics especially designed to fit the needs of modern industry. For an outline of the course of study see page 107.

IN ELECTRICAL ENGINEERING The course differs from that offered in mechanical engineering in that more stress is given to fundamental electrical engineering with special reference to the applications of electrical power and to public utility engineering. See page 130.

The requirements for admission are the same as for the regular four-year B.E.E. course. See page 40.

It is possible by an additional year of study to receive the degree of Bachelor of Electrical Engineering, provided the student signifies this intention at the beginning of the sophomore year.

IN CIVIL ENGINEERING In order to strengthen the instruction in the economic, financial, legal, and functional aspects of business without at the same time sacrificing the fundamental instruction of civil engineering in its various branches, the School of Civil Engineering offers an Administrative Option leading to the degree of B.C.E., also a four-year course in Administrative Engineering leading to the degree of B.S. in Administrative Engineering (B.S. in A.E.). Students working for the regular B.C.E. degree also take some of the administrative courses such as Engineering Law 290 and Engineering Management 293. See pages 65 and 71.

EMPLOYMENT AFTER GRADUATION Administrative engineering, considered as an application of civil, mechanical, and electrical engineering, occupies the wide border region in which there is an overlap of business management and technical engineering. Administrative engineering graduates, having had the same basic training as graduates in civil, mechanical, or electrical engineering, are fitted to start in on essentially all kinds of positions open to the latter. They do not, however, as a rule, take positions leading definitely toward careers in technical design or research. To do so is to waste a part of their special training. Their ultimate work is normally in the fields of production, accounting, finance, marketing, contracting, valuation, city management, research in problems of management, etc., or, in general, any part of the field covered by the general term management.

The opportunities in the field of administration for one trained as a civil engineer have been increasing with special rapidity in recent years. Railroad and public utility operation and management, highway administration, the broad field of construction, the operation and maintenance of public works, transit systems, river and harbor facilities, power developments, reclamation and conservation works, city and regional planning, and city management, offer large and rapidly growing fields of administrative service for the civil engineer.

This training is also useful in such business-engineering fields as sales engineering, purchasing, efficiency engineering, promotion, appraisal and valuation work, statistical and economic studies as related to construction, and the work of municipal, state, and federal officials.

Admission to the College

THE METHOD OF APPLICATION All correspondence concerning admission to the College of Engineering should be addressed to the Director of Admissions, Cornell University, Ithaca, N. Y., who will forward the necessary blank form of application on request. All credentials relating to the admission of a new student should be sent to the Director of Admissions as early as possible and in no case later than the first day of September.

An applicant for admission must not only satisfy the entrance requirements of the College of Engineering, which are printed on page 40, but must also comply with the University's rules governing admission. These rules require, of every applicant for admission to an undergraduate course of study, (1) a certificate of good character, (2) a deposit of $25, and (3) a certificate of vaccination against smallpox. These rules are fully and clearly stated in the University's *General Information Number*, which every candidate for admission should read carefully and which can be obtained by application to the Secretary of the University.

FOUR WAYS OF ENTRANCE There are four ways of satisfying the entrance requirements. They are fully described in the University's *General Information Number*, which every candidate for admission is advised to consult. In brief they are as follows:

1. By passing the required Cornell University entrance examinations.
2. By passing the College Entrance Examination Board's examinations in the required subjects.
3. By passing the necessary Regents examinations. This option is for students who have prepared in New York State.
4. By presenting an acceptable school certificate.

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. Since the number of applicants exceeds these limits 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 and who show evidence of professional promise.

ADMISSION AS A FRESHMAN

For admission to the Freshman class in a four-year or five-year course in Engineering an applicant must be at least sixteen years of age and must offer fifteen specific units of entrance subjects, as follows:

English		3 units
Mathematics:		
Elementary Algebra	1 unit	
Intermediate Algebra	1 "	
Plane Geometry	1 "	
Advanced Algebra or Solid Geometry	½ "	
Plane Trigonometry	½ "	
Total, Mathematics		4 units
History, 2 units, or One Foreign Language*, 2 units (German, French, Spanish, Italian, Greek, or Latin)		2 units
Physics or Chemistry**		1 unit
Electives		5 units
Total		15 units

*Students who expect to enter the Graduate School after obtaining a first degree should note that a minimum of two units of one foreign language, preferably German or French, is required of candidates for the master's degrees in Engineering.

**Candidates for admission to the School of Chemical Engineering *must* offer one unit of Chemistry, and should offer also one unit of Physics.

With respect to the specific list of entrance subjects the following paragraphs should be noted:

1. *Mathematics*. The four units of Mathematics required may be offered under the specific subjects and units above listed, or they may be offered as four years of continuous training in Mathematics throughout the high or preparatory school course, provided that in the latter case a declaration is attached to the certificate of credits stating that the course in Mathematics has included the essentials of the four units of Mathematics as required by the Gamma Examination of the College Entrance Board.

2. *Elective Units*. The five elective units may, with one exception, be made up of any of the entrance subjects and units acceptable to

Cornell University. For a list of those subjects and units, see the *General Information Number* (Table 1, on page 5.) The one exception is that credit for a single unit in a foreign language will not be granted unless the candidate offers three units in another foreign language or two units in each of two other foreign languages.

3. *Special Consideration of Units.* Applicants offering fifteen units which do not differ materially from the specific list may present their credits for special consideration, for under proper circumstances some adjustment may be permitted. If there is a deficiency in the mathematics specified, and it does not exceed a total of one unit, the applicant may be admitted, provided he agrees to remove this shortage in college during the first term, then to begin the regular freshman mathematics at mid-year and to complete the remainder of this course in the following summer session. It is preferable, however, for the student to be free from entrance shortages at the time he enters. Attention is called to the possibility of obtaining additional credits by attending the Summer Session (see the *Announcement of the Summer Session*) or by taking the September examinations.

4. *French or German Recommended.* It is recommended that if foreign language units are offered they be in French or German, for the reason that a knowledge of either of these tongues gives the student immediate access to important literature on the theory and practice of engineering. For the purpose of entrance requirements, the substitution, unit for unit, of scientific French or German is permitted, in lieu of a more general literary course in either of those subjects, and this substitution will apply to all such courses in any secondary schools approved by the Director of Admissions.

5. *Language and History.* The student preparing to enter the College of Engineering is strongly advised to offer at least three of his elective units in Language and History. His work in the four-year course in engineering will of necessity be largely scientific or technical. He will therefore do well in his preparatory years to avoid unnecessary specialization and to make his studies as liberal as possible. Applicants who have not had this broader education are recommended to take either a five-year course or a six-year course. More detailed information about courses requiring more than four years for graduation will be furnished upon application to the Dean of the College of Engineering.

6. *Practical Experience.* Students who have had some practical experience in engineering usually gain more than others from the courses offered by the College of Engineering. It is therefore recom-

mended that prospective students spend at least one summer vacation in practical work in connection with some kind of engineering.

SIX-YEAR COURSES The requirements for entrance to one of the six-year courses, leading to the degree of Bachelor of Arts and one of the bachelor's degrees in Engineering (B.C.E., B.M.E., B.E.E., or B.S. in A.E.), are those of the College of Arts and Sciences, where the candidate for the two degrees is registered during the first four years. They include less mathematical preparation than is specified for the four-year or five-year courses. The necessary arrangement of studies in the six-year course is set forth on page 11.

Payments to the University

TUITION FEE For instruction in the College of Engineering during the regular session the University charges a tuition fee at the rate of four hundred dollars a year, payable in two installments, $220 at the beginning of the first term and $180 at the beginning of the second. (See the *General Information Number.*)

OTHER FEES For certain services or privileges which the student enjoys the University charges fees over and above that charged for tuition. (See the *General Information Number.*) Every undergraduate student of the College of Engineering is required to pay fees as follows:

A Matriculation and Examination Book Fee of $11 is required of every student upon entrance to the University. This fee must be paid at the time of registration. A new undergraduate student who has made the required deposit of $25 with the Treasurer does not make an additional payment of this fee, because the Treasurer draws on the deposit for it.

A Health and Infirmary Fee of $6 a term is required at the beginning of each term.

A Willard Straight Hall Membership Fee of $5 a term is required at the beginning of each term.

A Physical Recreation Fee of $4 a term is required at the beginning of each term.

A Laboratory Fee is required to be paid, one-half at the beginning of each term, at the following annual rates: Freshmen in the College of Engineering, $25; Sophomores, Juniors, and Seniors in Mechanical Engineering and Electrical Engineering, $25; students in the last three years of the course in Chemical Engineering, $25; Sophomores, Juniors, and Seniors in Civil Engineering, $8.

DEPOSITS *Laboratory Deposits.* In some courses, particularly in the first two years of the course in Chemical Engineering, the student is required to make in advance at the Treasurer's office a deposit of money to cover the cost of material to be used and supplies to be consumed by him in the course of the term. Accounts are kept and charges are entered against the deposit. At the end of the term any balance remaining of the deposit is returned to the student.

R.O.T.C. Uniform Deposit of $20. Every student enrolled for the Basic Course of Instruction in Military Science and Tactics is required immediately upon registration at the beginning of his Freshman year, to deposit $20 at the Treasurer's office for the purchase of his military uniform. An immediate deposit is required because enrollment in the Department of Military Science and Tactics takes place at once. Most of the amount of the student's deposit is returned to him as earned uniform allowance upon his completion of the two-year Basic Course.

LIVING COSTS The average student's allowance for the necessary expenses of the Freshman year at Ithaca, over and above the amount of the tuition fee, ought to be at least $800. That is the sum of $550 for room and board; $150 for fees, including laboratory fees and deposits, books, instruments, stationery, and other supplies; $50 for laundry, and $50 for miscellaneous personal expenses. This subject is discussed at length in the *General Information Number.*

Means of Financial Aid

AID FOR NEW STUDENTS Cornell University's provision of financial help for new students of the College of Engineering is limited to certain scholarships which are awarded on the basis of competition and almost always to students entering the Freshman class. They consist of twenty-five University Undergraduate Scholarships, 150 State Cornell Scholarships for residents of the State of New York, thirty John McMullen Regional Scholarships for students coming from outside New York State, and a few others most of which are restricted to residents of certain localities.

Thirty *John McMullen Regional Scholarships* are awarded annually to selected students entering the College of Engineering. Each scholarship has an annual value of $400 and may be held throughout an undergraduate course of study provided the recipient maintain a satisfactory academic record. These scholarships are allotted among fifteen districts of the United States. New York State is excluded because residents of this State are eligible to other Cornell scholarships. Application blanks and instructions are sent, about February 1 of each year, to the principals and headmasters of accredited schools for their use in recommending outstanding candidates who are interested in obtaining an education in engineering. The recommendations are to be sent to the Dean of the College of Engineering before April 1. A faculty committee selects the most promising candidates in each district and forwards their applications to alumni scholarship committees in the respective districts for personal investigation. Appointments are made by the President of the University on the final recommendation of the Dean.

For particulars of all other scholarships that are open to new students the *General Information Number* should be consulted.

LOANS AND GRANTS Most 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 a standing Committee on Student Aid administers for the trustees. The benefits of these loan funds are reserved for students who have been in residence and good standing at Cornell University for at least a year and preference

is given to applicants of high scholastic standing who are within a year or two of graduation.

On a limited scale financial aid is afforded students by means of gifts which, though often denominated scholarships, are more properly called grants because their primary purpose is the relief of pecuniary need. These 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 new students.

Funds available for loans and grants are listed and described in the *General Information Number*.

Following is a list of such funds provided for the benefit of students of the College of Engineering:

The John McMullen Undergraduate Scholarships: The Board of Trustees has established at the present time forty-eight of these undergraduate scholarships of an annual value of $200 each, and divided them among the four Schools of the College of Engineering. These scholarships are awarded primarily for the purpose of providing able students with scholastic opportunities which would otherwise be denied them. They are not normally granted to Freshmen. Applications should be made to the director of the school concerned before April 1.

The Frank William Padgham Scholarship, founded by Amos Padgham of Syracuse, New York, in memory of his son, Frank William Padgham, M.E. '88, entitles the holder to free tuition and engineering fees in the regular courses in the Sibley School of Mechanical Engineering or in the School of Electrical Engineering. It cannot be held in connection with a New York State Scholarship. It will be awarded to the candidate, if any, who has had his preparatory education in the public schools of Syracuse, New York, and who, having been admitted to the regular course in either of the Schools named, shall be approved by the University Faculty's Committee on Undergraduate Scholarships. If no candidate from the schools of Syracuse applies, the scholarship may be awarded to a student who has received his preparatory education elsewhere. Application should be made to the Dean of the College of Engineering before April 1.

The Fred Lewis Wilson Scholarship: Open to undergraduates in Mechanical or Electrical Engineering. Mrs. Mary Northrup Wilson bequeathed Cornell University about $4,000 to found and perpetuate one or more scholarships in honor of her son, Fred Lewis Wilson, who was graduated from Sibley College with the class of 1892. These scholarships are awarded, for a period of not more than two years each, to undergraduates who have been at least one year in the University. Applications should be made to the Dean of the College before April 1.

The John Leisenring Wentz Scholarship: Open to undergraduates in Mechanical or Electrical Engineering; consists of the income of a fund of $5,500, given the University in 1920 by Mrs. Lewis Audenried in memory of John Leisenring Wentz, a member of the class of 1898. It is awarded at the end of each academic year to a member of the incoming senior class who is in need of pecuniary aid; the beneficiary must have maintained a high scholastic standing during his junior year. Applications should be made to the Dean of the College before April 1.

The William Delmore Thompson Scholarship: Open only to undergraduates in Mechanical Engineering; established in memory of William Delmore Thompson of the class of 1918; pays $40 a year and is for the benefit of self-supporting students of mechanical engineering. It is awarded at the beginning of the junior year, and if the student's work proves satisfactory it is continued through the senior year. Applications should be made to the Director of the School of Mechanical Engineering before April 1.

The Judson N. Smith Scholarship: Open to upperclassmen in the School of Civil Engineering; pays $160 a year, the income of a fund given by Mrs. Sarah L. Smith of Saranac Lake, New York, in memory of her son. It is awarded by the Faculty of the School of Civil Engineering at the end of each year to a student of the incoming senior or junior class in that school, of good character and scholarship and needing pecuniary aid. Applications must be made to the Director of the School of Civil Engineering before April 1.

Otto M. Eidlitz Scholarships: Open to undergraduates in the College of Engineering. These scholarships were founded in 1929 by a bequest of Otto M. Eidlitz, C.E. '81, of $25,000 to Cornell University to establish a scholarship fund in the College of Engineering for students who require financial assistance. With the avails of this bequest three scholarships of an annual value of $325 have been established. These scholarships are awarded by the Dean of the College of Engineering to such students as appear to be most deserving because of their character and intellectual promise. Applications should be made to the Dean before April 1.

The Sylvester Edick Shaw Scholarship, the income of a fund of $4,000 given in 1929 by Sylvester Edick of Newfane, is awarded to a student designated by the alumni of Cornell University who are residents of Niagara County at the time of the award. If the alumni fail to make such designation, the award is made by the principal of the Lockport High School, preference being given to the student who is most in need of financial assistance and who is studying Mechanical or Electrical Engineering. The student has the benefit of the scholarship for the entire period of his course, provided his conduct and progress in his work are satisfactory. Applications should be made to the Dean before April 1.

The Joseph N. Evans Scholarship, consisting of the annual income from a bequest of $3,000 given by the will of Mrs. Joseph N. Evans in memory of her husband. Open to any undergraduates in the College of Engineering upon application to the Dean. Applications should be made to the Dean before April 1.

The Redmond Stephen Colnon Scholarships: Supported by the income from $20,000 bequeathed by Mrs. Katharene Fruin Colnon in 1935 in memory of her husband. Four scholarships of $200 each are awarded annually (two in Mechanical Engineering and one each in Civil and Electrical Engineering) to sophomores, juniors, or seniors, upon the recommendation of the School concerned. Candidates in order to be eligible must be upon the annual Honor List, and may hold the scholarships for more than one year provided they remain upon that list. Applications should be made to the Director of the school concerned before April 1.

The Wurts Loan Fund, the gift of Alexander Jay Wurts, in memory of his mother, Laura Jay Wurts, was founded in 1912 to assist needy students of the two upper classes in the Sibley School of Mechanical Engineering. Upon the recommendation of the Dean of the College of Engineering, loans from the income of this fund may be awarded by the Faculty of the College of Engineering, with the approval of the Treasurer, to one or more students each year.

The Carl Richard Gilbert Award was founded in 1929 by Mr. and Mrs. A. S. Gilbert in memory of their son, Carl Richard Gilbert, who died during his Junior year. The value of the award is about $190 annually and is available for students in the School of Electrical Engineering. Awards from this fund are made on the recommendation of the Dean of the College and the Director of the School of Electrical Engineering, and with the approval of the Faculty of Engineering, to one or more worthy students each year.

The Martin J. Insull Loan Fund was founded in 1924 by Martin J. Insull, M.E., '93, of Chicago, to be used for making loans to deserving students in the College of Engineering who have been pursuing their studies there for at least one year. Loans are made on the unsecured promissory note of the student borrowing, bearing five per cent interest annually, and payable within three years from the time the borrower leaves the University through graduation or otherwise.

The Robert Critchlow Dewar Loan Fund, the joint gift of Mrs. James M. Dewar and the Cornell Society of Civil Engineers, in honor of Robert Critchlow Dewar, C.E. '09, is available for undergraduates in the School of Civil Engineering upon recommendation of the Director of that school.

The William C. Seidell Book Fund of $1,000 was founded by Gerrit S. Miller. The income is used for the purchase of books for young men who are working their way through the School of Civil Engineering, and is paid upon the recommendation of the Director of the school, preference being given to underclassmen.

The John N. Ostrom Fund was founded by John N. Ostrom, C.E. '77, for making loans to students in the School of Civil Engineering upon recommendation of the Director of that School. The loans are to be in the amount of $200 per annum to each student.

A special loan fund for deserving and needy students in Chemical Engineering has been established by alumni. Applications should be made to the Director of the School of Chemical Engineering.

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 Uni-

versity generally. The Secretary of the University publishes a list of them under the title *Prize Competitions*, a copy of which will be mailed on request addressed to his office. 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 his 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 of the College

Edmund Ezra Day, S.B., A.M., Ph.D., LL.D., President of the University.

Livingston Farrand, A.B., M.D., L.H.D., LL.D., President Emeritus.

Solomon Cady Hollister, B.S., C.E., Dean of the College and Professor of Civil Engineering.

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.

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.

Fred Asa Barnes, M.C.E., Professor of Railroad Engineering.

Paul Halladay Underwood, C.E., Professor of Surveying.

Sidney Gonzales George, C.E., Professor of Mechanics of Engineering.

Ernest William Schoder, Ph.D., World War Memorial Professor of Experimental Hydraulics.

Francis Joseph Seery, S.B., Professor of Hydraulic Engineering.

Samuel Latimer Boothroyd, M.S., Professor of Astronomy.

Charles Leopold Walker, C.E., Professor of Sanitary Engineering and Secretary of the College Faculty.

Herbert Henry Scofield, M.E., Professor of Testing Materials.

Walter L. Conwell, C.E., Professor of Highway Engineering.

Leonard Church Urquhart, C.E., Professor of Structural Engineering.

Charles Edward O'Rourke, C.E., Professor of Structural Engineering.

William Edward Stanley, B.S. in C.E., C.E., Professor of Sanitary Engineering.

Gilmore David Clarke, B.S., Professor of Regional Planning, and Dean of the College of Architecture.

Earle Nelson Burrows, M.C.E., Assistant Professor of Structural Engineering.

Leonard Alexander Lawrence, B.S., Assistant Professor of Surveying.

Carl Crandall, C.E., Assistant Professor of Civil Engineering.

John Edwin Perry, B.S. in C.E., Assistant Professor of Railroad Engineering, and Personnel Officer of the School of Civil Engineering.

Eric Vail Howell, M.C.E., Assistant Professor of Mechanics, and Secretary of the Faculty of Civil Engineering.

Romeyn Y. Thatcher, C.E., Assistant Professor of Civil Engineering.

Herbert Theodore Jenkins, B.S. in C.E., M.S.E., Assistant Professor of Civil Engineering.

Claude M. Pendleton, C.E., Assistant Professor of Civil Engineering.

Fred J. Spry, M.C.E., Instructor in Surveying.

HAROLD VERN HAWKINS, B.S. in C.E., M.C.E., Ph.D., Instructor in Hydraulics.

TREVOR RHYS CUYKENDALL, B.S. in E.E., M.S., Ph.D., Marc Eidlitz Instructor in Civil Engineering.

SIBLEY SCHOOL OF MECHANICAL ENGINEERING

WILLIAM NICHOLS BARNARD, M.E., Director of the School, and Professor of Heat-Power Engineering.

ALBERT WILLIAM SMITH, B.M.E., M.M.E., Professor of Mechanical Engineering, Emeritus.

DEXTER SIMPSON KIMBALL, A.B., M.E., D.Sc., D.Eng., LL.D., Professor of Mechanical Engineering, Emeritus.

MILLARD CLAYTON ERNSBERGER, A.B., M.E., Professor of Heat-Power Engineering, Emeritus.

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

CALVIN DODGE ALBERT, M.E., Professor of Machine Design.

ALBERT EDWARD WELLS, Sibley Professor of Mechanic Arts.

FRANK OAKES ELLENWOOD, A.B., M.E., Professor of Heat-Power Engineering.

WILL MILLER SAWDON, B.S., M.M.E., Professor of Experimental Engineering, assigned to Engineering Research.

GEORGE BURR UPTON, M.M.E., Professor of Automotive Engineering.

SEYMOUR STANTON GARRETT, C.E., World War Memorial Professor of Industrial Economics.

VICTOR RAYMOND GAGE, M.M.E., Professor of Experimental Engineering.

FREDERICK GEORGE SWITZER, M.M.E., Professor of Mechanics and Hydraulic Engineering.

CLARENCE ELLSWORTH TOWNSEND, M.E., Professor of Engineering Drawing.

FRED STILLMAN ROGERS, B.S., M.E., Professor of Machine Design.

ADAM CLARKE DAVIS, JR., M.E., Professor of Experimental Engineering.

WALTER RODNEY CORNELL, B.S., C.E., Professor of Mechanics of Engineering.

JOHN ROBERT BANGS, JR., M.E., Professor of Administrative Engineering.

CHARLES OSBORN MACKEY, M.E., Professor of Heat-Power Engineering, and Secretary of the Faculty of Mechanical Engineering.

JAMES NORMAN GOODIER, B.A., M.A., Ph.D., Sc.D., Acting Professor of Mechanics.

ROY EDWARDS CLARK, M.E., Assistant Professor of Heat-Power Engineering.

ENOCH FRANCIS GARNER, M.E., Assistant Professor of Machine Design.

WARREN HOWARD HOOK, M.E., Assistant Professor of Heat-Power Engineering.

WILLIAM EMERSON MORDOFF, M.E., Assistant Professor of Machine Construction.

HAROLD CHARLES PERKINS, M.E., Assistant Professor of Mechanics of Engineering.

William Cook Andrae, M.M.E., Assistant Professor of Experimental Engineering.

Stephen Farrell Cleary, M.M.E., Assistant Professor of Engineering Drawing.

George Raymond Hanselman, M.E., M.S., Assistant Professor of Administrative Engineering.

Joseph Olmstead Jeffrey, M.M.E., Assistant Professor of Experimental Engineering.

John Robert Moynihan, M.M.E., Assistant Professor of Experimental Engineering and Personnel Officer of the School of Mechanical Engineering.

Harry John Loberg, M.E., M.S. in Eng., Assistant Professor of Administrative Engineering.

Paul Howard Black, M.E., M.S. in Eng., Assistant Professor of Machine Design.

Clyde Ira Millard, E.E., Assistant Professor of Industrial Engineering.

Cyrl Waldie Terry, M.E., M.M.E., Assistant Professor of Experimental Engineering.

Cecil Werner Armstrong, B.S. in M.E., M.E., M.S. in Eng., Assistant Professor of Mechanics of Engineering.

Willis R. Slaughter, B.S., Major U. S. Ordnance Dept., Assistant Professor of Military Science and Tactics.

Robert Cunningham Morris, Instructor in Machine Design.

Ralph W. Hodges, Instructor in Introductory Engineering Laboratory.

Kennedy Furlong Rubert, Jr., M.M.E., Aero.E., Ph.D., Instructor in Experimental Engineering.

Howard Newton Fairchild, M.E., E.E., Instructor in Heat-Power Engineering.

Herbert Lybrand Manning, B.S. in M.E., Instructor in Industrial Engineering.

Kendall Crittenden White, E.E., Instructor in Administrative Engineering.

Frederick Seward Erdman, B.S., B.S. in M.E., M.M.E., Instructor in Experimental Engineering.

Bartholomew Joseph Conta, B.S., M.S., Instructor in Experimental Engineering.

William Pearson Bebbington, B.Chem., Instructor in Experimental Engineering.

Millard Vernon Barton, B.S. in M.E., M.S. in C.E., Instructor in Machine Design.

George Hamor Lee, B.S., M.S. in Eng., Instructor in Mechanics of Engineering.

Andrew Schultz, Jr., B.S. in A.E., Instructor in Administrative Engineering.

Myron Warren Lee, M.E., Instructor in Engineering Drawing.

John Campbell Georgian, B.M.E., Instructor in Machine Design.

Gordon Matthews Hutchison, B.S. in M.E., Instructor in Engineering Drawing.

William Howden Kreamer, B.M.E., Instructor in Engineering Drawing.

Edmond Joseph Schiller, Jr., Sc.B. in E.E., Instructor in Machine Design.

Dana Demarest Sherrill, B.S. (M.E.), Instructor in Machine Design.

Louis Schoudel Bock, M.E., Instructor in Administrative Engineering.

Niles Otto Myklestad, Cand. Polyt., Instructor in Mechanics of Engineering.

George Kissam Williams, E.E., M.E.E., Instructor in Mechanics of Engineering.

Lewis Dalcin Conta, B.S. in M.E., M.S., Instructor in Experimental Engineering.

John Henry Shank, Met.E., Instructor in Experimental Engineering.

Reginald Brown Allen, B.S. in A.E., Assistant in Administrative Engineering.

George Robert Latham, 3rd, B.S. in E.E., Assistant in Mechanical Engineering.

Burdette N. Howe, Foreman in the Machine Shop.

Charles E. Patterson, Foreman in the Foundry.

Walter Liston Head, Assistant in Introductory Engineering Laboratory.

Howard Stanley Bush, Assistant in the Pattern Shop.

Ernest Stanley Yawger, Assistant in the Pattern Shop.

Arthur J. Mack, Assistant in the Machine Shop.

SCHOOL OF ELECTRICAL ENGINEERING

William Abbett Lewis, Jr., B.S., M.S., Ph.D., Director of the School and Professor of Electrical Engineering.

Paul Martyn Lincoln, M.E. (in E.E.), D.Eng., Professor of Electrical Engineering, Emeritus.

Vladimir Karapetoff, C.E., M.M.E., D.Sc., Professor of Electrical Engineering.

William Cyrus Ballard, Jr., M.E. (in E.E.), Professor of Electrical Engineering.

Robert Franklin Chamberlain, M.E. (in E.E.), Professor of Electrical Engineering and Personnel Officer of the School of Electrical Engineering.

Burdette Kibbe Northrop, M.E. (in E.E.), Assistant Professor of Electrical Engineering.

Lawrence Adams Burckmyer, Jr., B.S. (in E.E.), E.E., Assistant Professor of Electrical Engineering.

Everett Milton Strong, B.S. in E.E., Assistant Professor of Electrical Engineering.

True McLean, E.E., Assistant Professor of Electrical Engineering.

Michel George Malti, B.A., B.S. in E.E., M.E.E., Ph.D., Assistant Professor of Electrical Engineering.

MILES GORDON NORTHROP, E.E., Assistant Professor of Electrical Engineering.

WALTER WENDELL COTNER, B.S. (in E.E.), E.E., M.E.E., Instructor in Electrical Engineering.

WILBUR ERNEST MESERVE, B.S. (in E.E.), M.S., M.E.E., Ph.D., Instructor in Electrical Engineering.

FRANK JESSUP BRISTOL, E.E., Instructor in Electrical Engineering.

WILLIAM DANIEL MOEDER, E.E., Instructor in Electrical Engineering.

JOHN PALEN WOOD, M.E., M.E.E., Instructor in Electrical Engineering.

HARRY SOHON, E.E., M.E.E., Ph.D., Instructor in Electrical Engineering.

HOWARD GODWIN SMITH, E.E., M.E.E., Ph.D., Instructor in Electrical Engineering.

ELTON WRIGHT JONES, B.S. (in E.E.), M.S., Instructor in Electrical Engineering.

EMMETT WHITNEY MANNING, B.S. (in E.E. and Math.), M.S., Instructor in Electrical Engineering.

SCHOOL OF CHEMICAL ENGINEERING

FRED HOFMANN RHODES, Ph.D., Director of the School, Professor of Chemical Engineering, and Personnel Officer of the School.

CHARLES CALVERT WINDING, Ph.D., Assistant Professor of Chemical Engineering.

OSCAR JOSEPH SWENSON, Ph.D., Assistant Professor of Chemical Engineering.

WILLIAM NICHOLS BARNARD, M.E., Professor of Heat-Power Engineering.

CLYDE WALTER MASON, Ph.D., Professor of Chemical Microscopy and Metallography.

ADAM CLARKE DAVIS, JR., M.E., Professor of Experimental Engineering.

ALBERT WASHINGTON LAUBENGAYER, Ph.D., Professor of Inorganic Chemistry.

MARTIN JENKINS BARNETT, B.S., Assistant in Chemical Engineering.

GEORGE NORMAN CORNELL, B.Chem., Assistant in Chemical Engineering.

JOSEPH MAJOR COLEMAN, B.S., Assistant in Chemical Engineering.

CORNELIUS M. VANDERWAART, B.S., Assistant in Chemical Engineering.

Officers

Dean of the College . . . . . S. C. HOLLISTER
Office: Sibley Dome

Director of the School of Civil Engineering . . . . . W. L. MALCOLM
Office: Room 12, Lincoln Hall

Director of the School of Electrical Engineering . . . . . W. A. LEWIS, JR.
Office: Franklin Hall

Director, Sibley School of Mechanical Engineering . . . . . W. N. BARNARD
Office: Room 18, West Sibley

Director of the School of Chemical Engineering . . . . . F. H. RHODES
Office: Room 74, Baker Laboratory of Chemistry

Director of Admissions. . . . . E. F. BRADFORD
Office: Morrill Hall

OTHER MEMBERS OF THE COLLEGE STAFF

MAUDE S. NEWMAN, Assistant to the Dean.

RAYMOND F. HOWES, Assistant to the Dean.

LULU M. MARKELL, Secretary to the Dean.

ELIZABETH PAGE, Secretary, Personnel and Employment Office.

MARY R. KORHERR, Secretary to the Director of the School of Civil Engineering.

MABEL H. WALBRIDGE, Librarian of the School of Civil Engineering.

DOROTHY S. WILLIAMS, Secretary to the Director of the Sibley School of Mechanical Engineering.

LENA GERTRUDE MARSH, Librarian of the Sibley School of Mechanical Engineering.

KATHERINE HANDLEN, Secretary to the Director of the School of Electrical Engineering.

MRS. I. M. BATCHELOR, Librarian of the School of Electrical Engineering.

HELEN J. TERRY, Secretary to the Director of the School of Chemical Engineering.

COUNCIL OF THE ENGINEERING EXPERIMENT STATION

SOLOMON CADY HOLLISTER, B.S., C.E., Director of the Station and Chairman of the Council.

WILLIAM LINDSAY MALCOLM, M.A., B.S.C., M.C.E., Ph.D., in Charge of Research in Civil Engineering.

WILLIAM NICHOLS BARNARD, M.E., in Charge of Research in Mechanical Engineering.

WILLIAM ABBETT LEWIS, JR., B.S., M.S., Ph.D., in Charge of Research in Electrical Engineering.

FRED HOFMANN RHODES, Ph.D., in Charge of Research in Chemical Engineering.

WILL MILLER SAWDON, B.S., M.M.E., Secretary.

MEMBERS OF THE EXPERIMENT STATION STAFF, 1938–39

DAVID DROPKIN, M.E., M.M.E., Ph.D., Westinghouse Research Associate.

FRITZ HERZOG, Ph.D., Westinghouse Research Associate.

LAWRENCE BRYON SPENCER, E.E., Westinghouse Research Assistant.

JOHN M'MULLEN GRADUATE SCHOLARS, 1938–39

JOSEPH JERRY BREZINA, M.E.
PAUL EVANS DITTMAN, E.E.
NICHOLAS KULIK, M.E.
JAMES HENRY NORRIS, B.S. in A.E.
EDGAR SCHOIJ, B.S.
WILBUR R. LEPAGE, E.E.
CHARLES D. T. RAUDENBUSH, B.S. in E.E.
PAUL GEORGE BOHLKE, B.S. in A.E.
JOHN OSCAR OSTERBERG, B.S., C.E., M.S.
WILLIAM EDWARD PARKINS, B.S.
GLEN JOHN SCHOESSOW, B.S., M.S. in M.E.
WILLIAM PHILIP SIMPSON, B.S. in C.E.
GEORGE WINTER, Engrg. Dipl., Munich Poly.
DON LEE STOCKTON, B.S. in Chem.E.

HOLDERS OF OTHER GRADUATE SCHOLARSHIPS AND FELLOWSHIPS, 1938–39

Dimitry Morkovin, B.S. in B.A., M. in B.A., B.S. in M.E., Sibley Fellowship.
Louis Leslie Otto, M.E., Sibley Fellowship.
Lawrence Thomas Wright, Jr., B.S. in M.E., the Edgar J. Meyer Memorial Fellowship.
Theodore Marion Hoefer, B.S. in E.E., the Charles Bull Earle Memorial Fellowship.
Jack Wilcox Gaul, C.E., Graduate Scholarship in Civil Engineering.
Chung-Hai Li, B.S. in C.E., M.C.E., Graduate Tuition Scholarship.
Ta-Ching Liu, B.S. in C.E., M.C.E., Graduate Tuition Scholarship.
Chen-Hsu T'ang, B.S. in C.E., M.C.E., the Elon Huntington Hooker Fellowship in Hydraulics.
Douglas Kent Jones, B.S. in C.E., M.S. in C.E., the McGraw Fellowship.

The Freshman Year

PRESCRIBED A single schedule of courses of instruction is prescribed for all members of the Freshman class in the College of Engineering (*except those in the School of Chemical Engineering; for their program see, further on, the list of courses given in that School*). This prescribed schedule is outlined below. Each course of instruction is numbered and will be found described under that number on one of the following pages. The initials C.E. or M.E. or E.E. indicate that a course is required of the students of a particular school; their absence indicates that a course is generally required.

REQUIRED COURSES OF INSTRUCTION	HOURS *First Term*	HOURS *Second Term*
Analytical Geometry and Calculus 5a, 5b	5	5
General Physics, 11, 12.	4	4
General Chemistry 102 or 104	3	3
Drawing 200, 201 (C.E.).	3	3
Drawing and Descriptive Geometry 120 (M.E., E.E.)	3	0
Mechanical Drafting 121 (M.E., E.E.)	0	3
Elementary Surveying 110 (C.E.).	3 or 0	0 or 3
Elementary Surveying 111 (M.E., E.E.).	2 or 0	0 or 2
Wood Shop 102 (M.E., E.E.).	0 or 1	1 or 0
Introductory Engineering Laboratory 103	0 or 1	1 or 0
Introductory Lectures 130.	1	0
Hygiene 1, 2.	1	1
Total number of hours a term (C.E.).	20 or 18	17 or 19
Total number of hours a term (M.E., E.E.)	19	18

In addition to taking the above courses all Freshmen must satisfy the University's requirement of three hours a week throughout the year in Military Science and Tactics (see the *General Information Number*).

The schedules of study of the later years will be found in following pages under the heads of the several Schools.

Here follows a description of the several courses of instruction outlined in the above list. The courses in Mathematics, Physics, and Chemistry are given in the College of Arts and Sciences. All the others except Hygiene and Military Science are given in the College of Engineering.

MATHEMATICS

5a. *Analytical Geometry and Calculus*. First term. Credit five hours. Repeated in second term.

5b. *Analytical Geometry and Calculus*. Second term. Credit five hours. Given also in first term.

Course 5a or 5b may not, without special permission, be taken simultaneously with any of the other courses in Mathematics. Courses prerequisite to 5a or 5b are Solid Geometry and Trigonometry.

PHYSICS

11. *General Physics*. Required of Freshman Engineering students. First term. Credit four hours. Prerequisite Mathematics 1 and 3 or the equivalent. Entrance physics is desirable but not required.

Two lectures, two recitations and one laboratory period a week as assigned, covering the subjects of mechanics, wave motion, sound, and heat.

Rockefeller Hall. Professor GRANTHAM and instructors.

12. *General Physics*. Required of Freshman Engineering students. Second term. Credit four hours. Prerequisite Mathematics 1 and 3 or the equivalent. It is recommended, though not required, that Physics 11 precede this course.

Two lectures, two recitations, and one laboratory period a week as assigned, covering the subjects of electricity and light.

Rockefeller Hall. Professor GRANTHAM and instructors.

CHEMISTRY

Entrance credit in chemistry does not carry with it University credit in Courses 102 *or* 104. *If a student entering the University from a preparatory school desires credit for these courses, he must pass an examination set by the Department of Chemistry. This examination is held in Ithaca on the same day in September as the entrance examination. University credit in Courses* 104*a and* 104*b that is obtained by passing this examination does not carry with it entrance credit in Chemistry.*

102. *General Chemistry*. Throughout the year. Credit three hours a term. Both terms of the course must be completed to obtain credit unless the student is excused by the department. Open only to those students who do not offer entrance chemistry. Deposit, $11 each term. Professor BROWNE, Professor LAUBENGAYER, and assistants. Lecture: Th, or F, 11, *Main Lecture Room, Baker*. Recitation: one hour a week, to be arranged. Laboratory: one 2½ hour period, to be arranged.

This course deals with the fundamental laws and theories of chemistry and the properties of the more common elements and their compounds.

104. *General Chemistry*. Throughout the year. Credit three hours a term. Both terms of the course must be completed to obtain credit unless the student is excused by the department. Prerequisite, entrance credit in chemistry. Deposit $11 each term. Professors LAUBENGAYER, PAPISH, and assistants. One lecture: M 11, T 9 or 11, *Main Lecture Room, Baker*. Recitation: one hour a week, to be arranged. Laboratory: one 2½ hour period, to be arranged.

This course deals with the fundamental laws and theories of chemistry and the properties of the more common elements and their compounds.

DRAWING, SURVEYING, SHOPWORK, INTRODUCTORY LABORATORY AND INTRODUCTORY LECTURES

102. *Woodshop*. Freshmen. One hour either term as assigned. Wood working; the use of hand and machine tools for wood working followed by instruction in pattern making, construction of core boxes, etc.; demonstration of form turning. Messrs. BUSH and YAWGER. *Rand Hall, Third floor.*

103. *Introductory Engineering Laboratory*. Freshmen. One hour either term as assigned. Elementary laboratory work and study of the various materials, processes, and machines commonly used in engineering work. Demonstrations, followed usually by practice in forging, welding, hardening, and tempering, drop forging, metallizing and brazing, oxy-acetylene cutting and welding, atomic hydrogen, and electric welding. Also study of pipe and pipe fittings, soil pipe and fittings, threaded fastenings, bearings, instruments of measurement, steam engine, gasoline engine, electric motors, and steam pump. Assistant Professor MORDOFF and Messrs. HODGES and HEAD.

110. *Elementary Surveying*. Required of freshmen in Civil Engineering. Either 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. *Lincoln Hall*. Professor UNDERWOOD, Assistant Professor LAWRENCE, and Mr. SPRY.

111. *Elementary Surveying*. Required of freshmen in Mechanical and Electrical Engineering. Either term as assigned. Credit two hours. Use of steel tape, level, and transit; fundamental surveying methods; measurement of lines, angles, and differences of elevation; land surveying. Textbook: Breed and Hosmer's *Elementary Surveying*. First term, two recitations or two field or computation periods a week. Second term, two recitations a week during the first half of the term, and two field or computation periods a week during the remainder of the term. *Lincoln Hall*. Professor UNDERWOOD, Assistant Professors LAWRENCE, CRANDALL, and THATCHER, and Mr. SPRY.

120. *Drawing and Descriptive Geometry*. Required of candidates for the degree of B.E.E. or B.M.E. or B.S. in A.E. with special reference to either E.E. or M.E. First term. Credit three hours. One recitation and 2 two and one-half hour drawing periods a week.

Coordinated instruction in subjects prerequisite to a study of the engineering applications of drawing. The drafting arts. Geometric analysis and composition of structures including considerations of: the elements of structure and their properties, interspace relations of structural elements, determinants of elements and structural organization along paths of physical and functional ties. Graphic computation and description of the geometric qualities and quantities of structure. Professor TOWNSEND, Assistant Professor CLEARY, and instructors. *East Sibley*.

121. *Mechanical Drafting*. Required of candidates for the degree of B.E.E. or B.M.E. or B.S. in A.E. with special reference to either E.E. or M.E. Second term. Credit three hours. One recitation and 2 two and one-half

drawing periods a week. Prerequisite course 120 and must be taken with or preceded by courses 102 and 103.

Basic studies of the functional and structural divisions of machines, structural standards and shop methods of producing structural qualities and quantities are coordinated in this course with instruction and drill in the fundamental techniques of determining machine structure by layouts and specifying structural information on working drawings in a manner consistent with both the convenience of the shop and the need of restricting the accumulation of production errors. Freehand sketching pictorial drawing, tracing, etc. are studied and applied in this work.

This is the first course in the engineering curriculum which deals with a subject of express engineering application. Students who become proficient in this subject are eligible for employment as junior mechanical draftsmen and are thus afforded their first opportunity for summer work of recognized value as basic training in the field of engineering practice. The benefits to be derived when studies of fundamentals are overlapped with practical experience are of such importance that every eligible student should attempt to take advantage of this opportunity. Professor TOWNSEND, Assistant Professor CLEARY, and instructors. *East Sibley.*

125 a and b. *Drawing.* Required of candidates for the degree of Bachelor of Chemical Engineering. Throughout the year. Credit two hours a term. One recitation and one two and one-half hour drawing period a week. A brief course in the basic subjects of drawing and the techniques of applying these subjects to the determination of structure by layouts and the specification of structure on working drawings. Professor TOWNSEND, Assistant Professor CLEARY, and instructors. *East Sibley.*

130. *Introductory Lectures.* Freshmen. Credit one hour. One lecture a week. This course of lectures is designed to introduce the first-year men to the various fields of engineering, and to demonstrate to them some of the simpler and more general methods of engineering construction. It is the purpose of the lectures to awaken the interest of the freshmen in their chosen profession through the aid of vivid description, of stimulating biography, and of personal experience. *Lecture room to be assigned in the fall.*

200. *Drawing* (C.E. students). First term. Credit three hours. Use of drawing instruments, free-hand lettering, titles, geometrical problems, simple orthographic projection, technical sketching. Text book: French, *Engineering Drawing. Lincoln Hall.* Assistant Professors JENKINS, PERRY, THATCHER, and Mr. SPRY.

201. *Drawing* (C.E. students). Second term. Credit three hours. Orthographic projection, sections, scale drawings, practical problems, tracing, blueprinting, conventional signs, topographic mapping, isometric drawing. Text book: French, *Engineering Drawing. Lincoln Hall.* Assistant Professors JENKINS, PERRY, THATCHER, and Mr. SPRY.

REQUIRED COURSES IN HYGIENE

1. *Hygiene.* First term. Credit one hour. Required of all freshmen. One lecture-recitation each week, with preliminary examination and final. The use of a text-book will be required.

Students must report for registration and assignment to section, the men at the *Old Armory*, the women at *Sage Gymnasium*.

Sections for men: Professor SMILEY, Assistant Professors GOULD, SHOWACRE, DEYOE, ROSE, and Doctor PARRATT.

Sections for women: Assistant Professor EVANS, Doctors CUYKENDALL and STELLE.

2. *Hygiene*. Second term. Credit one hour. Required of all freshmen. One lecture-recitation each week, with preliminary examination and final. The use of a text-book will be required.

Students must report for registration and assignment to section, the men at the *Old Armory*, the women at *Sage Gymnasium*.

Sections for men: Professor SMILEY, Assistant Professors GOULD, SHOWACRE, DEYOE, ROSE, and Doctor PARRATT.

Sections for women: Assistant Professor EVANS, Doctors CUYKENDALL and STELLE.

ELECTIVE COURSES IN HYGIENE

3. *Health Supervision of School Children*. Second term. Credit two hours. Assistant Professor GOULD. T Th 12. Histology lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*.

A practical course of lectures and demonstrations designed to familiarize the student with the facts and methods necessary for making an effective health supervision of school children. Prerequisites suggested but not demanded: Human Physiology and Anatomy. Open to sophomores, juniors, and seniors.

4. *Advanced First Aid*. First and second term. Credit one hour. Assistant Professor SHOWACRE. Anatomy lecture room, *Stimson*, F 9. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

This course will include a discussion and practical demonstration of the main methods at hand for preventing accidents and for giving emergency treatment.

5. *Industrial Hygiene*. First term. Credit one hour. Assistant Professor GOULD. Th 12. Histology lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

Factory sanitation, ventilation, and illumination; occupational poisoning and disease; factory legislation; accident prevention; fatigue in industry; preventive medicine in the industries.

6. *School Hygiene*. Professor YOUNG. See Physical Education 24.

7. *Rural Hygiene*. Second term. Credit one hour. Assistant Professor DEYOE. W 12. Histology Lecture Room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

A general consideration of the health problems peculiar to rural areas with the presentation of practical schemes for the solution of these problems as far as possible.

8. *Hygiene: Mental Hygiene*. First term. Section 2 repeated second term. Credit two hours. Section 1. *Boardman*. M F 11. Assistant Professor ROSE. Section 2. Histology Lecture Room, *Stimson*. W F 2. Dr. STELLE. Registration at Hygiene Office, *Old Armory*.

The relationship of the structure of the total personality to environmental maladjustment as evidenced by physical and social behavior; a discussion of

the more common personality difficulties and the role of insight in the prevention of these.

9. *Hygiene: Mental Hygiene*. Second term. Credit two hours. Prerequisites: Hygiene 1, 2 and 8. M F 11. *Boardman*. Assistant Professor Rose.

A study of the social applications of psychiatry to Child Guidance, Juvenile Delinquency, the problem of crime and the care of the psychotic. Recommended for those interested in social welfare work and especially psychiatric social work.

MILITARY SCIENCE AND TACTICS

1. *Basic Course*. Required. Throughout the year. The complete course covers two years. Three hours a week, either M T W or Th 1:40–4:10 P.M.

The course of training is that prescribed by the War Department for Senior Division Units of the Reserve Officers' Training Corps for basic students. Instruction is offered in Infantry, Field Artillery, and Signal Corps. For details concerning the course see the Announcement of the Department of Military Science and Tactics.

Required of all able bodied first 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 terms of residence, otherwise the student will not be permitted to register again in the University without the consent of the faculty.

Advanced standing: With the approval of the Department of Military Science and Tactics, credit may be allowed a student for all or part of the Basic Course requirement, upon presentation of evidence of satisfactory work completed at an approved institution.

2. *Advanced Course*. Elective. Throughout the year. Credit two hours a term. The complete course covers two years. Prerequisite, Basic Course in the arm of service selected. Five hours a week, and in addition attendance at a Summer Training Camp of six weeks duration. Hours by assignment. *Drill Hall*.

The course of training is that prescribed by the War Department for Senior Division Units of the Reserve Officers' Training Corps for advanced students. Instruction is offered in Infantry, Field Artillery, Ordnance, and Signal Corps.

Upon successful completion of the Advanced Course a student may be commissioned as a Reserve Officer of the United States Army, in the appropriate arm or service, upon the recommendation of the Professor of Military Science and Tactics. For details concerning the course see the Announcement of the Department of Military Science and Tactics.

3. *Advanced Signal Corps Course*. Elective. Three lectures a week and one hour of leadership throughout the junior and senior years. Credit one hour a term. Prerequisite courses Physics 21, 22. Concurrent courses Electrical Engineering Principles 411, 412, or Electrical Engineering 405, 406 or E.E. Theory 415, 416. Courses 451, 452, 452a, desirable but not required. First year covers wire and radio communication and military subjects. Second year, in general, is of a military nature.

4. *Ordnance Problems*. Course 3 M 53. See description on page 122.

School of Civil Engineering

THE COURSES OF STUDY The courses of study offered by the School of Civil Engineering leading to the degree of Bachelor of Civil Engineering or to that of Bachelor of Science in Administrative Engineering are planned to provide fundamental instruction necessary for the practice of the profession. They all contain training in those subjects which the Faculty considers essential. Great latitude is given to provide for liberalization in the regular course, while a series of optional courses of study is offered as a guide to those who have the desire to add further to their fundamental preparation in any of the several branches of civil engineering. All of these technical optional courses of study have a common background of technical courses paralleling those of the regular course; so that a student electing to follow one of the technical options will also be well prepared in the other branches of civil engineering.

A student may defer electing to follow one of the options until the beginning of the junior year. The same sequence of dependent courses must be followed.

A student desiring to specialize in a field requiring it may, subject to the approval of his class adviser, defer certain junior courses of instruction not fundamental or prerequisite to the senior work until the senior year in order to take elective or required courses of the senior year in the junior year. A student may not, however, anticipate the work of the curriculum by more than one year.

For the professional degree of C.E., see page 12.

REQUIREMENTS AND CREDITS In several of the Courses and Options in the School of Civil Engineering, elective credit toward meeting the degree requirements may be obtained for satisfactory work on the board of *The Cornell Engineer*. Credit is limited to the junior and senior years with a maximum of two hours credit each year, i.e., a total credit of four hours. However, in the case of the Administrative and Transportation Engineering Options, and the B.S. in A.E. Course, each of which provides for only three elective hours, not more than three hours of *The Cornell Engineer* credit can be used toward the degree requirement. Such credit cannot be used toward the degree in case of the Sanitary Engineering and Hydraulic Engineering Options, where electives are restricted.

Not more than four hours credit for elective work in Advanced Military Science and Tactics will be accepted toward meeting the degree requirements. However, in the case of the Administrative and Transportation Engineering Options and the B.S. in A.E. Course, each of which provides for only three elective hours, not more than three hours of credit in Advanced Military Science and Tactics may be used toward the degree requirement. Such credit may not be used toward the degree in case of the Sanitary Engineering and Hydraulic Engineering Options, where electives are restricted.

An organized inspection trip during the second semester is required of all juniors in Civil Engineering except those excused by the Director and is optional for seniors and graduates. The trip is in charge of a faculty committee and the student is required to write and submit a satisfactory report to the committee.

The next following pages contain outlines of the several courses and options in the School of Civil Engineering.

1. The Regular Four-Year Course

	(FOR THE DEGREE OF B.C.E.)	HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	3 or 0	0 or 3
	Engineering Geology 501	0 or 3	3 or 0
	The Elements of Field Astronomy 182	0	2
	Drawing 203	0	2
	Descriptive Geometry 204	3	0
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220	5	0
	Mechanics Laboratory and Computations 220-A, 220-B	2	0
	Mechanics of Engineering 221	0	4
	Mechanics Laboratory 221-A	0	1
	Route Surveying and Drawing 260-B	0	3
	Engineering Construction 264	3 or 0	0 or 3
	English 2	0 ro 3	3 or 0
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation)		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 34 HOURS	Introduction to Economics, Economics 3	3 or 0	0 or 3
	Materials of Construction 225	0 or 3	3 or 0
	Materials Laboratory 226	0 or 3	3 or 0
	Hydraulics 240	4	0
	Sewerage and Sewage Disposal 252	0	3
	Treatment of Water 253-A	0	2
	Engineering Management 293	3 or 0	0 or 3
	Stress Analysis and Structural Design 270	4	0
	Structural Design 271	0	3
	Concrete Construction 280	0 or 3	3 or 0
	Soil Mechanics 287	3 or 0	0 or 3
FOURTH YEAR 35 HOURS	Heat-Power Equipment 3P43	0	3
	Electrical Equipment 418	3	0
	Engineering Problems 223	0	2
	Water Supply 230	0 or 3	3 or 0
	Highway Engineering 265	3 or 0	0 or 3
	Foundations 281	3 or 0	0 or 3
	Engineering Law 290	0 or 3	3 or 0
	Elective*	9	6

Grand total for the Four-Year Course ..... 148 hours

*Of the elective hours, at least six must be taken in the School of Civil Engineering. The elective courses taken outside the School of Civil Engineering must be selected from among those not open to freshmen, unless the course selected has the special approval of the class adviser. See also page 62.

2. Administrative Option

	(FOR THE DEGREE OF B.C.E.) (For the Administrative Engineering Course, see page 71)	HOURS First Term	HOURS Second Term
FIRST YEAR	See The Freshman Year, page 56	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	3 or 0	0 or 3
	Engineering Geology 501	0 or 3	3 or 0
	The Elements of Field Astronomy 182	0	2
	Drawing 203	0	2
	Descriptive Geometry 204	3	0
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220	5	0
	Mechanics Laboratory and Computations 220-A, 220-B	2	0
	Mechanics of Engineering 221	0	4
	Mechanics Laboratory 221-A	0	1
	Route Surveying and Drawing 260-B	0	3
	Engineering Construction 264	3 or 0	0 or 3
	English 2	0 or 3	3 or 0
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation)		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 35 HOURS	Introduction to Economics, Economics 3	0	3
	Business and Industrial Management 3A23	4	0
	Accounting for Engineers 3A31	0	3
	Engineering Management 293-A	0	3
	Materials of Construction 225	3	0
	Materials Laboratory 226	3	0
	Concrete Construction 280	3	0
	Stress Analysis and Structural Design 270	4	0
	Structural Design 271	0	3
	Hydraulics 240	0	4
	Treatment of Water 253-A	0	2
FOURTH YEAR 35 HOURS	Money and Banking, Economics 11	0	3
	Corporation Finance, Economics 31	0	3
	Engineering Law 290	3	0
	Sewerage and Sewage Disposal 252	3	0
	Engineering Problems 223	2	0
	Water Supply 230	3	0
	Highway Engineering 265	0	3
	Heat-Power Equipment 3P43	0	3
	Electrical Equipment 418	3	0
	Foundations 281	0	3
	Elective*	3	3

Grand total for the Four-Year Course . . . . . 149 hours

*Any of the following courses may be taken profitably as an elective: Industrial Combinations, Ec. 32; Public Utilities, Ec. 33; Transportation, C.E. 269; Valuation Engineering, C.E. 295; Municipal Administrative Engineering, C.E. 256. See also page 62.

3. Sanitary Engineering Option

(FOR THE DEGREE OF B.C.E.)

		HOURS First Term	HOURS Second Term
FIRST YEAR	See The Freshman Year, page 56	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	3 or 0	0 or 3
	Engineering Geology 501	0 or 3	3 or 0
	The Elements of Field Astronomy 182	0	2
	Drawing 203	0	2
	Descriptive Geometry 204	3	0
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220	5	0
	Mechanics Laboratory and Computations 220-A, 220-B	2	0
	Mechanics of Engineering 221	0	4
	Mechanics Laboratory 221-A	0	1
	Route Surveying and Drawing 260-B	0	3
	Engineering Construction 264	3 or 0	0 or 3
	English 2	0 or 3	3 or 0
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation)		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 34 OR 35 HOURS	Introduction to Economics, Economics 3	0	3
	Stress Analysis and Structural Design 270	4	0
	Hydraulics 240	4	0
	Sewerage and Sewage Disposal 252	0	3
	Treatment of Water 253-A	0	2
	Concrete Construction 280	0	3
	Materials of Construction 225	3	0
	Materials Laboratory 226	0	3
	Sanitary Biology 250	3	0
	Sanitary Biology 251	2	0
	Water and Sewage Analysis 251-A	2	0
	Elective Sanitary Engineering Courses*	0	2 or 3
	*From Course 256-B—credit 2 hours, or Course 256-A—3 hours.		
FOURTH YEAR 36 HOURS	Electrical Equipment 418	3	0
	Water Supply 230	0	3
	Highway Engineering 265	0	3
	Engineering Law 290	0	3
	Foundations 281	0	3
	Structural Design 271	3	0
	Sewerage Works 254	3	0
	Control and Treatment of Water Supplies 253	0	3
	Treatment of Wastes 255	3	0
	Soil Mechanics 287	3	0
	Elective Sanitary Engineering Courses**	3	0
	**Any desirable combination of the following: 255-A, 256, 256-B, 257, 258, 259, 291d, 297d.		
	Grand total for the Four-Year Course	149 or 150 hours	

4. Structural Engineering Option

	(FOR THE DEGREE OF B.C.E.)	HOURS First Term	HOURS Second Term
FIRST YEAR	See The Freshman Year, page 56	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	3 or 0	0 or 3
	Engineering Geology 501	0 or 3	3 or 0
	The Elements of Field Astronomy 182	0	2
	Drawing 203	0	2
	Descriptive Geometry 204	3	0
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220	5	0
	Mechanics Laboratory and Computations 220-A, 220-B	2	0
	Mechanics of Engineering 221	0	4
	Mechanics Laboratory 221-A	0	1
	Route Surveying and Drawing 260-B	0	3
	Engineering Construction 264	3 or 0	0 or 3
	English 2	0 or 3	3 or 0
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation)		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 34 HOURS	Introduction to Economics, Economics 3	0 or 3	3 or 0
	Materials of Construction 225	3 or 0	0 or 3
	Materials Laboratory 226	3 or 0	0 or 3
	Hydraulics 240	0 or 4	4 or 0
	Advanced Mechanics 222	0	3
	Stress Analysis and Structural Design 270	4	0
	Structural Design 271	0	3
	Concrete Construction 280	3 or 0	0 or 3
	Foundations 281	3	0
	Soil Mechanics 287	0 or 3	3 or 0
	Treatment of Water 252-A	0	2
FOURTH YEAR 36 HOURS	Water Supply 230	0	3
	Highway Engineering 265	0	3
	Engineering Law 290	0	3
	Electrical Equipment 418	3	0
	Heat-Power Equipment 3P43	0	3
	Sewerage and Sewage Disposal 252	3	0
	Advanced Structural Analysis 272	3	0
	Fixed Arches 283	3	0
	Engineering Mathematics 224-A	3	0
	Bridge Design 274 or Highway Bridges 284	0	3
	Reinforced Concrete Design 285	3	0
	Elective	0	3
	Grand total for the Four-Year Course		149 hours

5. Hydraulic Engineering Option

	(FOR THE DEGREE OF B.C.E.)	HOURS First Term	HOURS Second Term
FIRST YEAR	See The Freshman Year, page 56.	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	3 or 0	0 or 3
	Engineering Geology 501	0 or 3	3 or 0
	The Elements of Field Astronomy 182	0	2
	Drawing 203	0	2
	Descriptive Geometry 204	3	0
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220	5	0
	Mechanics Laboratory and Computations 220-A, 220-B	2	0
	Mechanics of Engineering 221	0	4
	Mechanics Laboratory 221-A	0	1
	Route Surveying and Drawing, 260-B	0	3
	Engineering Construction 264	3 or 0	0 or 3
	English 2	0 or 3	3 or 0
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation)		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 34 HOURS	Introduction to Economics, Economics 3	0 or 3	3 or 0
	Hydraulics 240	4	0
	Stress Analysis and Structural Design 270	4	0
	Structural Design 271	0	3
	Sewerage and Sewage Disposal 252	0	3
	Treatment of Water 253-A	0	2
	Materials of Construction 225	3 or 0	0 or 3
	Materials Laboratory 226	3 or 0	0 or 3
	Concrete Construction 280	3 or 0	0 or 3
	Foundations 281	0 or 3	3 or 0
	Soil Mechanics 287	0 or 3	3 or 0
FOURTH YEAR 37 HOURS	Heat-Power Equipment 3P43	0	3
	Electrical Equipment 418	3	0
	Water Supply 230	3	0
	Engineering Law 290	3	0
	Highway Engineering 265	0	3
	Hydraulic Measurements 242	3	0
	Hydraulic Construction 231	0	3
	Hydraulic Group Options*	3	3
	Elective	3	6
	Grand total for the Four-Year Course	149 hours	

*From Courses Water Power 232, Hydraulic Engineering 233, Conservancy and Reclamation Problems 234, Water Power and Pumping Plants 236, Engineering Mathematics 224-A, Hydrodynamics, Physics 451 and 452, Advanced Hydraulics 241, Hydraulic Engineering Design 291 (c), Hydraulics Research 297 (c), Thesis 298.

6. Transportation Engineering Option

	(FOR THE DEGREE OF B.C.E.)	HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	3 or 0	0 or 3
	Engineering Geology 501	0 or 3	3 or 0
	The Elements of Field Astronomy 182	0	2
	Drawing 203	0	2
	Descriptive Geometry 204	3	0
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220	5	0
	Mechanics Laboratory and Computations 220-A, 220-B	2	0
	Mechanics of Engineering 221	0	4
	Mechanics Laboratory 221-A	0	1
	Route Surveying and Drawing 260-B	0	3
	Engineering Construction 264	3 or 0	0 or 3
	English 2	0 or 3	3 or 0
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation)		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 35 HOURS	Introduction to Economics, Economics 3	3	0
	Materials of Construction 225	0 or 3	3 or 0
	Materials Laboratory 226	0 or 3	3 or 0
	Hydraulics 240	4 or 0	0 or 4
	Stress Analysis and Structural Design 270	4	0
	Structural Design 271	0	3
	Concrete Construction 280	0 or 3	3 or 0
	Foundations 281	3 or 0	0 or 3
	Soil Mechanics 287	0	3
	Route Location 263	0	3
	Engineering Management 293	3 or 0	0 or 3
FOURTH YEAR 37 HOURS	Heat-Power Equipment 3P43	0	3
	Engineering Problems 223	0	2
	Engineering Law 290	3	0
	Transportation 269	0	3
	Electrical Equipment 418	3	0
	Valuation Engineering 295	0	3
	Highway Engineering 265	3	0
	Highway Laboratory 266 *or* Railroad Maintenance of Way 261	0	3
	Advanced Highway Engineering 267 *or* Railroad Operation and Management 262	0	3
	Sewerage and Sewage Disposal 252	3	0
	Treatment of Water 253-A	0	2
	Water Supply 230	3	0
	Elective	3	0
	Grand total for the Four-Year Course		151 hours

7. Geodetic Engineering Option

	(FOR THE DEGREE OF B.C.E.)	HOURS First Term	HOURS Second Term
FIRST YEAR	See The Freshman Year, Page 56	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	3 or 0	0 or 3
	Engineering Geology 501	0 or 3	3 or 0
	The Elements of Field Astronomy 182	0	2
	Drawing 203	0	2
	Descriptive Geometry 204	3	0
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220	5	0
	Mechanics Laboratory and Computations 220-A, 220-B	2	0
	Mechanics of Engineering 221	0	4
	Mechanics Laboratory 221-A	0	1
	Route Surveying and Drawing 260-B	0	3
	Engineering Construction 264	3 or 0	0 or 3
	English 2	0 or 3	3 or 0
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation).		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 34 HOURS	Introduction to Economics, Economics 3	3	0
	Materials of Construction 225	0	3
	Materials Laboratory 226	0	3
	Hydraulics 240	4	0
	Sewerage and Sewage Disposal 252	0	3
	Treatment of Water 253-A	0	2
	Engineering Management 293	3	0
	Stress Analysis and Structural Design 270	4	0
	Structural Design 271	0	3
	Concrete Construction 280	0	3
	Mapping 214	2	0
	Topographic Surveying 214-A	1	0
FOURTH YEAR 35 HOURS	Heat-Power Equipment 3P43	0	3
	Electrical Equipment 418	3	0
	Engineering Problems 223	0	2
	Water Supply 230	0	3
	Highway Engineering 265	3	0
	Engineering Law 290	3	0
	Problems in the Adjustment of Observations 215	1	0
	Least Squares: Adjustment of Observations 216	2	0
	Geodesy and Geodetic Laboratory 218	3	0
	Photographic and Aerial Surveying 219	0	3
	Foundations 281	0	3
	Elective	3	3

Grand total for the Four-Year Course ..... 148 hours

A FOUR-YEAR COURSE

(B.S. IN A.E.) A four-year course leading to the degree of Bachelor of Science in Administrative Engineering is given in the School of Civil Engineering. The requirements for admission are the same as for the regular course leading to the degree of Bachelor of Civil Engineering. An outline of this course in Administrative Engineering follows. (See also the Administrative Option, page 65.)

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, on page 56	20 or 18	17 or 19
SECOND YEAR 37 HOURS	Public Speaking I	0	3
	Engineering Geology 501	0	3
	Drawing 202, 203	1	2
	Advanced Surveying 211	3	0
	Mechanics of Engineering 220, 221	5	4
	Route Surveying and Drawing 260-B	0	3
	Engineering Construction 264	3	0
	English 2	3	0
	Introduction to Economics, Economics 3	3	0
	Business and Industrial Management 3A23	0	4
SUMMER COURSES 5 HOURS	Summer Survey 213 (four weeks in summer vacation)		4
	Location Surveying 260-A (one week in summer vacation)		1
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 36 HOURS	Materials of Construction 225	3	0
	Materials Laboratory 226	3	0
	Hydraulics 240	0	4
	Engineering Management 293-A	0	3
	Stress Analysis 270	3	0
	Structural Design 271	0	3
	Concrete Construction 280	3	0
	Treatment of Water 253-A	0	2
	Accounting for Engineers 3A31	3	0
	Money and Banking, Economics 11	3	0
	Corporation Finance, Economics 31	0	3
	Psychotechnology in Business and Industry, Psychology 16b	0	3
FOURTH YEAR 35 HOURS	Engineering Problems 223	2	0
	Water Supply 230	0	3
	Highway Engineering 265	3	0
	Engineering Law 290	3	0
	Advanced Engineering Law 290-A	0	3
	Sewerage and Sewage Disposal 252	3	0
	Transportation 269	0	3
	Valuation Engineering 295	0	3
	Municipal Administrative Engineering 256	3	0
	Electrical Equipment 418	3	0
	Heat-Power Equipment 3P43	0	3
	Elective	0	3
	Grand total for the Four-Year Course		150 hours

A FIVE-YEAR COURSE

(B.C.E. *and* B.S. IN A.E.) It is possible to arrange the work of a five-year course of study so that the degree of B.C.E. may be obtained at the end of the fourth year and the degree of B.S. in A.E. at the end of the fifth. Declaration of intention to take this five-year course of study should be made at the beginning of the second year.

A SIX-YEAR COURSE

(A.B. *and* B.C.E.) The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the Freshman engineering subjects before beginning his fourth year, and he must complete the Sophomore subjects in Civil Engineering before beginning his fifth year. By attending two Summer Sessions this combined course can be completed in five years. Assistance in arranging the course can be obtained from the Director of the School.

THE COURSES OF INSTRUCTION

The courses of instruction in the following list are designed for members of the Sophomore, Junior, and Senior classes in the School of Civil Engineering. The courses that are designed for members of the Freshman class have already been described under the head of The Freshman Year. The courses in Geology, Economics, English, Physics, Psychology, and Public Speaking are given in the College of Arts and Sciences.

GEOLOGY

501. *Engineering Geology*. Required of all sophomores in Civil Engineering. Either term. Credit three hours. The practical application of geologic principles and the occurrence of such economic materials as are of importance to engineering students, the whole subject being treated with reference to their needs. Lectures and laboratory work. *McGraw Hall*. Professor RIES.

ECONOMICS

3. *Introduction to Economics*. Required of all sophomores or juniors in Civil Engineering. Either term. Credit three hours. A survey of the existing economic order, its more salient and basic characteristics, and its operation. *Goldwin Smith Hall*. Professor O'LEARY.

11. *Money and Banking*. Required for Administrative Option and B.S. in A.E. Course in Civil Engineering. Elective for others. Either term. Credit three hours. Prerequisite, Economics I or its equivalent. A study of the his-

tory and the theory of money and banking. *Goldwin Smith Hall.* Professor REED.

31. *Corporation Finance.* Required of juniors or seniors in Administrative Option and B.S. in A.E. Course in Civil Engineering. Either term. Credit three hours. Prerequisite, course 3A31, Accounting for Engineers.

A study of the financial problems of the business corporation from the points of view of the management, the investor, and the public. *Goldwin Smith Hall.* Professor O'LEARY.

ENGLISH

English 2. Required of all sophomores in Civil Engineering. Either term. Credit three hours. The course is a training in the reading and writing of English. *Goldwin Smith Hall.* Professor SIBLEY, Assistant Professor TENNEY, and others. Registration in charge of Assistant Professor TENNEY.

PSYCHOLOGY

16b. *Psychotechnology in Business and Industry.* Required of juniors in the B.S. in A.E. Course in Civil Engineering. Second term. Credit three hours.

A critical review of the attempts to apply psychological facts and methods to the solution of technological problems. *Goldwin Smith Hall.* T Th S at 11. Dr. ARTHUR RYAN.

PUBLIC SPEAKING

1. *Public Speaking.* Required of all sophomores in Civil Engineering. Either term. Credit three hours. Designed to give the student the fundamentals of speech preparation and to help him acquire a simple, direct manner of speaking. Original speeches and interpretation of selections. *Goldwin Smith Hall.* Professor WICHELNS.

MECHANICAL ENGINEERING

3A23. *Business and Industrial Management.* Required of all sophomores or juniors in the Administrative Engineering Option and the B.S. in A.E. Course in Civil Engineering. Either term. Credit four hours.

This course is intended as a survey of the problems of business and industrial organization. It deals with the establishment of business policies, types of business and industrial ownership, together with the functions of finance, control, machine production, personnel, and marketing. Elementary consideration will be given to the problems of the selection of plant site, time and motion study, wage systems and the selection of personnel, all of which will be developed in greater detail in subsequent courses. Four lecture-discussion periods a week with regularly assigned problems. *West Sibley.* Professor BANGS.

3A31. *Accounting for Engineers.* Required of juniors in the Administrative Option and the B.S. in A.E. Course in Civil Engineering. Either term. Credit three hours. Theory of debits and credits; development of books of original entry; voucher system; analysis of financial statements; financial mathematics; negotiable instruments; modern mechanical methods of performing the accounting function. Two recitations and one 2½ hour computing period a week. *West Sibley.* Professor BANGS and others.

3P43. *Heat-Power Equipment*. Required of all seniors in Civil Engineering. Second term. Credit three hours. For a description of this course see page 123 of this Announcement. *West Sibley*. Professor ELLENWOOD.

ELECTRICAL ENGINEERING

418. *Electrical Equipment*. Required of all seniors in Civil Engineering. First term. Credit three hours. *Franklin Hall*. Professor BALLARD. For description of this course see page 134 of this Announcement.

ASTRONOMY

182. *The Elements of Field Astronomy*. Required of Civil Engineering sophomores except in the B.S. in A.E. Course. Second term. Credit two hours. Prerequisite, Surveying 110 or (Astronomy 180 and Mathematics 3). The determination of time, latitude, longitude, and azimuth by observations on the sun and stars using a surveyor's transit and a watch. Textbooks: *Textbook of Practical Astronomy* by Nassau and *Determination of Azimuth, Time and Latitude* by Engineering Students. One one-hour recitation and one two-hour laboratory period a week, some of the laboratory periods being in the late afternoon and at night for observations on sun and stars. Professor BOOTHROYD.

183. *Nautical Astronomy*. Elective. First term. Credit three hours. Prerequisite, Mathematics 3. Position of a ship by dead reckoning and by astronomical observation, with laboratory exercises, using sextant to determine time, latitude, and longitude. Students who already have two hours credit for Course 182 will get one hour additional credit upon completion of the extra work necessary to obtain credit for Course 183. Civil Engineering sophomores may take this course instead of Course 182 and count the extra hour credit as a Civil Engineering Elective. Textbook: *Navigation* by Jacoby. Each student should have access to a copy of the *American Nautical Almanac* for the year. Lectures and recitations M F at 11 with one two-hour laboratory period a week to be arranged. Some of the laboratory and recitation periods during the first four weeks of the term are used for sextant observations of the sun during the day and of the moon, stars, and planets at night. Professor BOOTHROYD and Dr. SHAW.

186. *Geodetic Astronomy*. Elective. First term. Credit three hours. Prerequisites, Astronomy 182 and Advanced Surveying 211 or (Mathematics 4a and 4b and General Astronomy 187) or approved equivalents. Not given in year 1939–40. The theory and practice of the precise determination of time, latitude, longitude, and azimuth. Textbook: Hosmer's *Geodesy*, Second Edition. Lecture and discussion, one hour a week and evening observing at the Observatory together with the reduction of observations which will average about 5 hours a week throughout the term. The laboratory work may be spread throughout the year if it seems desirable to do so. Professor BOOTHROYD. See also Course 297a on page 95.

DESCRIPTIVE GEOMETRY AND DRAWING

(200 and 201. *Drawing*. C.E. Freshmen. Credit three hours each term. See description under The Freshman Year.)

202. *Drawing*. Required of sophomores in the B.S. in A.E. Course in Civil Engineering. First term. Credit one hour. A study of the representation of lines, planes, surfaces, and solids, with practical applications. Assistant Professor JENKINS.

203. *Drawing*. Required of all sophomores in Civil Engineering. Second term. Credit two hours. Lettering, with practice in forming letters and combining them into appropriate titles; projections and intersections of practical problems; structural detailing and tracing; reading engineering drawings. Practice with water colors in rendering of flat and curved surfaces. Textbook: French's *Engineering Drawing*. Assistant Professor JENKINS.

204. *Descriptive Geometry*. Required of all Civil Engineering sophomores except in the B.S. in A.E. Course. First term. Credit three hours.

Instruction and drill in the fundamental conceptions of descriptive geometry, including orthographic projection and representation of the point, line, and plane. A study of the sections, developments, and intersections of surfaces and solids with applications in practical problems. Assistant Professor JENKINS.

205. *Advanced Drawing*. Elective. Juniors and seniors. Second term. Credit three hours. Perspective drawings, rendered in pencil, ink, and washes, of buildings, concrete bridges, dams, and other engineering works; building details of window frames, doors, stairs, and other simple units, to give the student some insight into detailing parts of plans, and to further familiarize him with reading working drawings. Problems in concrete, structural, topographical, highway, and sanitary drafting; engineering drawings, rendered in color, to enable the student to supplement ordinary working drawings with artistic representations so portrayed as to be readily intelligible to non-technical persons. Assistant Professor JENKINS.

SURVEYING

(110. *Elementary Surveying*. C.E. freshmen. Either term. Credit three hours. See The Freshman Year, page 58 for description).

211. *Advanced Surveying*. Required of all sophomores in Civil Engineering. First term. Credit three hours. Prerequisite, Elementary Surveying 110. City and mining surveying; surveys of the United States public lands; rectangular coordinate systems for cities and states; earth volumes, topographic, hydrographic, and geodetic surveying; transit and stadia and plane table surveys; sextant; soundings, triangulation; base lines; precise and trigonometric leveling; elements of photographic surveying; map projections. Textbooks: Breed and Hosmer's *Elementary Surveying*, Vol. I, and *Higher Surveying*, Vol. II. Two recitations and one field period a week during the first half of the term, and three recitations a week during the remainder of the term. Professor UNDERWOOD and Assistant Professor LAWRENCE.

212. *Advanced Surveying*. For students in Landscape Architecture. First term in alternate years. Given in 1939–40. Credit two hours. Prerequisite Elementary Surveying 110 or 111. Profile leveling; cross-sectioning; earthwork; circular curves and spirals; vertical curves. Textbook: Breed and Hosmer's Vol. I, *Elementary Surveying*. Recitations, computation, and field work. Assistant Professor LAWRENCE.

212-A. *Advanced Surveying.* For students in Landscape Architecture. Second term in alternate years. Given in 1939–40. Credit two hours. Prerequisite Elementary Surveying 110 or 111. Topographic surveying; transit and stadia methods; plane table; survey plotting. Triangulation. Textbook: Breed and Hosmer's Vol. I, *Elementary Surveying.* Recitations, computations, and field work. Assistant Professor LAWRENCE.

213. *Summer Survey:* (Topographic, Hydrographic, and Geodetic Survey Camp.) Required of all Civil Engineering students, following the sophomore year. Credit four hours for course 213 and one hour for course 260-A. Prerequisite Advanced Surveying 211. 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 four weeks is required for course 213 (four hours credit) and one week for course 260-A (one hour credit; see page 85 for description of this course). Date of beginning of the camp will be announced in the second term. Professors UNDERWOOD and BOOTHROYD, Assistant Professors LAWRENCE, PERRY, THATCHER, and Mr. SPRY.

214. *Mapping.* Elective for upperclassmen and required for juniors in the Geodetic Engineering Option in Civil Engineering. First term. Credit two hours. The construction of a final topographic map of the area covered by the field work of Course 213 during the preceding summer. The field sheets are combined for this purpose, reduced in scale from 1:4800 to 1:12000, and reproduced, using the triangulation system as a base for the work. Lectures and drawing. Two laboratory periods a week. Professor UNDERWOOD.

214-A. *Topographic Surveying.* Required for juniors taking the Geodetic Engineering Option in Civil Engineering, elective for others. First term. Credit one hour. Prerequisite courses 211 and 213. Methods of making topographic surveys for mapping to a large scale. The use of the plane table in such surveys. Solutions of the three-point problem; two-point problem; location of details by direction and distance. Field work and mapping. One field or drawing period a week. Professor UNDERWOOD.

215. *Problems in the Adjustment of Observations.* Elective for upperclassmen and required for seniors taking the Geodetic Engineering Option in Civil Engineering. First term. Credit one hour. Prerequisite, course 213. A series of examples in the adjustment of typical surveying work such as leveling, direct measurement of lines and angles, and simple triangulation figures, using the methods of least squares. Lectures and problems. Professor UNDERWOOD.

216. *Least Squares: Adjustment of Observations.* Required of seniors taking the Geodetic Engineering Option in Civil Engineering, elective for others. First term. Credit two hours. Prerequisites, Calculus and Physics. The course is designed for students who have experimental investigations in view. Applications are made to problems in physics, astronomy, mechanics, hydraulics, surveying, etc., with some attention given to the derivation of empirical

formulae. Textbook: Leland's *Practical Least Squares*. Two recitations and lectures a week, as may be arranged. Professor UNDERWOOD.

217. *Advanced Topographic Surveying*. Elective. Upperclassmen. Second term. Credit two hours. Prerequisite, course 213. Economics of surveying methods. Surveys for special purposes, such as extensive construction work, storage and distribution of water for irrigation; earthwork on a large scale, lines of communication, topographic reconnaissance, etc.; photographic surveying. Lectures, recitations, and assigned readings. Two hours a week. Professor UNDERWOOD.

218. *Geodesy and Geodetic Laboratory*. Elective for upperclassmen and required for seniors taking the Geodetic Engineering Option in Civil Engineering. First term. Credit three hours. Prerequisites, courses 182 and 211. 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. Professor BOOTHROYD. Not given in 1939–40.

219. *Photographic and Aerial Surveying*. Elective for upperclassmen and required for seniors taking the Geodetic Engineering Option in Civil Engineering. Second term. Credit three hours. Prerequisite, Advanced Surveying 211. The principles of photographic surveying; surveys with camera stations on the ground, including stereoscopic methods; aerial surveys and the making of maps from such surveys; ground control. Recitations, lectures, and collateral reading. Three hours a week. Professor UNDERWOOD.

For *Research in Geodetic Engineering*, see course 297i on page 96.

MECHANICS OF ENGINEERING

220. *Mechanics of Engineering*. Required of all Civil Engineering sophomores. First term. Repeated in one section, second term, if there are sufficient students. Credit five hours. Prerequisite course, Mathematics 5b. (See Courses 220-A and 220-B 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. Text book: George & Rettger *Mechanics of Materials*. Five recitations a week. Professor GEORGE and Assistant Professor HOWELL.

220-A. *Mechanics Laboratory*. Required of Civil Engineering sophomores except in the B.S. in A.E. Course. First term. Credit one hour. Courses 220, 220-A, 220-B are closely correlated and should be taken concurrently. This course consists of experiments (both qualitative and quantitative) designed to illustrate the principles of mechanics covered in Course 220. In general the

experiments are performed by the students themselves, and a complete, well-arranged report on each experiment is required of each student. Instruction in the use of the slide rule and of the planimeter is included in the work. One two and one-half hour period a week in the laboratory. Professor GEORGE and Assistant Professor HOWELL.

220-B. *Mechanics Computations*. Required of civil engineering sophomores except in the B.S. in A.E. Course. First term. Credit one hour. To be taken with Course 220. Devoted to the solution of problems related to the topics covered concurrently in Course 220. One computation period of two and one-half hours a week under instruction. Professor GEORGE and Assistant Professor HOWELL.

221. *Mechanics of Engineering*. Required of Civil Engineering sophomores. Second term. Repeated in one section, first term, if there are sufficient students. Credit four hours. Continuation of Mechanics 220. Prerequisite course, Mechanics 220. Mechanics of materials including stress and strain, tension, shearing, 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 & Rettger *Mechanics of Materials*. Four recitations a week. Professor GEORGE and Assistant Professor HOWELL.

221-A. *Mechanics Laboratory*. Required of Civil Engineering sophomores except in the B.S. in A.E. Course. Second term. Credit one hour. Courses 221 and 221-A are closely correlated and should be taken concurrently. Experiments designed to illustrate the principles of mechanics studied in Course 221. One two-and-one-half hour period a week. Professor GEORGE and Assistant Professor HOWELL.

222. *Advanced Mechanics*. Elective. Seniors and graduates. Either term. Credit three hours. Prerequisites, courses 220 and 221. 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 derivatives. Textbook: Seeley *Advanced Mechanics of Materials*. Recitations, three hours a week. Professor GEORGE.

223. *Engineering Problems*. Required of Civil Engineering seniors except in the Sanitary, Structural, and Hydraulic Engineering Options. Either term. Credit two hours. Prerequisites, courses 220, 221, and 240. The object of this course is to provide a review involving additional practice in using the principles and methods of applied mechanics. A series of problems, such as occur in ordinary engineering practice, and covering a wide range of topics, is given out for solution. Computations and reports. Five hours a week. Professor GEORGE and Assistant Professor HOWELL.

224-A. *Engineering Mathematics*. Elective. Seniors and graduates. Required of Civil Engineering seniors in the Structural Engineering Option. First term. Credit three hours. Prerequisite, Mathematics 5b. An elementary course in ordinary differential equations with applications to engineering problems. Trigonometry, calculus, and algebra are dealt with in so far as this is necessary for a clear understanding of the treatment of differential equations. The purpose of this course is to lay the foundation for the more advanced courses

in engineering mathematics. Textbook: Phillips, *Differential Equations*. Three recitations a week.

224-B. *Advanced Engineering Mathematics*. Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite, Course 224-A. This course is an introduction to the mathematics used in the solution of advanced engineering problems. Special emphasis is given to partial differentiation. Fourier Series, line integrals, formation of partial differential equations, integration in form of infinite series of several of the partial differential equations arising in engineering problems, vector notation, conformal representation, determinants, theory of the complex variable, development of function into series, etc., are reviewed in so far as a knowledge of these are essential to the course.

224-C. *Advanced Differential Equations*. Elective for graduates only. First term. Credit three hours. Prerequisites, courses 224-A and 224-B or their equivalents. A systematic study of differential equations. Partial differential equations and their solutions are emphasized. Dr. CUYKENDALL.

224-D. *Special Mathematical Topics*. Elective. Graduates only. Second term. Credit three hours. Prerequisites, courses 224-A and 224-B. The content of this course depends largely on the needs and interests of those enrolled. Generalized coordinates, vector analysis, and the calculus of variation are three subjects to be considered.

228. *Theory of Elasticity*. Elective. Primarily for graduate students. Second term. Credit three hours. Prerequisites, courses 224-A and 224-B. Theories of elastic breakdown. Fundamental relations of stress and strain; Airy stress function. Problems in two-dimensional and three-dimensional stress and strain. Analogies and their application to solutions of engineering problems in elasticity.

228-A. *Engineering Physics of Metals*. Elective. Primarily for graduate students. Second term. Credit three hours. An introduction to the physical basis of matter in relation to its elastic and plastic behaviour. Topics for discussion include atomic basis of generalized Hooke's Law, atomic cohesive forces and potential troughs, the yield value, primary bonds, dipole and Van der Waal's forces, influence of temperature on elastic properties, thermoelastic basis of internal friction, experimental and theoretical strengths of crystals, distortion of the lattice, Smekal's criticism of Born's lattice theory of metals, evidence of submicroscopic structure, elementary concepts of the cooperative phenomena in metals. Dr. CUYKENDALL.

229-A. *Elastic Foundations and Thin Structural Shells*. Elective. Primarily for graduate students. First term. Credit three hours. Study of the properties of elastic foundations and the application of the elastic foundation theory to the analysis of large diameter, low head tanks, hemispherical domes, hemispherical leaders on large pipes, and thin shell pipes under flexure. Three hours a week. Dr. HAWKINS.

MATERIALS OF CONSTRUCTION

225. *Materials of Construction*. Required of all Civil Engineering juniors. Either term. Credit three hours. Prerequisite course 221. 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. Professor SCOFIELD.

226. *Materials Laboratory*. Required of all Civil Engineering juniors except in the B.S. in A.E. Course. Either term. Credit three hours. Prerequisite course 221 and must be taken with or preceded by 280. 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 225 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. Professor SCOFIELD, Drs. HAWKINS and CUYKENDALL.

227. *Testing of Materials. (Laboratory.)* Given especially for students in the College of Architecture. Second term. Credit one hour. A brief course in laboratory methods comprising tests of beams and columns in steel, wood, and concrete. Professor SCOFIELD, Drs. HAWKINS and CUYKENDALL.

227-A. *Concrete and Concrete Materials*. Elective for seniors and graduates in Mechanical, Chemical, Electrical, and Administrative Engineering. Either term. Credit one hour. A brief course in the study of concrete and the materials entering into concrete. The course will consist of lectures and laboratory work. One 2½ hour period a week. Professor SCOFIELD and Dr. HAWKINS.

For *Research in Engineering Materials*, see Course 297b on page 95.)

HYDRAULIC ENGINEERING

230. *Water Supply*. Required of all Civil Engineering seniors. Either term. Credit three hours. Prerequisite, course 240. About half of 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. The second half of the term is devoted to a review of the methods of developing public water supplies from the serveral sources; typical structures; a study of the working conditions and fundamental data for designing conduits; distributing reservoirs; and a network of street mains; particular attention being given to the requirements for fire protection and the economics of pumped supplies. In the problems, applications of the text are made to particular localities, the topographic maps of cities and drainage basins forming the bases of the problems. Students contemplating extensive election of courses in hydraulics should arrange to take this course the first term. Courses 231, 232, and 233 are elaborations of details in this course. Textbooks: Turneaure & Russell, *Public Water Supplies*, Hoyt & Grover, *River Discharge*. Three recitations a week. Professor SEERY.

231. *Hydraulic Construction*. Elective for seniors and graduates and required of Civil Engineering seniors in the Hydraulic Engineering Option. 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. Professor SEERY.

232. *Water Power*. Elective. Seniors and graduates. Either term. Credit three hours. Prerequisites, courses 230 and 240 or the equivalent. The subject matter of the course covers the technique of hydraulic turbines, the analysis of test data, 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. Professor SEERY.

233. *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. Professor SEERY.

234. *Conservancy and Reclamation Problems*. Elective. Seniors and graduates. Second term. Credit three hours. Flood flow estimates; planning for and designing of flood protection structures, irrigation, and drainage works. The Miami Conservancy work will be the chief source of material for the course. Lectures, recitations, and abstracting of references. Professor SEERY.

236. *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 230 and 232. Professor SEERY.

(For *Hydraulic Engineering Design*, see course 291c on page 94.)

THEORETICAL AND EXPERIMENTAL HYDRAULICS

240. *Hydraulics*. Required of all Civil Engineering juniors. Either term. Credit four hours. Prerequisites, courses 220 and 221. 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. About ten of the recitation periods are utilized for demonstration lectures. Professors SCHODER and WALKER and Dr. HAWKINS.

240-A. *Hydraulics*. For special groups. First term. Credit one hour. This course covers the laboratory work only of course 240. One laboratory period a week. Professor SCHODER.

241. *Advanced Hydraulics*. Elective for seniors and graduates. Second term. Credit three hours. Prerequisite, course 240. Topics selected from the following list are taken up, subject to changes to suit group requirements: stability of flotation; barometric levelling; flow over weirs and dams, free and submerged; backwaters and non-uniform flow in open channels; the hydraulic jump; water hammer; surges in pipes and canals; viscous flow of fluids and flow of air in pipes; hydraulic similitude and flow in models; some introductory elements of hydrodynamics; impulse wheels and turbines; centrifugal pumps. Lectures, recitations, and problems. Three hours a week. Professor SCHODER.

242. *Hydraulic Measurements*. Elective for seniors and graduates and required for seniors in the Hydraulic Engineering Option in Civil Engineering. First term. Credit three hours. Prerequisite, course 240. Experimental studies involving usually (as time permits) current meters and floats in canal or river; Pitot tubes in pipes; water meters; weirs; the hydraulic jump; special features of orifices, nozzles, Venturi meters, pipes; model studies; such other occasional experimental measurements as opportunity offers in the laboratory or in the neighborhood of Ithaca; the determination of efficiency, capacity, and characteristics of hydraulic machinery by tests. Three periods a week in laboratory or computing room. Professor SCHODER.

(For *Engineering Research in Hydraulics*, see course 297c on page 95.)

MUNICIPAL AND SANITARY ENGINEERING

250. *Sanitary Biology*. Required of juniors in the Sanitary Engineering Option in Civil Engineering. Elective for other juniors, seniors, and graduates. 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. Professor WALKER.

251. *Sanitary Biology*. Required of juniors in the Sanitary Engineering Option in Civil Engineering. Elective for other juniors, seniors, and graduates. First 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. Professor WALKER.

251-A. *Water and Sewage Analysis*. Required of juniors in the Sanitary Engineering Option in Civil Engineering. Elective for other 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 analyses of water and of sewage, physical and chemical. Textbooks: *Standard Methods of Water Analysis*, A.P.H.A., *Water and Sewage Analysis*, Eldridge, Theroux, and Mallman. Two laboratory periods a week with lectures, recitations, and laboratory work. Professor WALKER.

252. *Sewerage and Sewage Disposal.* Required of all juniors or seniors in Civil Engineering. Either term. Credit three hours. Prerequisite, course 240. 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 dealing with construction and with subject matter illustrating recitation and class room work are assigned. The problems are largely of the nature of separate designs. Textbook: Metcalf and Eddy, *Sewerage and Sewage Treatment.* Two recitations and one computing period a week. Professors WALKER and STANLEY.

253. *Control and Treatment of Water Supplies.* Required of seniors in the Sanitary Engineering Option. Elective for other seniors and graduates. Second term. Credit three hours. 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 study of the design and operation of water treatment plants is included. Textbook: Ellms' *Water Purification.* Two recitations and one computation period a week. Professor STANLEY.

253-A. *Treatment of Water.* Required of all juniors or seniors in Civil Engineering. Second term. Credit two hours. Prerequisite, course 240. This course is designed to be an introductory course dealing with the design and the operation of water treatment plants, consideration being given to filter construction and to the conditions calling for treatment of water for domestic or industrial use. Textbook: Turneaure & Russell, *Public Water Supplies.* One recitation and one inspection, computing, design, or seminar period a week. Professors STANLEY and WALKER.

254. *Sewerage Works.* Required of seniors in the Sanitary Engineering Option in Civil Engineering. Elective for other seniors and graduates. First term. Credit three hours. Prerequisite, course 252. 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 and 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. Professor STANLEY.

255. *Treatment of Wastes.* Required for seniors in the Sanitary Engineering Option in Civil Engineering. Elective for other seniors and graduates. First term. Credit three hours. Prerequisite, course 252. 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, 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. Numerous references, bulletins, reports. Three lectures or recitations a week. Professor WALKER.

255-A. *Trade Waste Analysis.* Elective for seniors and graduates. Second term. Credit two hours. Prerequisites, courses 250, 251-A, 255. Advanced work in the analysis of trade wastes. Professor WALKER.

256. *Municipal Administrative Engineering.* Required for Civil Engineering seniors in the B.S. in A.E. Course. Elective for other seniors and graduates. First term. Credit three hours. A study of civic government and the relationships between the civil engineer in public service and various city, county, state, federal, and special governmental bodies, with which he may become associated; the limitations on the activities of the public works agency usually imposed by law or regulations and the effect of these on the activities of the engineer; methods of financing governmental operations, including bond issues, sinking funds, special assessments, service and rental charges. Lectures, reports, and readings. Three periods a week. Professor STANLEY.

256-A. *Public Health Engineering.* Elective for seniors and graduates. Second term. Credit three hours. A study of the relation between engineering and public health. Organization and operation of Boards of Health, vital statistics, public health laws, and the sanitary code. Lectures, reports, and readings. Three periods a week. Professor STANLEY.

256-B. *Rural Sanitation.* Elective for juniors, seniors, and graduates. Second term. Credit two hours. A course dealing with the sanitation of rural areas, trailer and other camps, summer hotels, and swimming pools. Attention is given to water supply, sewage and garbage disposal, and to the problem of milk sanitation. Lectures, reports, and recitations. Two periods a week. Professor WALKER.

257. *Conference on Present Methods of Water Treatment.* Elective for seniors and graduates. Either term. Credit three hours. A critical study of specific problems in water treatment, control of water-sheds, the construction and operation of existing water treatment plants. Readings, investigations, inspections, and reports. Hours to be arranged. Professor STANLEY.

258. *Conference on Present Methods of Sewage Disposal.* Elective for seniors and graduates. Either term. Credit three hours. A critical study of specific problems in sewage disposal, sewage treatment methods, the construction and operation of existing sewage treatment plants. Readings, investigations, inspections, and reports. Hours to be arranged. Professor STANLEY.

259. *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 purification of trade wastes, the value of disinfection, etc. Professors WALKER and STANLEY.

(For *Sanitary Engineering Design and Research*, see courses 291d and 297d on pages 94 and 95.)

TRANSPORTATION ENGINEERING

260-A. *Location Surveying*. Required of all Civil Engineering students as a part of Summer Survey Camp, following the sophomore year. Credit one hour. Taken concurrently with course 213 (Four hours credit. See description on page 76.) Each section is required to make complete preliminary and location surveys for a line two or three miles long. In this work the section is divided into level, transit, topography, and cross-section parties, as the different phases of the work are encountered. Finally structure and right of way surveys are made. The assignments of the men are changed every day so that each student receives practice in the various kinds of field work. Attendance at summer camp for one week is required. Date of beginning will be announced in the second term. Professor BARNES, Assistant Professors PERRY and THATCHER, and Mr. SPRY.

260-B. *Route Surveying and Drawing*. Required of all Civil Engineering sophomores. Second term. Credit three hours. Prerequisite, Advanced Surveying 211. 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. Each section is divided into parties of three so that each student obtains more individual instruction, more practice in handling instruments, and a more intimate knowledge of the problems than he would in larger parties. 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 260-A 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: Pickets & Wiley *Route Surveying* and Crandall *Earthwork Tables*. One recitation and two field or drawing periods a week. Professors BARNES and CONWELL, Assistant Professors CRANDALL, PERRY, and THATCHER.

261. *Railroad Maintenance of Way*. Elective. Seniors and graduates. This course or course 266 is required for seniors in the Transportation Engineering Option in Civil Engineering. First term. Credit three hours. Prerequisite, course 260-B. 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 alinement. Textbook: Tratman *Railway Track and Maintenance*. Lectures and recitations three hours a week. Professor BARNES and Assistant Professor PERRY.

262. *Railroad Operation and Management*. Elective. Seniors and graduates. This course or course 267 is required of seniors in the Transportation Engineering Option in Civil Engineering. Second term. Credit three hours. Prerequisite, course 260-B. 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 yards, 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. Professor BARNES and Assistant Professor PERRY.

263. *Route Location.* Required of juniors in the Transportation Engineering Option in Civil Engineering. Elective for seniors and graduates. Second term. Credit three hours. Prerequisites, courses 260-A and 260-B. A detailed study is made of the economic principles and other factors governing the location of new routes for both railroads and highways, and the revision of existing lines to effect the most efficient and satisfactory transportation. Some of the topics treated are estimation of traffic and revenue; costs and rates; steam, electric, and other locomotive and motor operation; gradients, distance, curvature, and rise and fall; line and grade revisions; grade crossing eliminations; location surveys and estimates. Lectures and recitations with problems involving investigations of projects, revisions, and comparisons of alternate routes. Textbook: Williams' *Design of Railway Location.* Three hours a week. Professor BARNES.

264. *Engineering Construction.* Required of all Civil Engineering sophomores. Either term. 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. About one-third of the term is devoted to such topics as the history of engineering and the rôle of the civil engineer in the progress of civilization, cooperation with other professions, day labor and contract methods of control, types of contracts, elements of cost, including depreciation and overhead, life and economic selection of structures, planning and plant layouts including the plotting and use of the Mass Diagram. The other two-thirds of the term are devoted to the 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. Professors BARNES and CONWELL and Assistant Professors CRANDALL, PERRY, and THATCHER.

265. *Highway Engineering.* Required of all Civil Engineering seniors. Elective for certain graduates. Either term. Credit three hours. Prerequisites, courses 260-A and 260-B. The course consists of lectures and recitations considering the economic selection of routes, economics of location, modern tendencies in design and practice, subgrade soils, drainage, subgrade stabilization, finance, and the technique of construction and maintenance of flexible and rigid types of pavements. In addition to the class work a problem is assigned which requires a complete redesign for modern traffic conditions of an old highway. Lectures and recitations three hours a week. Professor CONWELL.

265-A. *Low Cost Roads*. Elective. Seniors and graduate students. Either term. Credit three hours. Prerequisite, course 265 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. Professor CONWELL.

266. *Highway Laboratory*. Elective. Seniors and graduates. This course or course 261 is required of seniors in the Transportation Engineering Option in Civil Engineering. Either term. Credit three hours. Prerequisite, course 265 or may be taken concurrently with course 265. 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. Professor CONWELL.

266-A. *Advanced Highway Laboratory*. Elective. Seniors and graduates. Either term. Credit three hours. Prerequisites, courses 265 and 266. 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. Professor CONWELL.

267. *Advanced Highway Engineering*. Elective. Seniors and graduates. This course or course 262 is required of seniors in the Transportation Engineering Option in Civil Engineering. 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. Professor CONWELL.

268. *Modern Highway Planning and Design*. Elective. Seniors and graduate students. Second term. Credit three hours. Prerequisite, course 265 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. Professors CLARKE and CONWELL.

269. *Transportation*. Required of seniors in the Transportation Engineering Option and the B.S. in A.E. Course in Civil Engineering and may be elected by other qualified 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. Professors BARNES and CONWELL.

(For *Railroad and Highway Engineering Design and Research*, see Courses 291e, 291g, 297e, 297g on pages 94 and 95.)

STRUCTURAL ENGINEERING

270. *Stress Analysis and Structural Design.* Required of all juniors in Civil Engineering (Juniors in the B.S. in A.E. Course take only the stress analysis portion). Either term. Credit four hours (three hours for B.S. in A.E.). Prerequisites, courses 220 and 221.

Stress Analysis. Graphic Analysis of simple and cantilever beams, roof trusses, and framed bents. Determination of position of moving concentrated loads for maximum shears and moments in beams and deck girders; also for through girders and maximum floor beam reactions for same. Stresses due to dead load, live load, impact, and wind load in the principal types of simple trusses employed in modern construction. Stiff web systems and counter bracing. Three-hinged roof and bridge arches. Practical problems in actual stress computation throughout the course. Textbook: Urquhart and O'Rourke's *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: Jacoby and Davis's *Timber Design and Construction.* Computation and drawing, two and one-half hours a week. Professors URQUHART and O'ROURKE, Assistant Professors BURROWS and PENDLETON.

270-A. Required of Army graduate students who are candidates for the M.S. in Engineering degree. Credit two hours. A shortened course based on the content of course 270. Two recitations a week. Professor MALCOLM.

271. *Structural Design.* Required of all juniors or seniors in Civil Engineering. Either term. Credit three hours. Prerequisite, course 270 or 270-A. 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: Urquhart and O'Rourke's *Design of Steel Structures.* Three computation or drawing periods a week. Professors URQUHART and O'ROURKE, and Assistant Professor BURROWS.

272. *Advanced Structural Analysis.* Elective for seniors and graduates and required of seniors in the Structural Engineering Option in Civil Engineering. Either term. Credit three hours. Prerequisite, course 270. 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. Three recitations a week. Professors URQUHART and O'ROURKE.

273. *Steel Buildings*. Elective. Seniors and graduates. First term. Credit three hours. Prerequisites, courses 220, 221, and 271. 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 framework 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. Assistant Professor BURROWS.

274. *Bridge Design*. Elective. Seniors and graduates. This course or course 284 is required for seniors in the Structural Engineering Option in Civil Engineering. Second term. Credit three hours. Prerequisite, course 271. 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. Assistant Professor BURROWS.

275. *Investigation of Existing Bridges*. Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite, course 271. 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. Assistant Professor BURROWS.

280. *Concrete Construction*. Required of all Civil Engineering juniors. Either term. Credit three hours. Prerequisites, courses 220 and 221. (Preferably taken concurrently with or preceded by course 225.) 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. Professors URQUHART and O'ROURKE and Assistant Professor PENDLETON.

281. *Foundations*. Required of all Civil Engineering juniors or seniors except in the B.S. in A.E. Course. Either term. Credit three hours. Prerequisites, courses 220 and 221. Piles and pile driving, including timber, concrete, tubular and sheet piles; cofferdams; box and open caissons; pneumatic cais-

sons 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 foundations; underpinning buildings; subterranean explorations; unit loads. Textbook: Jacoby and Davis's *Foundations of Bridges and Buildings*. Recitations, collateral reading in engineering periodicals, and illustrated reports. Three hours a week. Professors URQUHART and O'ROURKE.

282. *Reinforced Concrete Building Design*. Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite, course 280. 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. Professors URQUHART and O'ROURKE.

283. *Fixed Arches*. Elective for seniors and graduates and required for seniors in the Structural Engineering Option in Civil Engineering. First term. Credit three hours. Prerequisites, courses 270, 271, and 280. Theory of the curved beam; the closed ring; the fixed arch. Influence lines for arches of various forms. Selection of curvature of axis for various loadings. Effect of temperature and rib-shortening. Effect of plastic flow on stresses in a reinforced concrete arch. Design of a reinforced arch and its abutments. Lectures, recitations, and computations. Six hours a week. Professors URQUHART and O'ROURKE.

284. *Highway Bridges*. Elective. Seniors and graduates. This course or course 274 is required for seniors in the Structural Engineering Option in Civil Engineering. Second term. Credit three hours. Prerequisite, course 280. Design of short span bridges and their abutments. Comparison of the economy of steel and reinforced concrete superstructures for bridges of this type. Reports and drawings. Professor O'ROURKE.

285. *Reinforced Concrete Design*. Elective for seniors and graduates and required for seniors in the Structural Engineering Option in Civil Engineering. Either term. Credit three hours. Prerequisite, course 280. Design of footings: single and multiple columns of reinforced concrete, I-beam grillages. Design of bins and tanks, subsurface and supported on towers. Design of a highway bridge. Reports and sketches. Three two-hour periods a week. Professors URQUHART and O'ROURKE.

287. *Soil Mechanics*. Required of juniors in the Regular Four-Year Course and the Sanitary, Structural, Hydraulic, and Transportation Engineering Options in Civil Engineering. Either term. Credit three hours.

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. Professor O'ROURKE and Assistant Professors JENKINS and PENDLETON.

288. *Applied Soil Mechanics*. Elective for seniors and graduate students. Second term. Credit three hours. Prerequisite, course 287. Advanced application of soil mechanics, based on the principles and physical studies of course 287. 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. Professor O'Rourke and Assistant Professors Jenkins and Pendleton.

(For *Structural Engineering Design and Research*, see Course 291a, 291f, 297f on pages 94 and 95.)

ADMINISTRATIVE ENGINEERING

290. *Engineering Law*. Required of all Civil Engineering seniors. Juniors admitted only by special permission. Also open to seniors in Architecture, Mechanical, Chemical, and Electrical Engineering, and other seniors submitting acceptable qualifications. Either term. Credit three hours. Essentials of contracts and contract principles; agency, tort, and independent contractor; use and conveyance of lands and waters, including irrigation law, real estate documents, boundary lines, eminent domain and title searches; corporations, partnerships and other contracts of association; sales and transportation contracts; negotiable instruments; bankruptcy, mechanics liens, patents, trademarks, copyrights, courts, wills, and laws of insurance. The course culminates with the preparation of a set of contract documents for an assigned construction job, including advertisement, bond, form of proposal, information to bidders, agreement form, specifications, and general conditions with clauses covering payments, time limit, arbitration, extras, liquidated damages, and abandonment of contract. Tucker's *Contracts in Engineering* is used as a text, supplemented liberally from other sources. Lectures and recitations three hours a week. Professor Barnes, Assistant Professors Crandall, Perry, and Thatcher.

290-A. *Advanced Engineering Law*. Required of seniors in B.S. in A.E. Course in Civil Engineering and open to others who have completed course 290. Second term. Credit three hours. Some of the topics treated in course 290 are here enlarged upon and extended, particularly laws relating to the various phases of construction contracts, employer-employee relationship, workman's compensation, mechanics liens, patents, copyrights, trademarks, and insurance. Among other subjects covered are suretyship, conditional sales, bailments, trusteeship, and taxation. Actual cases are used for illustrating the above and reference is also made to recent court decisions regarding engineering matters. Lectures and recitations three hours a week. Professor Barnes and Assistant Professors Crandall, Perry, and Thatcher.

293. *Engineering Management*. Required of juniors in the Regular Four-Year Course and the Transportation and Geodetic Engineering Options in Civil Engineering. Also open to qualified juniors and seniors in other courses. Either term. Credit three hours. This course is devoted mainly to the management of construction work but also treats briefly of such larger problems as economics of plant location and economic selection of plant, or structure, to fulfill a given purpose. Management is treated under its two main heads,—planning and operation. Under planning are such subjects as the selection of methods of procedure which will result in maximum economy, the planning

of a thoroughly coordinated organization of men and machines to carry out these methods and the scheduling and estimating of the work in accordance with the adopted plans. Under operation are selecting, training and maintaining labor forces including pay systems, accident prevention, welfare work, etc., purchasing, operation, and maintenance of equipment and keeping the records essential to the management for comparing results with schedules, i. e., cost keeping. Bookkeeping is recognized also as an essential tool of management and the fundamentals of double entry bookkeeping are given, together with the use of control accounts, financial statements, and budgets. Blanks and forms for cost keeping for actual or assumed jobs are required and each student also works out problems in bookkeeping. Lectures and recitations three hours a week. Professor BARNES and Assistant Professor CRANDALL.

293-A. *Engineering Management.* Required of juniors in the Administrative Engineering Option and the B.S. in A.E. Course in Civil Engineering. Second term. Credit three hours. Prerequisite, an elementary course in accounting. Covers the same ground as course 293 except that bookkeeping is omitted and more attention is given to management proper, especially to personnel and labor relations. Cost accounting on engineering construction work is included. Three hours a week. Professor BARNES.

295. *Valuation Engineering.* Elective for seniors and graduates and required for seniors in the B.S. in A.E. Course in Civil Engineering. Second term. Credit three hours. Prerequisite, courses 264 and 290 or taken concurrently with 290. Theory and practice of valuation or appraisal for purposes of utility rate making, purchase or sale, eminent domain or condemnation cases, mergers or joint ownership, taxation and assessment, issuance of securities, bank loans, insurance, uniform system of accounting, and improved management. Topics considered include scientific systems of real estate assessment, federal railroad valuation, rate disputes, court rulings, computation of actual rates for gas, telephone, electrical supply and street railways, valuation of land, mines, water power, factories, railroads, toll bridges, buildings, and all kinds of property both tangible and intangible. Detailed examples of forms and methods with outline of typical valuation reports. Lectures, recitations, and reports. Assistant Professor CRANDALL.

(For *Management Engineering Research*, see Course 297h on page 96).

REGIONAL AND CITY PLANNING

(By Cooperation of the College of Architecture)

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 28. Professor CLARKE and Mr. MACKESEY.

711. *City Planning Practice.* Elective. Second term. Credit three hours. Prerequisite, course 710. The procedures 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 28. Professors CLARKE and Mr. MACKESEY of the College of Architecture.

712. *Regional Planning Practice.* Elective. Open to graduates and upperclassmen in all colleges of the University. Throughout the year. Credit four hours upon completion of the course. A study of the principles involved in county, regional, state, and national planning. Includes discussion of following factors involved: land use, (submarginal farm land, reforestation, soil conservation, erosion, etc.), water resources (flood control, power, pollution, potable water), recreation, transportation, public services, and public works. Occasional lectures will be given by members of other faculties and outside lecturers. Students wishing to register should see Mr. Mackesey at the College of Architecture on registration day. Lectures, assigned reading, reports, and examinations. Hours to be arranged. 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 phases of housing as subject. These programs 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 28. Assistant Professor HARTELL 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. 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-6. Professor CLARKE.

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 study of examples. T 8–10. White B-6. Professor CLARKE.

GENERAL COURSES

291. *Engineering Design.* Elective. Seniors. Credit three or more hours. The student may make complete designs in one of the following sub-divisions, subject to approval. Hours to be arranged.

(a) *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.

(c) *Hydraulic Engineering.* Second term. Prerequisite course 240. For best results Hydraulic Engineering Design should be preceded by Course 230, 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. Professor SEERY.

(d) *Sanitary Engineering.* Either term. Credit three hours. This course should be preceded by Courses 252 and 253-A 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 works, works for handling trade wastes, 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. Professors WALKER and STANLEY.

(e) *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. Professor BARNES and Assistant Professor PERRY.

(f) *Structural Engineering.* Either term. Prerequisite, courses 270, 271, and 280. 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. Professor URQUHART and Assistant Professor BURROWS.

(g) *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. Professor CONWELL.

297. *Engineering Research.* Elective. Seniors and graduates. Credit three or more hours. Research may be taken in one of the following subdivisions or two or more departments may cooperate in the assignment of special problems. Hours to be arranged.

(a) *Geodetic Astronomy.* Second term. Prerequisites, courses 186 and 216. Investigations of instrumental errors; variation of latitude and azimuth; any 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. Professor BOOTHROYD.

(b) *Engineering Materials.* Either or both terms. 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 225 and 226 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. Professor SCOFIELD.

(c) *Hydraulics.* Either term. Prerequisite, course 240 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. Professor SCHODER.

(d) *Sanitary Engineering.* 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. Professors STANLEY and WALKER.

(e) *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. Professor BARNES.

(f) *Structural Engineering.* Second 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. Professor URQUHART.

(g) *Highway Engineering.* Either term. Prerequisites, courses 265 and 266. 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 soils, subgrade stabilization, and the effects of modifications in design of bituminous and non-bituminous mixtures provide a wide range of topics for research. Professor CONWELL.

(h) *Management Engineering*. Either term. Special problems relating to the economic, legal, and financial aspects of engineering construction projects, management of public works and appraisals. Professor BARNES.

(i) *Geodetic Engineering*. 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. Professor UNDERWOOD.

298. *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 results 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 AND GRADUATE COURSES

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.

Sibley School of Mechanical Engineering

FOUR-YEAR COURSE The four-year course of study leading to the degree of Bachelor of Mechanical Engineering, which the Sibley School of Mechanical Engineering offers, contains the courses of instruction in mathematics, physics, chemistry, mechanics, materials, kinematics and machine design, heat-power engineering, electrical engineering, and experimental engineering that are considered essential to the basic training for this degree. Provision is made in the later years of the course for specialization in any one of several recognized fields of mechanical engineering, for the sake of the student who may develop a special interest in one of those fields. That specialization is strictly limited in extent, however, and is not permitted to encroach upon the mastering of fundamentals, which is considered of primary importance. Therefore credit for any such special work may not exceed from eight to twelve hours.

The several varieties of specialization which are provided for, and which are known as options, are shown in the following pages, where the special courses of instruction peculiar to each option are printed in *italics*. In all but two of them the special work is limited to the Senior year. In those two, Aeronautical Engineering (Option E) and Metallurgical Engineering (Option G), the specialization begins in the Junior year and the student who is to take one of them must therefore make his decision before the beginning of that year.

For the professional degree of M.E. see page 12.

Option A. Power-Plant Engineering

The object of the special courses in this option is to acquaint the student with load-curves and their characteristics, station factors, power-plant economics, and the cost of plants and of their component parts and output; the principles of the economic selection and operation of the power-plant machinery with respect to character of the loading, the cost factors, and the local conditions involved; the design of steam power plant equipment with regard to these considerations and the structural requirements; plant location and layout; and similar topics. The special work in this option is confined to the senior year and is taught by lectures supplemented by a computing and layout course.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Strength of Materials 3M22b	0	2
	Physics 21, 22	3	3
	Kinematics, Recitations 3D21	2	0
	Kinematics, Drawing 3D23	2	0
	Kinematics, Recitations and Drawing 3D24	0	3
	Materials of Engineering 3X21, 3X22	3	3
	Economic Organization 3A21	3	0
	Pattern Shop 3S21	0 or 1	1 or 0
	Foundry 3S22	0 or 1	1 or 0
	Applied Mathematics 3M32	0	3
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 38 HOURS	Heat-Power, 3P31, 3P32	3	3
	E. E. Theory 415, 416	3	3
	Machine Design, Recitations, 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Accounting 3A31	0	3
	Fluid Mechanics 3M33	4	0
	Machine Shop 3S31	3	0
	Industrial Organization 3A35	0	2
FOURTH YEAR 38 HOURS	Heat-Power Engineering 3P41, 3P42	3	3
	Mechanical Laboratory 3X41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
	Steam Power Plants Lectures 3P44, 3P45	2	2
	Computing and Design 3P46, 3P47	2	2
	Power Plant Economics 3P50	2	0
	Non-resident Lectures 3G41	0	1
	Electives (See suggested list on page 108)	1 or 4	5 or 2
	Grand total for the Four-Year Course		150 hours

Option B. Heat Engineering

(Fluid Flow, Heat Transmission, Refrigeration, and Air Conditioning)

The purpose of the special work in this option is to train men in the fundamentals required in solving problems encountered in the rapidly expanding fields of air conditioning, refrigeration, and the industrial utilization of heat. Extended instruction in the basic principles of fluid flow, heat transfer, properties of mixtures, and refrigeration are given during the first term of the senior year. In the second term important applications of these principles in air conditioning for the purpose of improving human comfort and for the control of the properties of hygroscopic materials during manufacturing processes are given.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Strength of Materials 3M22b	0	2
	Physics 21, 22	3	3
	Kinematics, Recitations 3D21	2	0
	Kinematics, Drawing 3D23	2	0
	Kinematics, Recitations and Drawing 3D24	0	3
	Materials of Engineering 3X21, 3X22	3	3
	Economic Organization 3A21	3	0
	Pattern Shop 3S21	0 or 1	1 or 0
	Foundry 3S22	0 or 1	1 or 0
	Applied Mathematics 3M32	0	3
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 38 HOURS	Heat-Power 3P31, 3P32	3	3
	E. E. Theory 415, 416	3	3
	Machine Design, Recitations 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Accounting 3A31	0	3
	Fluid Mechanics 3M33	4	0
	Machine Shop 3S31	3	0
	Industrial Organization 3A35	0	2
FOURTH YEAR 38 HOURS	Heat-Power Engineering 3P41, 3P42	3	3
	Mechanical Laboratory 3X41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	Heat Engineering 3P57, 3P58	4	4
	Refrigeration 3P49	2	0
	Non-resident Lectures 3G41	0	1
	Electives (See suggested list on page 108)	4	5

Grand total for the Four-Year Course ..... 150 hours

Option C. Industrial Engineering

This option is intended for those who wish to enter the commercial side of engineering or who are particularly interested in industrial organization and administration. In the special senior courses in this option the following topics are discussed: Modern time-keeping and cost-finding systems; methods of planning work and insuring production; time and motion studies; purchasing; problems in administration; plant locating; heating; lighting; powering; safety engineering; fire protection and similar subjects. In the drafting and designing courses the graphical work includes the application of these fundamental principles to planning industrial enterprises. Students expecting to elect this option are advised to read for preparation as much industrial history and kindred subjects as possible.

		HOURS	
		First Term	*Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M31	5	0
	Strength of Materials 3M22a	0	3
	Strength of Materials 3M22b	0	2
	Physics, 21, 22	3	3
	Kinematics, Recitations 3D21	2	0
	Kinematics, Drawing 3D23	2	0
	Kinematics, Recitations and Drawing 3D24	0	3
	Materials of Engineering 3X21, 3X22	3	3
	Economic Organization 3A21	3	0
	Pattern Shop 3S21	0 or 1	1 or 0
	Foundry 3S22	0 or 1	1 or 0
	Applied Mathematics 3M32	0	3
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 38 HOURS	Heat-Power 3P31, 3P32	3	3
	E. E. Theory 415, 416	3	3
	Machine Design, Recitations 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Accounting 3A31	0	3
	Fluid Mechanics 3M33	4	0
	Machine Shop 3S31	3	0
	Industrial Organization 3A35	0	2
FOURTH YEAR 38 HOURS	Heat-Power Engineering 3P41, 3P42	3	3
	Mechanical Laboratory 3X 41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	Heating, Ventilating, and Refrigeration 3X44	3	0
	Industrial Engineering 3I43, 3I44	3	3
	Industrial Relations 3A49	2	0
	Cost Accounting 3A47	0	3
	Industrial Engineering 3I48	0	2
	Non-resident Lectures 3G41	0	1
	Electives (See suggested list on page 108)	2	1
	Grand total for the Four-Year Course		150 hours

Option D. Automotive Engineering

The specialization in this option is confined to the senior year and begins in the first term with the study of the broad purposes of the automotive vehicle taken as a whole; the main functions, steering, driving, braking, suspension; power for operation; power transmission; the specific structures and their detailed actions. The second term deals with the power plant theory, design, and operation; nature of working fluid; preparation for and control of combustion; power conversion; efficiencies and mechanism of the engine. There are two lectures and two computing periods a week. The latter are usually devoted to analytical work, but sometimes to drawing, laboratory, or demonstration.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Strength of Materials 3M22b	0	2
	Physics 21, 22	3	3
	Kinematics, Recitations 3D21	2	0
	Kinematics, Drawing 3D23	2	0
	Kinematics, Recitations and Drawing 3D24	0	3
	Materials of Engineering 3X21, 3X22	3	3
	Economic Organization 3A21	3	0
	Pattern Shop 3S21	0 or 1	1 or 0
	Foundry 3S22	0 or 1	1 or 0
	Applied Mathematics 3M32	0	3
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 38 HOURS	Heat-Power 3P31, 3P32	3	3
	E. E. Theory 415, 416	3	3
	Machine Design, Recitations 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Accounting 3A31	0	3
	Fluid Mechanics 3M33	4	0
	Machine Shop 3S31	3	0
	Industrial Organization 3A35	0	2
FOURTH YEAR 38 HOURS	Heat-Power Engineering 3P41, 3P42	3	3
	Mechanical Laboratory 3X41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
	Automotive Lectures 3B41, 3B42	2	2
	Automotive Design 3B43, 3B44	2	2
	Non-resident Lectures 3G41	0	1
	Electives (See suggested list on page 108)	3 or 6	5 or 2
	Grand total for the Four-Year Course		150 hours

Option E. Aeronautical Engineering

Students who are interested in aeronautical work may find a limited amount of specialization in aeronautics desirable in the senior year. For this option, the student must have elected an introductory course in aerodynamics in the junior year, and should preferably have had some instruction in practical flying. Flight training is not offered by the University, but can be obtained at the Ithaca Airport, within two miles of the Cornell campus. The student is introduced to practical engineering work by problems in the design and construction of airplanes. The study of aeronautic power plants is undertaken with the automotive group.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Strength of Materials 3M22b	0	2
	Physics 21, 22	3	3
	Kinematics, Recitations 3D21	2	0
	Kinematics, Drawing 3D23	2	0
	Kinematics, Recitations and Drawing 3D24	0	3
	Materials of Engineering 3X21, 3X22	3	3
	Economic Organization 3A21	3	0
	Pattern Shop 3S21	0 or 1	1 or 0
	Foundry 3S22	0 or 1	1 or 0
	Applied Mathematics 3M32	0	3
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 38 HOURS	Heat-Power 3P31, 3P32	3	3
	E. E. Theory 415, 416	3	3
	Machine Design, Recitations 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Accounting 3A31	0	3
	Fluid Mechanics 3M33	4	0
	Machine Shop 3S31	3	0
	Aerodynamics 3B35	0	2
FOURTH YEAR 38 HOURS	Heat-Power Engineering 3P41, 3P42	3	3
	Mechanical Laboratory 3X41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	Automotive Power 3B42	0	2
	Internal Combustion Engines 3P52	2	0
	Airplane Design Recitations 3B46	2	0
	Airplane Design Computations 3B47, 3B48	2	2
	Industrial Organization 3A35	2	0
	Heating, Ventilating, and Refrigeration 3X44	0	3
	Non-resident Lectures 3G41	0	1
	Electives (See suggested list on page 108)	2	2

Grand total for the Four-Year Course ..... 150 hours

Option F. Hydraulic Power Plant Engineering

The aim of the special course in this option is to cover all topics essential to an intelligent cooperation between engineers engaged in either the design, construction, or operation of water power developments or in the transmission of energy. Special consideration is given to financial and economic phases and to the elements of design and construction affecting economical operation. The special instruction is given in the senior year by lectures, supplemented by work in computing periods. A course covering electrical power plants and transmission and distribution is also included.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Strength of Materials 3M22b	0	2
	Physics 21, 22	3	3
	Kinematics, Recitations 3D21	2	0
	Kinematics, Drawing 3D23	2	0
	Kinematics, Recitations and Drawing 3D24	0	3
	Materials of Engineering 3X21, 3X22	3	3
	Economic Organization 3A21	3	0
	Pattern Shop 3S21	0 or 1	1 or 0
	Foundry 3S22	0 or 1	1 or 0
	Applied Mathematics 3M32	0	3
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 38 HOURS	Heat-Power 3P31, 3P32	3	3
	E. E. Theory 415, 416	3	3
	Machine Design, Recitations 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Accounting 3A31	0	3
	Fluid Mechanics 3M33	4	0
	Machine Shop 3S31	3	0
	Industrial Organization 3A35	0	2
FOURTH YEAR 37 HOURS	Heat-Power Engineering 3P41, 3P42	3	3
	Mechanical Laboratory 3X41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
	Hydraulic Power Plant Lectures 3M41, 3M42	2	2
	Hydraulic Power Plant Computations 3M43, 3M44	2	2
	Electric Power Plant Design 441	3	0
	Non-resident Lectures 3G41	0	1
	Electives (See suggested list on page 108)	0 or 2	5 or 3

Grand total for the Four-Year Course ..... 150 hours

Option G. Metallurgical Engineering

This option of studies does not represent a complete curriculum in Metallurgy, because that would require a much wider specialization in Physical Chemistry, Metallography, and Metallurgy than is here included. The option is intended to give students who are interested in the metallurgical field, mainly iron and steel, some training which will enable them to get a start along this line.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Strength of Materials 3M22b	0	2
	Physics 21, 22	3	3
	Kinematics, Recitations 3D21	2	0
	Kinematics, Drawing 3D23	2	0
	Kinematics, Recitations and Drawings 3D24	0	3
	Materials of Engineering 3X21, 3X22	3	3
	Economic Organization 3A21	3	0
	Pattern Shop 3S21	0 or 1	1 or 0
	Foundry 3S22	0 or 1	1 or 0
	Applied Mathematics 3M32	0	3
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR, IN 1939–40 38 HOURS	Heat-Power 3P31, 3P32	3	3
	E. E. Theory 415, 416	3	3
	Machine Design, Recitations 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Industrial Organization 3A35	0	2
	Introductory Metallography, Chem. 545	3	0
	Analytical Chemistry 201	4	0
	*Accounting 3A31	0	3
FOURTH YEAR, IN 1939–40 40 HOURS	Heat-Power 3P31, 3P42	3	3
	Mechanical Laboratory 3X41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	*Accounting 3A31	0	3
	Fluid Mechanics 3M33	4	0
	Machine Shop 3S31	3	0
	Applied Metallography 3X52	2	0
	Introductory Physical Chemistry 405	3	3
	Introductory Physical Chemistry Lab. 410	0	3
	Non-Resident Lectures 3G41	0	1

Grand total for the Four-Year Course ..... 152 hours

*Courses 3A31 and Chem. Eng. 750 will be given in alternate years for both juniors and seniors taking this option. The senior year for 1940–41 is made up as follows:

FOURTH YEAR, IN 1940–41 42 HOURS	Heat-Power 3P41, 3P42	3	3
	Mechanical Laboratory 3X41, 3X42	4	4
	Electrical Laboratory 435, 436	2	2
	Industrial Organization 3I31	0	2
	Machine Shop 3S31	3	0
	Physical Chemistry 405	3	3
	Physical Chemistry Laboratory 410	0	3
	Analytical Chemistry 201	4	0
	Applied Metallography 3X52	2	0
	Furnace Metallurgy, Chem. 750	0	3
	Non-Resident Lectures 3G41	0	1

Grand total for the Four-Year Course ... 152 hours

Option H. Elective Group of Studies or Thesis

In exceptional cases only, seniors who have made excellent records and can show a real need for specializing in Physics, Chemistry, Mathematics, or advanced work in Engineering, or in a field related thereto, may petition to be allowed to devote to such specialization the hours assigned to the group courses and electives in the other options.

Also, under this option, a limited number of well qualified seniors may, upon petitioning, be allowed to substitute for either the special or the elective courses of one of the other options an investigation or research of importance and of broad educational value in Mechanical Enigneering or in a field related thereto. The results of the investigation are to be embodied in a Thesis or Essay submitted in the manner and form required of graduate students.

A student desiring to take the special work under the provisions of this option must submit to the Director of the School and to the department principally concerned, a definite plan of the proposed work. The plan, which should be submitted in the Junior Year, must have definite objective and must state in detail the reasons for desiring the special work. Grand total for the Four-Year Course, 150 hours.

A FIVE-YEAR COURSE

(B.M.E. *and* B.E.E.) In various fields of practice and investigation the mechanical engineer often has use for a more extensive training in electrical engineering than can be included in a regular four-year course in mechanical engineering; similarly, the electrical engineer may desire to have had more instruction in heat-power engineering, hydraulic-power engineering, mechanics, experimental engineering, and other phases of mechanical engineering than can be given in a four-year electrical engineering course. To meet these broader requirements it may be possible to rearrange the required work in the respective four-year curricula in mechanical and electrical engineering so that both the B.M.E. and B.E.E. degrees may be obtained in a five-year period of study. The necessary readjustment of work for obtaining the two degrees must be

made with the Directors of the Schools of Mechanical Engineering and Electrical Engineering, before the beginning of the student's second year.

A FIVE-YEAR COURSE FOR THE B.M.E.

A five-year course leading to the degree of Bachelor of Mechanical Engineering may be arranged. The entrance requirements are the same as for the regular four-year course. In general the five-year course includes all the work of any of the four-year courses which are outlined in the preceding pages, and in addition the equivalent of one year's work in other studies, generally in the College of Arts and Sciences, designed to broaden the student's training. There is no fixed program, since much depends upon the student's special interests. A possible arrangement is suggested in the table below. The Group Lectures and Design Courses provided for in the fifth year are to be chosen from one of the options of the regular four-year course.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR	See The Sophomore Year of Option A, page 98	18 or 20	19 or 17
THIRD YEAR 38 HOURS	Heat-Power Engineering 3P31, 3P32	3	3
	Mechanical Laboratory 3X31, 3X32	4	3
	Machine Design, Recitations 3D31, 3D32	2	2
	Machine Design, Drawing 3D33	0	3
	Machine Shop 3S31	0	3
	Fluid Mechanics 3M33	4	0
	Electives	6	5
FOURTH YEAR 35 HOURS	Electrical Engineering 415, 416	3	3
	Industrial Organization 3A35	2	0
	Mechanical Laboratory	4	4
	Heat-Power Engineering 3P41, 3P42	3	3
	Accounting 3A31	0	3
	Electives	6	4
FIFTH YEAR 38 HOURS	Group Lectures	2	2
	Group Design	2	2
	Electrical Engineering 435, 436	2	2
	Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
	Non-resident Lectures 3G41	0	1
	Electives	10 or 13	12 or 9

Grand total for the Five-Year Course ..... 185 hours

A FOUR-YEAR COURSE (B.S. IN A.E.)

A four-year course leading to the degree of Bachelor of Science in Administrative Engineering is given in the School of Mechanical Engineering. The

significant feature of this course in Administrative Engineering is its coordination of technical instruction with instruction in economics and in business administration. The work in non-technical subjects begins in the second year and continues in increasing amount throughout the third and fourth years, as shown by the courses of instruction printed in *italics* in the following outline.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 40 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22	0	3
	Hydraulics 3M23	0	2
	Kinematics, Recitations 3D25	3	0
	Kinematics, Drawing 3D26	2	0
	Materials of Engineering 3X21, 3X22	3	3
	Pattern Shop 3S21	0	1
	Foundry 3S22	1	0
	Machine Shop 3S32	0	2
	English 2	0 or 3	3 or 0
	Technical Writing 3A33	2 or 0	0 or 2
	Business Statistics 3A41	0	3
	Business and Industrial Management 3A23	4 or 0	0 or 4
	Public Speaking 1	0 or 3	3 or 0
	In addition to these courses, sophomores are required to take Military Training.		
THIRD YEAR 35 HOURS	Heat Power 3P33, 3P34	3	3
	Machine Design, Recitations 3D34	2	0
	Machine Design, Drawing 3D35	0	2
	Mechanical Laboratory 3X33, 3X32	3	3
	Electrical Engineering 405, 406	4	4
	Accounting 3A31, 3A32	3	3
	Graphical Computations 3P55	2	0
	Economic Organization 3A21	0	3
FOURTH YEAR 38 HOURS	Mechanical Laboratory 3X41, 3X42	4	4
	Heat Power 3P54	0	2
	Industrial Engineering 3I43	3	0
	Industrial Relations 3A49	0	2
	Cost Accounting 3A47	0	3
	Corporation Finance 3A43 or *Economics* 31	3 or 0	0 or 3
	Engineering Business Law 3A43, 3A46	3	2
	Industrial Marketing 3A44	3	0
	Business and Industrial Problems 3A48	0	2
	Human Nature and Management 3A42	2	0
	Non-Resident Lectures 3G41	0	1
	Electives	0 or 4	4 or 0
	Grand total for the Four-Year Course		150 hours

A SIX-YEAR COURSE

(A.B. *and* B.M.E.) The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years.

The student must complete the Freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Mechanical Engineering before beginning his fifth year. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the Sibley School of Mechanical Engineering and to the Dean of the College of Arts and Sciences.

ELECTIVE SUBJECTS Courses of instruction which are given in the Sibley School of Mechanical Engineering and which are open to election by students are indicated by title and number in the following list. The figures in the last two columns indicate the credit in hours for the first and second term respectively.

Mechanical Technology 3D51 (not open to seniors)	0 or 2	2 or 0
Advanced Kinematics and Kinetics 3D52	0	3
Materials Handling 3D53	0	2
Dynamics and Vibrations of Machinery 3D54	3	0
Advanced Machine Design 3D55	0	3
Automotive Lectures 3B41, 3B42	2	2
Ordnance Problems 3M53 (one hour a term for two years)	1	1
Hydraulic Power Plants 3M41, 3M42	2	2
Photoelasticity 3M55	3	0
Applied Elasticity 3M56, 3M57	3	3
Steam Power Plants 3P44, 3P45	2	2
Fluid Flow, Heat Transmission, and Air Conditioning 3P48	2	0
Refrigeration 3P49	2	0
Power Plant Economics 3P50	2	0
Steam Turbine 3P51	0	2
Internal Combustion Engines 3P52	0	2
Steam Boilers and Boiler Plants 3P53	0	2
Graphical Computations and Representations 3P55	2	0
Experimental Engineering Research 3X51	1 to 3	1 to 3
Applied Metallography 3X52	2	0
Industrial Relations 3A49	0	2
Corporation Finance 3A34	0	3
A. S. M. E. Credit 3G51	0	1
Cornell Engineer Credit 3G52	0 or 2	2 or 0
Advanced Industrial Engineering 3I51	1 to 3	1 to 3
Industrial Auditing 3I52	0	2
Advanced Industrial Relations 3I53	0	2
Micro-Motion Laboratory 3I54	0	2
Engineering Business Law 3A50	0	2
Industrial Marketing 3A45	0	2
Industrial Engineering 3I48	0	2
Elective Subjects for Graduates and Advanced Students:		
Experimental Engineering Research 3X51	As assigned	
Special Hydraulic Power Plant Problems 3M52	2 to 5	2 to 5
Advanced Industrial Engineering 3I51	1 to 3	1 to 3
Advanced Heat-Power Engineering 3P60	1 to 5	1 to 5
Business and Industrial Research 3A51	As assigned	
Advanced Automotive Engineering 3B50	As assigned	
Advanced Machine Design 3D54 and 3D55	As assigned	

Following is a list of courses of instruction, given in other Schools of the College of Engineering or in other colleges of the University, which may be elected by students of the Sibley School of Mechanical Engineering:

Advanced Hydraulics 241	0	3
Hydraulic Measurements 242	3	0
Foundations 281	0 or 3	3 or 0
Engineering Law 290	0 or 3	3 or 0
Electrical Power Plants 441	3	0
Elements of Electric Railway Practice 461	2	0
Industrial Applications and Control 462	0	2
Transmission and Distribution 464	0	3
Illumination 466a, b	2	2
Elementary Differential Equations 41	0 or 3	3 or 0
Patents 488	1	0
Advanced Calculus 42	3	3
Introductory Qualitative Analysis 210	0 or 3	3 or 0
Introductory Quantitative Analysis 225	0 or 3	3 or 0
Introductory Physical Chemistry (Lect.) 405	3	3
Introductory Physical Chemistry (Lab.) 410	3	3
Introductory Chem. Microscopy (Lect. and Lab.) 530	0 or 3	3 or 0
Introductory Metallography 545	3	0
Advanced Metallography, Chem. 550	0	3
Gas and Fuel Analysis 250	0	3
Physics courses dependent upon prerequisites (Consult the Department)		
Introductory Geology 100	3 or 0	0 or 3
Engineering Geology 501	4 or 0	0 or 4
Money and Banking 11	3 or 0	0 or 3
Industrial Hygiene 5	1	0
Public Speaking 1a	3 or 0	0 or 3

For other subjects, such as Languages, History, Philosophy, Psychology, Government, Astronomy, Biology, Botany, Archaeology, Music, see the Announcements of the colleges concerned.

Note. Not more than four hours credit for elective work in Advanced Military Science and Tactics will be accepted toward meeting the degree requirements in any Course or Option in the School of Mechanical Engineering.

THE COURSES OF INSTRUCTION

The courses of instruction in the following list are designed for members of the Sophomore, Junior, and Senior classes in the Sibley School of Mechanical Engineering. The courses that are designed for members of the Freshman class have already been described under the head of The Freshman Year. The courses in Chemistry, Physics, Economics, and English are given in the College of Arts and Sciences, and those in Electrical Engineering in the School of Electrical Engineering.

CHEMISTRY

(Required of students taking Option G in M.E. See page 104.)

201. *Introductory Analytical Chemistry.* Repeated in the second term. Credit four hours. Prerequisite, Chemistry 101 and 105. Deposit, $25. Primarily for students majoring in the biological sciences. Professor NICHOLS and assistants. Lectures: T Th 10. *Baker* 177.

Laboratory sections: W F 1:40–4; S 8–1. *Baker* 252.

A study of the fundamental principles of qualitative and quantitative

analysis. Laboratory practice in gravimetric and volumetric quantitative methods.

405. *Introductory Physical Chemistry*. Throughout the year. Credit three hours a term. Prerequisite, Chemistry 305, Mathematics 5a and 5b and Physics 11 and 12 (or their substantial equivalent). Professor BRIGGS and assistants. Lectures, M W F 9. *Baker* 7.

A systematic presentation of modern 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 and the concept of activity; chemical kinetics and catalysis; written problems in physical chemistry.

410. *Introductory Physical Chemistry*. Throughout the year. Laboratory and recitations. Credit three hours a term. Prerequisite or parallel course, Chemistry 405. Deposit, $20. Professor BRIGGS and assistants. Laboratory sections: M T 1:40–4; Th F 1:40–4; and S 8–1. *Baker* 1. Recitations, to be arranged.

Qualitative and quantitative experiments illustrating the principles of physical chemistry and practice in performing typical physico-chemical measurements. Recitations on the general principles of physical chemistry, based upon the lectures given in Course 405.

545. *Introductory Metallography*. First term. Credit three hours. Prerequisite or parallel course, Chemistry 530 or Mechanical Laboratory 3X31, or special permission. Fee, $10. Professor MASON and assistant. Lecture, Th 10. Laboratory, M T or Th F 1:40-4; additional sections if warranted. *Baker* 384.

Laboratory practice, lectures, and reports. An introduction to the principles and methods involved in the study of the structure of metals. The relation of microscopical appearances to thermal history and mechanical properties. Preparation of specimens for macroscopical and microscopical study. Metallographic microscopes and their use.

ELECTRICAL ENGINEERING

E.E. 405, 406. *Fundamentals of Electrical Engineering*. Required of juniors in Administrative Engineering. Throughout the year. Credit four hours a term. Two lectures, a computing period, and a laboratory period each week.

First term: D. C. electric and magnetic circuits; study and tests of D. C. motors, generators, and control equipment; distribution and rates. Simple A. C. circuits.

Second term: A. C. circuits, measurements, and machinery; industrial applications; electronic apparatus.

A study of fundamental electrical principles and machinery and the application of electrical equipment in industry. Professor CHAMBERLAIN, Assistant Professors B. K. NORTHROP and STRONG, and Dr. SOHON.

E.E. 415, 416. *Principles of Electrical Engineering*. Required of juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 21, 22; Mechanics 3M21. Two lectures and a

recitation-computing period a week. First term: Electric and magnetic circuits, and direct-current machinery. Second term: Alternating-current circuits and machinery. A study of the fundamental electrical principles and their practical application to commercial electrical circuits and machinery, with a view primarily towards enabling the student to choose intelligently the proper type of electrical equipment for various service requirements met with in ordinary engineering practice. Assistant Professor STRONG and instructors.

E.E. 435, 436. *Electrical Laboratory for M.E. Seniors.* Required of seniors in Mechanical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 21, 22, Mechanics 3M21, and E.E. 415, 416. Professor CHAMBERLAIN and instructors.

CHEMICAL ENGINEERING

750. *Furnace Metallurgy.* Second term. Credit two hours. Prerequisite or parallel course, Chemistry 405. Professor RHODES. T Th 10. *Baker* 377.

Lectures. A discussion of the reactions involved in the smelting of ores and the furnace refining of metals. The discussion is accompanied by problems dealing with the various subjects discussed.

To be given in alternate years for all juniors and seniors taking option G, being alternated with Accounting 3A31. (Given in 1938–39.)

ENGLISH AND PUBLIC SPEAKING

English 2. First or second term. Credit three hours. Required of all sophomores in Administrative Engineering. A course in composition with readings mainly from contemporary English and American literature. Professor SIBLEY, Assistant Professor TENNEY, and others. Registration in charge of Assistant Professor TENNEY.

Public Speaking 1. Repeated in second term. Credit three hours. Required of students in Administrative Engineering. Professor WICHELNS, Assistant Professors MUCHMORE and WAGNER, and Messrs. BARNES, DEBOER, and HAGER.

Planned to give the fundamentals of speech preparation and to develop simple and direct speaking. Study of principles, and constant practice: readings on public questions; conferences; drills.

Foreign students and others whose pronunciation of English falls below the normal standard, and students with special vocal problems, are advised to confer with Assistant Professor THOMAS before registering for course 1.

PHYSICS

Physics 21. *General Physics.* Required of candidates for the degree of B.M.E., B.E.E., or B.Chem.E. First term. Credit three hours. Prerequisites, Physics 11 and 12 and Mathematics 5a and 5b. Two class-room periods a week and one laboratory period on alternate weeks. Laboratory work covering selected topics in electricity and magnetism. Professor GRANTHAM and instructors.

Physics 22. *General Physics.* Required of candidates for the degree of B.M.E., B.E.E., or B.Chem.E. Second term. Credit three hours. Prerequisites, Physics 11 and 12 and Mathematics 5a and 5b. Physics 21 desirable, but not required. Two class-room periods a week and one laboratory period on alternate weeks. Theory, problems, and laboratory work covering such

selected topics as thermionics, photoelectricity, photometry, kinetic theory, radiation, polarized light, and diffraction. Professor GRANTHAM and instructors.

For elective courses in other schools and colleges of the University, see page 109, and the special announcements of the schools and colleges.

ADMINISTRATIVE ENGINEERING (A)

3A21. *Economic Organization.* First term for M.E. and E.E. sophomores; second term for A.E. juniors. Credit three hours. Lectures, collateral reading, and discussion periods. A study of the form and functioning of the arrangements by which men work together in economic production, and apportion the resulting product. Professor GARRETT and Mr. SCHULTZ.

3A23. *Business and Industrial Management.* Required of all sophomores in Administrative Engineering. Either term. Credit four hours. Four lecture-discussion periods a week with regularly assigned problems. This course is intended as a survey of the problems of business and industrial organization. It deals with the establishment of business policies, types of business, and industrial ownership, together with the functions of finance, control, machine production, personnel, and marketing. Elementary consideration will be given to the problems of the selection of plant site, time and motion study, wage systems and the selection of personnel, all of which will be developed in greater detail in subsequent courses. Professor BANGS.

3A31. *Accounting for Engineers.* Required of all A.E. juniors and M.E. juniors or seniors. Given first term for A.E. and second term for M.E. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite course 3A21 or its equivalent. Theory of debits and credits; development of books of original entry; voucher system; analysis of financial statements; financial mathematics; negotiable instruments; modern mechanical methods of performing the accounting function. Professor BANGS, Assistant Professor HANSELMAN, Mr. BOCK, and Mr. SCHULTZ.

3A32. *Accounting for Engineers.* Required of all juniors in Administrative Engineering. Second term. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite course 3A31. Continues the work of 3A31, covering the extension of proprietorship; bond and stock issues and valuation; negotiable instruments; income tax; the variable budget; good will; depreciation; reserves; sinking funds; actuarial science; flexible budget; controversial accounting subjects; consolidated statements; statement analysis. Assistant Professor HANSELMAN and others.

3A33. *Technical Writing.* Required of all sophomores in Administrative Engineering. Either term as assigned. Two recitations a week. Credit two hours. A study of the forms of written expression with emphasis on those most frequently used in business and engineering: the writing of technical reports, articles, and editorials; the composition of business letters, such as credit, collection, inquiry, quotation, adjustment, and sales letters. Mr. WHITE.

3A34. *Corporation Finance.* Required of all seniors in Administrative Engineering, elective for upperclassmen in Mechanical Engineering. Second term. Credit three hours. Prerequisite courses 3A21 and 3A31.

A study of the financial problems of the business corporation from the points of view of the management, the investor, and the public. Professor O'LEARY.

3A35. *Industrial Organization.* Required of all juniors in Mechanical and in Electrical Engineering, and of fifth year students in Chemical Engineering. Either term. Credit two hours. Open only to upperclassmen except by special arrangement. A course of lectures on the development of modern industry, the reasons for changes that have taken place, and the principles that underlie modern methods of production. The course deals in a fundamental way with the types of industrial organizations and their control, with problems of plant location, factory layout, personnel work, motion and time study, wage systems, and with the principles of manufacturing costs. Professor BANGS and Mr. WHITE.

3A41. *Business Statistics.* Required of all sophomores in Administrative Engineering. First or second term. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite course 3A21.

Elements of the technique of statistical analysis. The collection, preparation, and use of business statistics. The sources of information. Business indices and business barometers. Professor GARRETT and Assistant Professor LOBERG.

3A42. *Human Nature and Management.* Required of all seniors in Administrative Engineering. First term. Credit 2 hours. A study of human nature in business and industry involving the psychological approach. Case demonstrations of business and industrial situations are used to illustrate the more important problems. Professor BANGS.

3A43. *Engineering Business Law.* Required of all seniors in Administrative Engineering. First term. Credit three hours. Three lecture-discussion periods a week. A study of the fundamental legal principles which relate to the usual business transactions with emphasis on the law of contracts. By the use of adequate case material the student is aided in his application of the general legal principles to specific situations. Assistant Professor HANSELMAN.

3A44. *Industrial Marketing.* Required of all seniors in Administrative Engineering. First term. Credit three hours. Two recitations and one lecture a week. A study of the field of industrial marketing using the case method of instruction. The scope of the course includes 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. Assistant Professor LOBERG.

3A45. *Industrial Marketing.* Elective. Second term. Credit two hours. One recitation and one 2½ hour laboratory period a week. Prerequisite course 3A44. The application of the principles of marketing to specific problems. Each student will develop a complete market study and analysis for given industrial products. Assistant Professor LOBERG.

3A46. *Engineering Business Law.* Required of all seniors in Administrative Engineering. Second term. Credit two hours. Two lecture-discussion periods a week. A study of fundamental legal principles relating to the usual business transactions with special emphasis on the laws of Sales and Corporations. By the use of adequate case material the student is aided in his applica-

tion of general legal principles to specific situations. Assistant Professor HANSELMAN.

3A47. *Cost Accounting*. Required of all students in Administrative Engineering and of Mechanical Engineering seniors electing the Industrial Engineering Option. First term. Credit three hours. One recitation, one lecture and one two and one-half hour computing period each week. Prerequisite, course 3A31, or its equivalent. A detailed study of manufacturing cost systems applied in the laboratory by problems dealing with order costs, process costs, and standard costs; a discussion of budgets and distribution costs; the use of calculating machines in the laboratory. Assistant Professor HANSELMAN, Mr. SCHULTZ, and Mr. BOCK.

3A48. *Business and Industrial Problems*. Required of all seniors in Administrative Engineering. Second term. Credit two hours. Prerequisite courses 3A21, 3A23, 3A31, 3A32, 3A41, 3A43, 3A44. A series of case studies of problems occurring during the launching and conduct of a small manufacturing enterprise. The attempt is made in this way to tie together the work previously taken in economics, statistics, accounting, marketing, business law, and human relations. Professor GARRETT.

3A49. *Industrial Relations*. Required of all students in Administrative Engineering and of Mechanical Engineering seniors electing the Industrial Engineering Option. Second term. Credit two hours. Two lectures or recitations a week. Prerequisite course 3A35, or 3A23. A discussion of the more important problems which arise from the relation of employer and employee under present conditions of industry. Such features are considered as the effect of organized labor, employment methods, methods of wage payment, committee systems, industrial education, and personnel service activities in general. Professor GARRETT.

3A50. *Engineering Business Law*. Elective. Second term. Credit two hours. Two lecture-discussion periods a week. A study of fundamental legal principles relating to common business transactions with special emphasis on the laws of Agency and Negotiable Instruments. By the use of adequate case material the student is aided in his application of general legal principles to specific situations. Assistant Professor HANSELMAN.

3A51. *Business and Industrial Research*. Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a very limited number of seniors and graduate students who have shown by training and aptitude their ability to carry on original investigations in business and industrial subjects. Professors BANGS and GARRETT, Assistant Professors HANSELMAN and LOBERG.

3A52. *Industrial Salesmanship*. Elective. Second term. Credit two hours. One recitation and one two and one-half hour laboratory period a week. A study of the basic principles of selling and the application of these principles to case problems. Assistant Professor LOBERG.

AUTOMOTIVE AND AERONAUTICAL ENGINEERING (B)

3B35. *Aerodynamics*. Juniors. Required in Option E. Second term. Credit two hours. Prerequisite courses 3M21 and 3M22a and b. Two recitations a week. Properties of air, airfoil characteristics, drag calculations, engine-propeller characteristics and their relation to airplane performance. Stability

calculations, performance estimates, and flight testing. Assistant Professor TERRY.

3B41. *Automotive Lectures*. Seniors and graduates. Required in Option D. First term. Credit two hours. Two lectures a week. Prerequisite courses 3P31 or 3P33, 3D31, 32, 33. The automobile, and the power required for its operation, but not including the power plant (for which see course 3B42). 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. Professor UPTON.

3B42. *Automotive Lectures*. Seniors and graduates. Required in Options D and E. Second term. Credit two hours. Two lectures a week. Prerequisite courses 3P31 or 3P33, 3D31, 3D32, 3D33. Analysis of automotive power plant design and operation; nature of the actual working fluid; preparation for and control of combustion in spark- and compression-ignition engines; volumetric, thermal, and mechanical efficiencies of engines; lubrication, fuels, etc. Professor UPTON.

3B43. *Automotive Computations*. Seniors and graduates. Required in Option D. First term. Credit two hours; two computing periods a week. Must be accompanied by course 3B41, which it parallels, but with more detailed studies to acquaint students with methods of attack on problems in operation or design. Professor UPTON.

3B44. *Automotive Power Computations*. Seniors and graduates. Required in Option D. Second term. Credit two hours; two computing periods a week. Must be accompanied by 3B42, which it parallels, but with more detailed studies in operation and design. Professor UPTON.

3B46. *Airplane Design*. Seniors. Required in Option E. First term. Credit two hours. Prerequisite 3B35. Two recitations a week. Layout procedure, weight and balance estimates, load factors, materials and costs. Principles of stress analysis and airplane computations. Assistant Professor TERRY.

3B47, 3B48. *Airplane Computations*. Seniors. Required in Option E. Throughout the year. Credit two hours a term. Prerequisite course 3B35; and must be accompanied or preceded by 3B46. Two computing periods a week. The student makes calculations and drawings similar to those required by the Department of Commerce for approval of the design of an airplane. Assistant Professor TERRY.

3B50. *Advanced Automotive Engineering*. Elective for qualified seniors and graduates. Either term. Credit two to five hours as arranged. Selected advanced topics and special problems as arranged. Professor UPTON and Assistant Professor TERRY.

DRAWING AND DESCRIPTIVE GEOMETRY

(See under The Freshman Year, page 58.)

MACHINE DESIGN (D)

3D21. *Kinematics, Recitations*. Sophomores in Mechanical Engineering. First term. Credit two hours. Prerequisite Drawing courses 120 and 121 and Mathematics 5a and 5b. Two 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; vector method of determining

linear and angular velocities and accelerations; cams; rolling curves and friction gearing; etc. Professor ROGERS, and Messrs. MORRIS, BARTON, SHERRILL, GEORGIAN, and SCHILLER.

3D23. *Kinematics, Drawing.* Sophomores in Mechanical Engineering. First term. Credit two hours. Must be taken with course 3D21. Prerequisite Drawing courses 120 and 121 and Mathematics 5a and 5b. Two drawing periods a week throughout the term devoted to drawing board applications of the theory and principles of course 3D21. Professor ROGERS, and Messrs. MORRIS, BARTON, SHERRILL, GEORGIAN, and SCHILLER.

3D24. *Kinematics, Recitations and Drawing.* Sophomores in Mechanical Engineering. Second term. Credit three hours. Prerequisite course 3D21. About twenty-five recitation periods and twenty drawing periods, for which two recitation and two drawing periods a week must be provided in the student's schedule. Recitation and drawing board work dealing with gears; gear cutting, linkwork and miscellaneous mechanisms; belt, rope, and chain drives; and trains of mechanism. Professor ROGERS, and Messrs. MORRIS, BARTON, SHERRILL, GEORGIAN, and SCHILLER.

3D25. *Kinematics, Recitations.* Sophomores in Electrical and Administrative Engineering. First term. (Make-up section, second term.) Credit three hours. Prerequisite, Drawing courses 120 and 121 and Mathematics 5a and 5b. 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; gear cutting; linkwork and miscellaneous mechanisms; belt, rope, and chain drives; and trains of mechanism. Professor ROGERS, and Messrs. MORRIS, BARTON, SHERRILL, GEORGIAN, and SCHILLER.

3D26. *Kinematics, Drawing.* Sophomores in Electrical and Administrative Engineering. First term. Credit two hours. Must be taken with course 3D25. Prerequisite Drawing courses 120 and 121 and Mathematics 5a and 5b. Two drawing periods a week throughout the term devoted to drawing board applications of the theory and principles of course 3D25. Professor ROGERS, and Messrs. MORRIS, BARTON, SHERRILL, GEORGIAN, and SCHILLER.

3D31. *Machine Design, Recitations.* Juniors in Mechanical Engineering. First term. Credit two hours. Prerequisite courses 3D21, 3D23, 3D24, 3X21, 3X22, 3M21 and 3M22a and b. Two 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 such considerations as suitability of materials, safety, lubrication, construction, etc. Assistant Professor BLACK and Mr. BARTON.

3D32. *Machine Design, Recitations.* Juniors in Mechanical Engineering. Second term. Credit two hours. Prerequisite course 3D31. Two 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 such considerations as suitability of materials, safety, lubrication, construction, etc. Assistant Professor BLACK and Mr. BARTON.

3D33. *Machine Design, Drawing.* Juniors in Mechanical Engineering. Second term. Credit three hours. Must be taken with course 3D32. Prerequisite course 3D31. Three drawing periods a week throughout the term. The

student for the first time undertakes the design of machine parts and unit assemblies and makes all the necessary calculations and drawings. Orderly, systematic calculations are insisted upon and such layout and detail drawings are made as are found necessary to complete each problem. Professor ALBERT, Assistant Professor BLACK, and Messrs. BARTON and GEORGIAN.

3D34. *Machine Design, Recitations.* Juniors in Electrical and Administrative Engineering and Seniors in Chemical Engineering. First term. (Make-up section, second term.) Credit two hours. Prerequisite courses 3D25, 3D26, 3X21, 3X22, 3M21, and 3M22a for Electrical and Administrative Engineers and 125, 3X21, 3X22, 3M21, and 3M22a for Chemical Engineers. Two 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 such considerations as lubrication, safety, suitability of materials, construction, etc. Professor ALBERT and Assistant Professor GARNER.

3D35. *Machine Design, Drawing.* Given the second term to Junior Administrative Engineers. Credit two hours. Must be taken with course 3D34 or in the term following. Prerequisite courses 3D25, 3D26, 3X21, 3X22, 3M31, and 3M22a. Two drawing periods a week throughout the term. The student for the first time undertakes the design of machine parts and unit assemblies and makes all the necessary calculations and drawings. Orderly systematic calculations are insisted upon, and such layout and detail drawings are made as are found necessary to complete each problem. Professor ALBERT, Assistant Professor GARNER, and Mr. MORRIS.

3D36. *Machine Design, Drawing.* Seniors in Chemical Engineering. Second term. Credit one hour. Prerequisite courses 125, 3X21, 3X22, 3M21, 3M22a, and 3D34. One drawing period a week throughout the term. Design of a unit of equipment peculiar to a chemical industry. Orderly systematic calculations are insisted upon and such layout and detail drawings are made as are found essential to the problem. Professor ALBERT.

3D51. *Mechanical Technology as Related to Design.* An elective for sophomores and juniors in engineering. Second term. Credit two hours. Two one hour periods a week. The purpose of the course is to show how the various mechanical processes are related to design and production. The course is based on textbooks, dealing principally with measuring and the processes of fashioning metals by machining, cutting, grinding, shearing, punching, drawing, rolling, hammering, pressing, moulding, etc. Each period is devoted to an oral quiz and informal discussion of the day's assignment, with occasional lectures on the general and particular relations of mechanical processes to design work. Professor ALBERT.

3D52. *Advanced Kinematics and Kinetics.* An elective for juniors, seniors, and graduates. Second term. Credit three hours. Prerequisite courses 3D21, 3D23, and 3D24, or 3D25 and 3D26. About twenty-four lecture and discussion periods and about twenty-one three-hour drawing periods during the term, for which two one-hour and two three-hour periods a week must be provided in the student's schedule. Graphical and semi-graphical treatment of linear and angular velocities and accelerations and of the resulting forces, stresses, and strains due to the form and mass of the moving parts of mechanisms and machines. Vibration and critical speeds and the theoretical basis and use of

balancing machines for securing static and running balance of machine parts will be treated as far as time permits. Professor ROGERS.

3D53. *Materials Handling.* An elective for juniors, seniors, and graduates. Second term. Credit two hours. Prerequisite courses 3D21, 3D22, and 3D24, or 3D25 and 3D26. Two lectures a week throughout the term. Treatment and analysis of the known methods of handling different kinds of materials and of the principles and considerations involved in a proper choice of the method of handling any given kind of material.

3D54. *Dynamics and Vibrations of Machinery.* Elective for seniors and graduates. First term. Credit three hours. Prerequisite courses 3D32 or 3D34 and 3M32. Two lecture and discussion periods and one laboratory period a week throughout the term. Graphical and analytical treatment of velocities, accelerations, static forces, inertia forces, and combined forces. Balancing of engines. Transverse and torsional vibrations, critical speeds, and balancing machines. Determination of forces in automotive engines. Assistant Professor BLACK.

3D55. *Advanced Machine Design.* Elective for seniors and graduates. Second term. Credit three hours. Prerequisite courses 3D32 or 3D34 and 3M32. Two lecture and discussion periods and one laboratory period a week throughout the term. Advanced problems in stress analysis of machine and structural members including consideration of fatigue, creep, stress concentration, stability, etc. Vibration and lubrication. Special problems. Assistant Professor BLACK and Mr. BARTON.

EXPERIMENTAL MECHANICAL ENGINEERING

(See courses listed under letter X on page 126.)

GENERAL COURSES (G)

3G52. *Cornell Engineer Credit.* Undergraduate members of the *Cornell Engineer* Board may receive not to exceed two hours of University credit in each term of their senior year (i. e. a maximum credit of four hours) for work satisfactorily done for *The Cornell Engineer*, provided they are elected to the Board during or before their sophomore year, and continue active members to the end of the term in which credit is desired.

3G41. *Non-resident Lectures.* Required for graduation of all seniors in Mechanical and Administrative Engineering. These lectures are given at some hour in the day specially set aside in the senior schedules. Seniors may also be required to attend certain of the non-resident lectures given in E.E. 491. Notices of the lectures will be posted on the bulletin board of the Sibley School of Mechanical Engineering. A notebook showing a résumé of each lecture attended (not more than one page for each lecture) must be handed in at the Director's office during block week at the end of the second term.

3G51. *A. S. M. E. Student Branch.* Sophomores, juniors, and seniors in Mechanical Engineering are urged to become members of the Student Branch of the American Society of Mechanical Engineers, the meetings of which, however, are open to all. Attendance at any fourteen Branch meetings entitles the member to one hour elective credit. Applications for membership should be made at the Director's Office in October of each year, or to Professor BLACK, Honorary Chairman of the Student Branch.

HEAT-POWER ENGINEERING

(See the courses listed under the letter P on page 123.)

HYDRAULIC POWER ENGINEERING

(See the courses listed under the letter M on page 121.)

INDUSTRIAL ENGINEERING (I)

3I43. *Industrial Engineering*. First term. Credit three hours. One lecture and two 2½ hour laboratory periods a week. Required of all Administrative Engineers and of Mechanical Engineers electing the Industrial Option. The laboratory work consists mainly of a study built around a case problem which concerns, in a specific and detailed manner, the location and layout of a factory for the production of automobile transmissions, supplemented with problems on materials handling equipment, time and motion study, plant organization, etc. The lectures cover the major features of modern industry as well as specific problems concerning the laboratory work. Assistant Professor MILLARD and Mr. MANNING.

3I44. *Industrial Engineering*. Second term. Credit three hours. One lecture and two 2½ hour laboratory periods a week. Prerequisite course 3I43. Required of all Mechanical Engineers electing the Industrial Option. Elective for seniors. A series of typical industrial problems dealing with modern production, such as, machine rate, production and materials control, wage payments, equipment selection, work simplification, etc. For the most part these problems are based on the work done in course 3I43. Assistant Professor MILLARD and Mr. MANNING.

3I48. *Industrial Engineering Economy*. Second term. Credit two hours. Two recitation and discussion periods a week. Prerequisite courses 3I43 and 3A31 or its equivalent. Required of all Mechanical Engineers electing the Industrial Option. Elective for seniors. A consideration of problems in engineering economy is approached by the question, "Will it Pay?" Assistant Professor MILLARD.

3I51. *Advanced Industrial Engineering*. Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a limited number of seniors and graduates. Special problems and investigations which are carried on under the direction of members of the department staff. Assistant Professor MILLARD and Mr. MANNING.

3I52. *Industrial Auditing*. Elective. For seniors and graduates. Credit two hours. One lecture and one computing period a week, second term. Prerequisite course—Accounting for Engineers 3A31 or its equivalent. A study of auditing theory and practice by the use of illustrative problems pertaining to manufacturing concerns. Assistant Professor MILLARD.

3I53. *Advanced Industrial Relations*. Elective. Second term. Credit two hours. Two one hour discussion periods a week. Prerequisite course 3A49 or its equivalent. The course consists of studies of problems in industrial relations by the case method. The object of the course is to teach the student to apply the fundamentals of industrial relations to specific situations arising in industry. Assistant Professor MILLARD and Mr. MANNING.

3I54. *Micro-motion Laboratory*. Elective. For seniors and graduates. Either term. Credit two hours. Two 2½ hour laboratory periods a week. Prereq-

uisite courses 3A35 or 3A23. The laboratory periods are devoted to practical research in the principal phases of Time Study and Motion Economy. Time studies and process charts are made in our own and outside shops. Motion economy is studied by the development of a specific problem in the laboratory during which motion pictures are made of the operations studied. Through micro-motion analysis of these pictures, simo-motion charts are made of the operation before and after improvement. A work place is designed and built, and the improved method tried out in the laboratory. Assistant Professor MILLARD and Mr. MANNING.

MACHINE DESIGN

(See the courses under the letter D beginning on page 115.)

MECHANICAL LABORATORY

(See the courses under the letter X beginning on page 126.)

MECHANICS OF ENGINEERING (M)

3M21. *Theoretical and Applied Mechanics.* Sophomores. First term. Credit five hours. Four recitations and one examination a week. Prerequisites, passing grades in Mathematics 5a and 5b. Motion of a particle: displacement, velocity, acceleration; graphs; force, mass, and acceleration; equations of motion; curvilinear and rectilinear motion; rotation about an axis; moments. Systems of particles: external and internal forces; general equations of motion; parallel forces; center of gravity. Statics: single pieces, cords, pulleys, structures, and mechanisms. Motion of a rigid body: translation; rotation, moment of inertia of solids; plane motion. Work and energy: work, power, energy; friction, brakes, dynamometers; efficiency and regulation of machines, momentum, and impulse; torque and angular momentum. Professors CORNELL, GOODIER, Assistant Professors PERKINS, ARMSTRONG, and Messrs. LEE, MYKLESTAD, and WILLIAMS.

3M22a. *Strength of Materials.* Sophomores. Nine weeks of second term. Credit three hours. Four recitations and one examination a week. Prerequisite course 3M21. 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. Professors CORNELL, GOODIER, Assistant Professors PERKINS, ARMSTRONG, and Messrs. LEE, MYKLESTAD, and WILLIAMS.

3M22b. *Strength of Materials.* Sophomores in Mechanical Engineering. Six weeks of second term. Credit two hours. Four recitations and one examination a week. A continuation of course 3M22a. Continuous beams; combined stresses; principal stresses; Mohr's circle of stress; theories of failure; thick walled cylinders; curved bars; unsymmetrical bending. Professor GOODIER, Assistant Professor ARMSTRONG, and Mr. LEE.

3M23. *Hydraulics.* Sophomores in Administrative and Electrical Engineering. Six weeks of second term. Four recitations and one examination a week. Credit two hours. Prerequisite course 3M21. Hydrostatics: pressures and centers of pressure. Hydrokinetics: general equations of energy; orifices, weirs, nozzles, Venturi meters, etc.; losses of head; flow in pipes. Hydro-

dynamics: forces on stationary and moving bodies. Professor CORNELL, Messrs. MYKLESTAD and WILLIAMS.

3M24. *Applied Mathematics.* Sophomores in Mechanical Engineering. Second term. Credit three hours. Prerequisite course 3M21. Three recitations a week. Curve plotting, choice of coordinates and scale, straight line plotting of simple equations; logarithmic plotting; fitting empirical equations to experimental data; first and second order differential equations; vibration problems in engineering; linear, torsional, and flexural vibrations without and with damping; forced vibrations; critical speeds; problems with two degrees of freedom. Professors SWITZER, GOODIER, and Mr. LEE.

3M33. *Fluid Mechanics.* Juniors in Mechanical Engineering. First term. Credit four hours. Prerequisite courses 3M21 and 3M24 or its equivalent, 3M32. One lecture and three recitations a week. The Mechanics of fluids, including liquids and gases. An extension of course 3M23 to include compressible as well as incompressible fluids; simplified theory of hydraulic turbines and centrifugal pumps. Professor SWITZER and Assistant Professor ARMSTRONG.

HYDRAULIC-POWER ENGINEERING (M)

3M41, 3M42. *Hydraulic Power Plants.* Seniors and graduate students. Lectures throughout the year. Credit two hours each term. Prerequisite courses 3M21, 3M22a, 3M22b, and 3M33. Power Development: description, design, and cost of reservoirs, dams, headworks, water conduits, surge chambers, power house, tail race, construction plant. Hydraulic Turbines: construction, installation, operating characteristics including effects of water hammer in long pipe lines and variable head, selection of equipment, testing, governing, and speed regulation. Power Study: market for power, competition and rates, hydrology, head, economics of pondage and storage, power available and usable within the load curve, economy of auxiliary power. Water power legislation and the Federal Power Commission. During the entire course considerable emphasis is placed upon the financial problems of construction and operation of the water power plant alone and as part of a large power system. Some time is devoted to elementary concrete design and foundations. Professor SWITZER.

3M43, 3M44. *Hydraulic Power Plant Problems.* Seniors and graduate students. Computation periods throughout the year. Credit two hours each term. Must be accompanied by course 3M41, 3M42. Problems are assigned involving the principles taken up in course 3M41, 3M42. Design problems are given to show the applications of the fundamental principles of mechanics, machine design, and hydraulics, to the solution of problems in the water power field. The characteristics of hydraulic turbines are studied through the use of experimental data on turbine performance, and these results are applied to specific problems in power plant practice. Problems in stream flow, pondage and storage, power available and its use under specified load conditions conclude the work. Professor SWITZER.

3M52. *Special Hydraulic Power Plant Problem.* Elective for seniors and graduates. Either term. Credit two to five hours as arranged. Must be preceded by or taken with 3M41, 3M42. Selected topics from course 3M43, 3M44 and other special problems to meet the individual needs of each student. Students who have completed course 3M43, 3M44 or equivalent, may elect this course for more advanced work. Professor SWITZER.

3M53. *Ordnance Problems.* Two lectures a week throughout one year, when taken as an elective engineering subject only. Also constitutes classroom requirements of first year of two year advanced course in Ordnance R.O.T.C. Unit. In the latter case, one additional hour a week of military training is required. In either case, credit of one hour each term. Prerequisite courses 3M21 and 3M22a. First term covers ammunition and explosives; design and manufacturing methods; ballistics. Second term: other ordnance material, including small arms, artillery, essentials of carriage design, and ordnance vehicles. Major SLAUGHTER.

3M55. *Photo-Elasticity.* Elective for seniors and graduates. First term. Credit two hours. One lecture and one laboratory-lecture period each week. Prerequisite course 3M22b. Optics of photo-elasticity; 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 photo-elastic observations and computations, isopachics. 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, and the determination of stress concentration factors. Professor SWITZER and Mr. LEE.

3M56, 3M57. *Applied Elasticity.* Elective for graduates, but open to qualified undergraduates. Throughout the year. Credit three hours each term. Three lectures a week. Prerequisite courses, 3M24 or its equivalent, 3M32 or 224-A or Math. 41 for first term and 224-B for second term, but may be taken concurrently. Either term may be taken separately.

The first term will be devoted to topics in stress-analysis, elastic vibrations, and elastic stability, which can be treated by elementary mathematical methods, such as those employed in simple tension, bending, and torsion. These topics will include effects of sudden loading; the propagation of waves of stress; the approximate determination of vibration frequencies and buckling loads; bending of beams on elastic foundations; bending of flat strips and circular plates; stress in thin shells due to internal pressure and due to heating; the concentration of stress by holes and notches; the relation of stress-analysis to fatigue testing.

In the second term more critical discussion, using more advanced methods, will be given to further problems according to the requirements of the group. Professor GOODIER.

3M58. *Mechanics of Vibration.* Elective for seniors and graduates. First term. Credit three hours. Prerequisite, Course 3M24. 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. Vibrations of taut wires, bars, beams, rings, membranes, and plates. Relation of vibration and noise. Detection and measuring instruments. Examples of diagnosis and preventive measures. Professor GOODIER.

HEAT-POWER ENGINEERING (P)

3P31, 3P32. *Heat-Power Engineering.* Required of all juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 21 and 22 and 3D21, 3D23, 3D24, 3M21, 3M22a and b. Three recitations a week throughout the year. Thermodynamics of gases and vapors; ideal cycles and their application in air compressors, internal combustion motors, steam engines, turbines, and power plants; modifications in actual machines; efficiencies and performances; study of engine losses and the usual means of reducing them; compound, uniflow, and other types of steam engines; types of air compressors, internal combustion engines; steam turbines; air-vapor mixtures; and heat transfer. On account of the importance of a thorough understanding of this subject, the student is required to solve a large number of problems in the classroom. Assistant Professor CLARK.

3P33, 3P34. *Heat-Power Engineering.* Required of juniors in Electrical Engineering, Chemical Engineering, and in Administrative Engineering. Not open to students in Mechanical Engineering. Throughout the year. Credit three hours a term. One lecture and two recitations a week. Prerequisite courses 3D25, 3D26, 3M21, 3M22a. The course is an abridged treatment of substantially the same ground as courses 3P31, 3P32, and 3P41, 3P42; it is supplemented in the senior year by course 3P54. The longer courses 3P31, 3P32, and 3P41, 3P42 may be substituted for this one. Assistant Professor HOOK and Mr. FAIRCHILD.

3P41, 3P42. *Heat-Power Engineering.* Required of all seniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite course 3P31, 3P32. Three periods a week. An extension of course 3P31, 3P32. Engine and turbine types; steam turbine theory, development of present forms, performance, economy, suitability for particular service; fuels and fuel resources; combustion, ideal and in the actual furnace and engine; steam-generating units and their performance; furnaces, boilers, superheaters, economizers, and air preheaters; exit losses; draft; flow of fluids in pipes; feed water heaters, condensers, cooling towers and other apparatus; feed water treatment; consideration of the economical combination of elements in plants. Refrigeration. Professor ELLENWOOD and Mr. FAIRCHILD.

3P43. *Heat-Power Equipment.* Required of all seniors in Civil Engineering. Second term. Credit three hours. Not open to students in Mechanical or Electrical Engineering. Prerequisite courses, Physics 11 and 12 (or the equivalent), Chemistry 106 a, b, C.E. 220 and 221. Basic consideration of the behavior of gases and vapors as applied to heat engines; also the operation, maintenance, application, performance, first cost, and operating cost of air compressors, compressed air equipment, internal-combustion engines of both the carburetor and compression-ignition types, steam boilers, engines, and turbines. This course is recommended for all students who wish to obtain a general basic knowledge of the usual types of heat engines with special attention given to those which are most commonly used by the civil engineer. Two lectures and one two-hour period used for laboratory, inspection, computing, or quiz purposes. *West Sibley.* Professor ELLENWOOD.

3P44, 3P45. *Steam-Power Plants.* M.E. seniors in Option A. Lectures throughout the year. Credit two hours a term. Prerequisite courses 3D31, 3D32, 3D33, and 3P31, 3P32; must be accompanied or preceded by courses

3P41 and 3P42. Load curves; station factors; power-plant economics; cost of plants and of their equipment and output; principles of economic selection of plant equipment with respect to the load curve, cost factors, and local conditions; steam prime movers, steam generators, condensers, and other plant apparatus; performance characteristics and design features of this apparatus; piping; coal and ash storage and conveying machinery; plant location; plant layout; and similar topics. Professor BARNARD.

3P46, 3P47. *Computing and Design.* M.E. seniors in Option A. Throughout the year. Credit two hours a term. Must be accompanied by 3P44, 3P45. Two three-hour periods a week. The practical solution of problems discussed in 3P44, 3P45. Professor BARNARD.

3P48. *Air Conditioning.* Elective for seniors. Second term. Credit two hours. Prerequisite courses, 3P31 and 3P32, or 3P33 and 3P34. Properties of mixtures of air and water vapor and the principles of air conditioning, including the heating, cooling, humidifying, dehumidifying, filtering, and distribution of air in enclosures for improving human comfort. Professor MACKEY.

3P49. *Refrigeration.* Elective for seniors. Required in Option B. First term. Credit two hours. Prerequisite course 3P32 or 3P34. Two lectures or recitations a week. A course dealing with the general principles, applications, and economic and commercial factors involved in various forms of modern refrigeration as applied to both domestic and industrial installations, including those pertaining to air conditioning. Professor ELLENWOOD.

3P50. *Power Plant Economics; Equipment Selection.* Elective for seniors. First term. Credit two hours. Prerequisite courses 3P31, 3P32 or 3P33, 3P34. 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 size of units; selection of equipment based on these and other determining considerations; economic operation. Applications to central stations and to industrial power and heating plants. Other similar topics. Professor BARNARD.

3P51. *Steam Turbines.* Elective for seniors. Second term. Credit two hours. Prerequisite courses 3P31, 3P32 or 3P33, 3P34. 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 turbine in engineering practice. Assistant Professor CLARK.

3P52. *Internal Combustion Engines.* Elective for seniors. First term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33 and 3P31, 3P32 or 3P33, 3P34. Two periods a week. Seminar. Reports and discussions. Fuels; general theory and salient points in the design and operation of internal combustion engines; study of existing commercial types, relative advantages, and questions of economy; current developments. Assistant Professor CLARK.

3P53. *Steam Boilers and Related Apparatus.* Elective for seniors. Second term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33, and 3P31, 3P32 or 3P33, 3P34. Two periods a week. Fuels, combustion, combustion apparatus; furnace and boiler types, proportions, materials, design of details;

superheaters, economizers, air heaters; accessories; equipment, arrangement and operation of steam-generating plants. Professor HOOK.

3P54. *Heat-Power Engineering.* Required of A.E. seniors. Elective for E.E. seniors. Not open to M.E. students. Second term. Credit two hours. Two lectures a week. A continuation of courses 3P33, 3P34. Professor BARNARD.

3P55. *Graphical Computation and Representation.* Required of A.E. juniors, and elective for others except freshmen. First term. Credit two hours. Slide rules; construction of net work charts and alignment charts for the solution of equations; and derivation of empirical equations from experimental curve. Professor MACKEY and Assistant Professor MILLARD.

3P57, 3P58. *Heat Engineering.* Throughout the year. M.E. seniors in Option B. Credit four hours a term. Must be accompanied or preceded by 3P41, 3P42, and 3P49. Properties of mixtures, dimensional analysis, fluid flow, heat transmission, selection of fans and pumps, and refrigeration; applications to problems in air conditioning. Professor MACKEY.

3P60. *Advanced Heat-Power Engineering Research.* Elective for graduate students and others qualified for advanced study in this field. Work and credit as arranged with Professors BARNARD, ELLENWOOD, MACKEY, and other members of the department.

SHOP WORK AND MACHINE CONSTRUCTION (S)

(For courses in Wood Working and Introductory Engineering Laboratory, see Courses 102 and 103 under The Freshman Year, page 58.)

3S22. *Foundry Work.* Required of M.E. and A.E. sophomores. Either term. Credit one hour. One, two and one-half hour period a week. Moulding, core making, mixing, and casting of metals; use of moulding machines. Demonstrations of large work and production in quantities. Mr. PATTERSON.

3S21. *Pattern Making.* Required of M.E. and A.E. sophomores. Either term. Credit one hour. Pattern making: the use of hand and machine tools, followed by instruction in pattern making, construction of core boxes, etc.; demonstration of form turning. Messrs. BUSH and YAWGER. *Rand Hall, Third Floor.*

3S31. *Machine Work.* Required of M.E. juniors. First term. Credit three hours. Nine hours of work a week. Prerequisite courses 102, 103, 3S22, and 3S21. Use of measuring instruments, hand and machine tools, fitting, and assembling; operation and use of jigs and other manufacturing fixtures; operation of semi-automatic and automatic machines, and the illustration of manufacturing methods generally. Professor WELLS, Messrs. HOWE and MACK.

3S32. *Machine Work.* Required of A.E. and E.E. sophomores. Second term. Credit two hours. Prerequisites 102 and 103. Six hours of work a week. Use of measuring instruments, hand and machine tools, fitting, and assembling; operation and use of jigs and other manufacturing fixtures; operation of semi-automatic and automatic machines, and the illustration of manufacturing methods generally. Professor WELLS, Messrs. HOWE and MACK.

3S50. *Extra Shop Work.* Work and credit as arranged with Professor WELLS.

EXPERIMENTAL MECHANICAL ENGINEERING (X)

3X21. *Materials of Engineering.* Required of M.E. and A.E. in M.E. sophomores, and of Chem. E. juniors. First term. Credit three hours. Prerequisite: Chemistry 102 a and b, or equivalent. An elementary lecture course in engineering materials covering fuels and their combustion, refractories, metallurgy of iron and steel, and the constitution of metals and alloys; with outside reading required on wood, stone, brick, cementing materials, and concrete. Assistant Professor JEFFREY.

3X22. *Materials of Engineering.* Required of M.E. and A.E. in M.E. sophomores, and of Chem. E. juniors. Second term. Credit three hours. Prerequisites: Chemistry 102 a and b, or equivalent, and 3X21. A continuation of Course 3X21, the lecture course continuing the study of the constitution of metals and alloys, the metallography of iron and steel, alloy steels, nonferrous metals and alloys; corrosion; including outside reading on rubber, plastics, leather, rope, etc., and the testing and inspection of materials. Assistant Professor JEFFREY.

3X23. *Materials of Engineering.* Required of E.E. and A.E. in E.E. sophomores. First term. Credit two hours. Prerequisite, Chemistry 102 a and b. An abridgement of Course 3X21 suited to the needs of students in Electrical Enginering. Assistant Professor JEFFREY.

3X24. *Materials of Engineering.* Required of E.E. and A.E. in E.E. sophomores. Second term. Credit two hours. Prerequisites: Chemistry 102 a and b, and 3X23. An abridgment of 3X22 and a continuation of Course 3X23 for students in Electrical Engineering. Assistant Professor JEFFREY.

3X31. *Materials Testing and Physical Metallurgy.* M.E. juniors. First term. Credit four hours. Prerequisite courses 3X21, 3X22, 3M21, and 3M22a. A laboratory course dealing with: the determination of physical properties of materials (principally metals and alloys) by means of various physical tests; a study of the behavior of materials in different kinds of loading; the selection of materials for a given use based upon the physical properties; the control of physical properties of ferrous and non-ferrous alloys by various forms of thermal and mechanical treatments, with emphasis on the relationship between the phase changes, the microstructure, and physical properties. A written report is required on each report. Professor DAVIS, Assistant Professors JEFFREY and MOYNIHAN, and Messrs. BEBBINGTON, L. D. CONTA, B. J. CONTA, and SHANK.

3X32. *Mechanical Laboratory—Experimental Engineering.* Credit three hours. M.E., E.E., A.E. juniors. Prerequisite courses: 3X21, 3M23 or 3M33, 3P31 or 3P33, 3P32 or 3P34. All of these courses must either have been completed or taken concurrently with 3X32. A laboratory course dealing with: The calibration and use of engineering instruments; the properties of oils; principles of lubrication; solid, liquid, and gaseous fuel analysis and calorimetry; fundamentals of fluid flow; steam engine performance and characteristics; internal combustion engine performance and combustion characteristics. A written report is required on each experiment. Professor DAVIS, Assistant Professors MOYNIHAN and JEFFREY, and Messrs. BEBBINGTON, B. J. CONTA, L. D. CONTA, and SHANK.

3X33. *Materials Testing and Physical Metallurgy.* E. E. and A. E. juniors and fourth year students in Chemical Engineering. First term. Credit three

hours. Prerequisites the same as for Course 3X31. This course is an abridgment of Course 3X31. Professor DAVIS, Assistant Professors JEFFREY and MOYNIHAN, and Messrs. BEBBINGTON, B. J. CONTA, L. D. CONTA, and SHANK.

3X34. *Mechanical Laboratory—Experimental Engineering.* Required of fourth year students in Chemical Engineering. Credit three hours. Prerequisite courses 3X21, 3M23, 3P33, and 3P34. All of these courses must either have been completed or taken concurrently with 3X34. A laboratory course dealing with principles of lubrication; fundamentals of fluid flow; heat transmission; steam engine performance and characteristics; internal combustion engine performance; combustion characteristics of fuels; air flow; centrifugal blower; centrifugal pump; air compressor; refrigeration. A written report is required on each experiment. Professors DAVIS and GAGE, Assistant Professors ANDRAE, JEFFREY, and MOYNIHAN.

3X41. *Mechanical Laboratory—Experimental Engineering.* For seniors in Mechanical Engineering and Administrative Engineering in M.E. First term. Credit four hours. Prerequisite courses 3X32, 3P31, or 3P33, and 3P32 or 3P34. Should be taken concurrently with 3P41. One laboratory period and one report each week. Comprehensive tests of internal combustion engines, steam power equipment, hydraulic pumps and turbines, air blowers and wind tunnel. The report of each test must be full and complete, including such items as basic theory of the apparatus, testing method used, original data, computations, results of the text expressed both numerically and graphically and a discussion of the salient points of the test and results. Professor GAGE, Assistant Professor ANDRAE, Dr. RUBERT, and Mr. ERDMAN.

3X42. *Mechanical Laboratory—Experimental Engineering.* For seniors in Mechanical Engineering and Administrative Engineering in M.E. Second term. Credit four hours. Should follow 3X41. One laboratory period each week alternating with one computing or discussion period. A written report is required for each experiment. Detailed study of the methods of testing and of computation as exemplified by tests of steam engines, air compressors, ice machines, and methods of measuring the flow of both liquids and gases. Reports required as in 3X41. Professor GAGE, Assistant Professor ANDRAE, Dr. RUBERT, and Mr. ERDMAN.

3X43. *Mechanical Laboratory—Experimental Engineering.* Required of seniors in Electrical Engineering and Administrative Engineering in E. E. First term. Credit two hours. Prerequisite courses 3X32, 3P33, and 3P34. Experiments selected by the faculty from course 3X41. Professor GAGE, Assistant Professor ANDRAE, Dr. RUBERT, and Mr. ERDMAN.

3X44. *Heating, Ventilating, and Refrigeration.* Required of seniors in Mechanical Engineering. Either term. Credit three hours. Lectures or recitations covering the methods of design and construction of various forms of heating and ventilating apparatus, and the principles of refrigeration. Professor SAWDON.

3X51. *Experimental Engineering Research.* Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a limited number of seniors and graduates who have available at least two laboratory periods a week and who have shown proficiency in engineering subjects. Special problems and investigations which are in general carried on in the labora-

tories under the immediate direction of the members of this department. Professors DAVIS, SAWDON, and GAGE, Assistant Professors ANDRAE, JEFFREY, and MOYNIHAN, and representatives of the department in which the student is taking his major work.

3X52. *Applied Metallography*. Elective. First term. Credit two hours. Prerequisite courses 3X21, 3X22, and 3X31. Covers in historical sequence the development of knowledge of the internal structure of metals, and the relation of structure and properties; the technique of metallographic research, study of application of the laws of physical chemistry to interpretation and correlation of results. Study of stable and metastable conditions; heat treatment theory and practice. The practical aim of metallography is constantly emphasized. Professor UPTON.

Also see courses listed in Option G, Metallurgical Engineering (page 104), and those under Chemistry on pages 109–110.

School of Electrical Engineering

FOUR-YEAR COURSE The regular four-year course of study leading to the degree of Bachelor of Electrical Engineering, which the School of Electrical Engineering offers, is outlined below. That outline is followed by information about alternative courses in which a student may obtain the degrees of B.E.E. and B.M.E., or the degrees of A.B. and B.E.E., or may pursue a course of study in the School of Electrical Engineering which leads to the degree of Bachelor of Science in Administrative Engineering.

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 37 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Hydraulics 3M23	0	2
	Physics 21, 22	3	3
	Kinematics, Rec. 3D25	3	0
	Kinematics, Dwg. 3D26	2	0
	Materials of Engineering 3X23, 3X24	2	2
	Econ. Organization 3A21	3	0
	Machine Shop 3S32	0	2
	Elec. Engineering 410	0	4
	English 2 or Pub. Speaking 1	0	3
	In addition to taking the courses named in the above schedule, all sophomores must satisfy the University's requirement of three hours a week throughout the year in Military Science and Tactics or in Physical Training. (See the *General Information Number*.)		
THIRD YEAR 36 HOURS	Elements of Electrical Engineering 411, 412	4	4
	Electrical Engineering Laboratory 431	4	0
	Electronics 450	0	4
	Heat Power 3P33, 3P34	3	3
	Mechanical Laboratory 3X33, 3X32	3	3
	Machine Design, Rec. 3D34	2	0
	Industrial Organization 3I31	2	0
	Elective	0	4
FOURTH YEAR 37 HOURS	Electrical Engineering Practice 421, 422	3	3
	Electrical Engineering Theory 423, 424	2	2
	Electrical Engineering Laboratory 433, 434	4	4
	Mechanical Engineering Laboratory 3X43	2	0
	Non-Resident Lectures 491	0	1
	Electrical Engineering Option*	3 or 6	6 or 3
	Elective	4 or 1	3 or 6
	Grand Total for the Four-Year Course		147 hours

*A student may select an option in Communication Engineering or Electric Power and Design. Other options as described on page 130 are open to specially qualified students.

OPTIONS IN SCIENCES A student who has completed the first two years of the regular four-year course with a satisfactory record and with excellent grades in Mathematics, Physics, and Mechanics may, if his class adviser approve, substitute a group of courses in Physics (or in another science such as Mathematics, Chemistry, or Economics) for certain courses of instruction normally required in the Junior and Senior years, namely, Machine Design 3D34, two hours, Industrial Organization 3I31, two hours, and Mechanical Laboratory 3X43, two hours. Such a substitution is permitted only after the student has made full use of his elective hours. Permission to continue in any of these options may be withdrawn at any time if the student's work is not satisfactory

A FIVE-YEAR COURSE (B.E.E. *and* B.M.E.) In various fields of practice and investigation the electrical engineer may need to have had more instruction in heat-power engineering, hydraulic-power engineering, mechanics, experimental engineering, and other phases of mechanical engineering than can be given in a regular four-year course in electrical engineering; similarly, the mechanical engineer often has use for a more extensive training in electrical engineering than can be included in a four-year course in mechanical engineering. To meet these broader requirements it may be possible to rearrange the required work in the respective four-year curricula in mechanical and electrical engineering so that both the B.M.E. and B.E.E. degrees may be obtained at the end of a five-year period of study. The necessary readjustment of work for obtaining both degrees must be made with the Directors of the Schools of Electrical Engineering and Mechanical Engineering before the beginning of the student's second year.

A SIX-YEAR COURSE (A.B. *and* B.E.E.) The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Electrical Engineering before beginning his fifth year. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the School of Electrical Engineering and to the Dean of the College of Arts and Sciences.

A FOUR-YEAR COURSE

(B.S. IN A.E.) A four-year course of study leading to the degree of Bachelor of Science in Administrative Engineering is given in the School of Electrical Engineering. The significant feature of this course in Administrative Engineering is its coordination of technical instruction with instruction in economics and in business administration. An outline of the course follows:

		HOURS *First Term*	HOURS *Second Term*
FIRST YEAR	See The Freshman Year, page 56	19	18
SECOND YEAR 38 HOURS	Mechanics 3M21	5	0
	Strength of Materials 3M22a	0	3
	Hydraulics 3M23	0	2
	Physics 21	3	0
	Kinematics, Rec. 3D25	3	0
	Kinematics, Drawing 3D26	2	0
	Materials of Engineering 3X23, 3X24	2	2
	English 2	0	3
	Technical Writing 3A33	0	2
	Economic Organization 3A21	3	0
	Business and Industrial Management 3A23	0	4
	Electrical Engineering 410	0	4
THIRD YEAR 39 HOURS	Heat Power 3P33, 3P34	3	3
	Machine Design, Rec. 3D34	2	0
	Mechanical Laboratory 3X33, 32	3	3
	Money and Banking, Econ. 11	0	3
	Accounting 3A31	0	3
	Business Statistics 3A41	3	0
	Electrical Engineering 411, 412	4	4
	Electrical Engineering Laboratory 431	4	0
	Electronics 450	0	4
FOURTH YEAR 37 HOURS	Mechanical Laboratory 3X43	2	0
	Cost Accounting 3I47	3	0
	Industrial Marketing 3A44	3	0
	Industrial Relations 3I46	0	2
	Corporation Finance 3A34	0	3
	Business Law 3A43, 3A46	3	2
	Public Speaking 1	0	3
	Electrical Engineering 401, 402	4	4
	Non-resident Lectures 491	0	1
	Electives	4	3

Grand total for the Four-Year Course . . . . . 151 hours

ELECTIVE COURSES

A student of the School of Electrical Engineering may elect any course of instruction offered by any department of the University provided he has the necessary preparation for it and also the approval of his class adviser. Not more than four hours of credit for Advanced Military Science, in addition to the Basic Course of the Freshman and Sophomore years, will be given toward meeting the requirements for the B.E.E. or the B.S. in A.E. degree.

Courses of instruction given in the School of Electrical Engineering and open to election by students are indicated by title and number in the following list. The figures in the last two columns indicate the credit in hours for the first and second terms respectively.

Circuit Analysis 420	0	3
Electric Power Plants 441	3	0
Electrical Design 442	0	4
Economics of Public Utilities 444	0	3
Electric Transmission and Distribution 463	3	0
Electrical Communication Engineering 451, 452	3	4
Electrical Communication Network Theory 453	3	0
Elements of Broadcast Engineering 456	0	2
Industrial Applications and Control 462	0	2
Illumination 465, 466	2	2
Engineering Mathematics 481, 482	2	2
Heaviside's Operational Analysis 485, 486	3	3
Patents 489	1	0
Special Electrical Engineering Problems 483, 484	1–3	1–3
A.I.E.E. Seminar 497, 498	1	1

Students of the School may elect from the following list of courses given in other schools and colleges:

Advanced Hydraulics 241	0	3
Hydraulic Measurements 242	3	0
Foundations 281	0 or 3	3 or 0
Engineering Law 290	0 or 3	3 or 0
Elementary Differential Equations 41	0	3
Advanced Calculus 42	3	3
Introductory Qualitative Analysis 210	0 or 3	3 or 0
Introductory Quantitative Analysis 225	0 or 3	3 or 0
Introductory Physical Chemistry (Lect.) 405	0 or 3	3 or 0
Introductory Physical Chemistry (Lab.) 410	3	3
Introductory Chem. Microscopy (Lec. and Lab.) 530	0 or 3	3 or 0
Metallography 545	2	0
Gas and Fuel Analysis 250	0 or 4	4 or 0
Introductory Geology 100	3 or 0	0 or 3
Engineering Geology 501	4 or 0	0 or 4
Money and Banking 11	3 or 0	0 or 3
Industrial Hygiene 5	1	0
Modern Physics 41	2	0
Special Topics in Physics 42	0	2
Introduction to Modern Physical Theory (170)	3	3
Human Nature and Management 3A47	0	2
Business and Industrial Problems 3A48	0	2
Elementary Psychology 1	2 or 0	0 or 2
Psychotechnology in Business and Industry 16b	3	0
Advanced Signal Corps Course (see page 61)	1	1

For courses in Mechanical Engineering see page 108.

THE COURSES OF INSTRUCTION

The courses of instruction in the following list are designed for members of the Sophomore, Junior, and Senior classes in the School of Electrical Engineering. The courses that are designed for members of the Freshman class have already been described under the head of The Freshman Year. The following list omits descriptions of some courses for students of Electrical Engineering because they are given by departments of the School of Mechanical Engineering and are described on other pages under that head, as are also the courses in Physics and Chemistry which are common to both Schools. For courses given in other colleges of the University the appropriate Announcements should be consulted. Advanced courses in the Department of Military Science and Tactics are described on page 61.

401. *Industrial Applications of Electric Power.* Required of seniors in Administrative Engineering in Electrical Engineering. First term. Four hours credit. Three recitations and one laboratory period a week. A study of the principles underlying the economic application of electricity to industrial problems such as motor drives and control; electric heating and the use of electric furnaces and ovens; transportation and handling of materials; illumination and its effect on economic production. Professor CHAMBERLAIN.

402. *Economics of Public Utilities.* Four hours credit. Continuation of 401 together with a study of the origin and development of public utilities, franchises, regulation and legislation, valuation, rates and rate structures, public ownership and public relations. Professor CHAMBERLAIN.

405, 406. *Fundamentals of Electrical Engineering.* Required of juniors in Administrative Engineering in Mechanical Engineering and of fifth year students in Chemical Engineering. Throughout the year. Credit four hours a term. Two lectures, a computing period, and a laboratory period each week. Prerequisite courses Physics 11, 12, and Mechanics 3M21.

First term: D. C. electric and magnetic circuits; study and tests of D. C. motors, generators, and control equipment; distribution and rates; simple A. C. circuits.

Second term: A. C. circuits, measurements, and machinery; industrial applications; electronic apparatus. A study of fundamental electrical principles and machinery and the application of electrical equipment in industry. Professor R. F. CHAMBERLAIN, Assistant Professors E. M. STRONG and B. K. NORTHROP, Dr. SOHON, Dr. SMITH, Mr. JONES, and Mr. BRISTOL.

410. *Elements of Electrical Engineering.* Required of sophomores in Electrical Engineering. Second term only. Credit four hours. Prerequisite courses Physics 11, 12, 21, Mathematics 5a and 5b. Two lectures and two computing periods a week. An introductory study of electrical phenomena and their application to engineering. Aims to provide a solid foundation for further study in electrical engineering. Assistant Professor STRONG and instructors.

411. *Elements of Electrical Engineering.* Required of juniors in Electrical Engineering. First term only. Credit four hours. Prerequisite E.E. 410. Two lectures, one recitation, and two computing periods a week. An introductory study of A. C. circuit fundamentals. Assistant Professor STRONG, Dr. MESERVE, and Mr. COTNER.

412. *Elements of Electrical Engineering.* Required of juniors in Electrical Engineering. Second term only. Credit four hours. Prerequisite E.E. 411. One lecture, one recitation, and one laboratory computing period a week. A continuation of E. E. 411. Application of circuit fundamentals to A. C. machinery and equipment. Assistant Professor STRONG, Dr. MESERVE, and Mr. COTNER.

415, 416. *Principles of Electrical Engineering.* Required of juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses Physics 11, 12 and Mechanics 3M21. Two lectures and one recitation-computing period a week. First term: electric and magnetic circuits, and direct-current machinery. Second term: alternating-current circuits and machinery. A study of the fundamental electrical principles and their practical application to industrial equipment. Emphasis is put on a quantitative study and understanding of basic electrical phenomena rather than on a survey of the characteristics and applications of currently available equipment. Assistant Professor STRONG, Dr. SMITH, and Mr. JONES.

418. *Electrical Equipment.* Required of seniors in C.E. First term. Credit three hours. Two lectures and one laboratory experiment with report each week. The purpose of the course is threefold: (1) To review and emphasize the fundamental physical principles applied in electrical engineering; (2) to familiarize the student with and give practice in the handling of electrical machinery; (3) to enable the student to choose the proper type of apparatus for any particular service demanded in ordinary elementary practice. Professor BALLARD and instructors.

420. *Circuit Analysis.* Elective for juniors in Electrical Engineering. Second term. Credit three hours. Prerequisites 410, 411, or their equivalent. Two lecture-recitations and one computing period a week. Mathematical introduction covering determinants, complex numbers, vectors, sine functions, dimensional analysis, and Fourier Series. Study of steady state circuits and networks subjected to sine and non-sine e.m.f. waves, and comprising constant and variable characteristics. Assistant Professor MALTI and instructors.

421, 422. *Electrical Practice.* Throughout the year. Credit three hours a term. Prerequisite courses 411, 412, and 431. Two lectures and one computing period a week. Practical aspects of the advanced electrical theory, as applied to various types of apparatus and to some manufacturing and operating problems, are discussed in this course. Professor LEWIS and instructors.

423, 424. *Advanced Electrical Theory.* Throughout the year. Credit two hours a term. Prerequisite courses 411, 412, 431. Two recitations a week. The work of the first term covers chiefly non-sinusoidal currents, circuits with distributed characteristics, unbalanced polyphase circuits and symmetrical components, electric transients and coupled circuits.

The second term is devoted to the laws of the magnetic and dielectric circuits with application to electrical machinery. This course is correlated with the courses 421 and 422, in which practical applications of the advanced electrical theory are considered. Assistant Professor MALTI and instructors.

431. *Electrical Laboratory for E.E. Juniors.* Required of juniors in Electrical Engineering. First term. Credit four hours a term. Prerequisite courses, Mechanics 3M21, E.E. 410, and must be accompanied by 411. One lecture, one recitation, one laboratory period each week. Experimental work on electrical measurements, direct current motors, generators, and auxiliary equipment. Professor CHAMBERLAIN, Assistant Professor B. K. NORTHROP, Dr. SOHON, and Mr. BRISTOL.

433, 434. *Advanced Electrical Laboratory.* Required of seniors in Electrical Engineering. Throughout the year. Credit four hours a term. Prerequisite courses, Electrical Engineering 431, 412, and 450. Two recitations, one laboratory period, and one report a week. Special and commercial tests on direct and alternating generators and motors, transformers, synchronous converter, and other apparatus; work on instruments and on electrical materials in the standardizing laboratory. Professor CHAMBERLAIN, Assistant Professor BURCKMYER, and Mr. WOOD.

435, 436. *Electrical Laboratory for M.E. Seniors.* Required of seniors in Mechanical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Mechanics 3M21 and E.E. 415, 416. One recitation a week, laboratory experiment and report alternate weeks. Shorter course but similar in scope to 433 and 434. Professor CHAMBERLAIN, Mr. WOOD, and Mr. MANNING.

441. *Electrical Power-Plant Design.* First term only. Credit three hours. Prerequisite courses 411, 412, and 431. One lecture, one recitation, and one computing period a week. Selection and arrangement of the proper electrical equipment for direct and alternating current power-plants. Some attention is also devoted to operating features, and to questions of public policy and finance. Assistant Professor M. G. NORTHROP.

442. *Electrical Design.* Elective for seniors in Electrical Engineering. Second term only. Credit four hours. Three recitations and one computing period a week. A study of the fundamental principles underlying the design of direct- and alternating- current machinery. Assistant Professor M. G. NORTHROP.

444. *The Economics of Public Utilities.* Elective for seniors in Electrical Engineering. Second term only. Credit three hours. Three recitations a week. A study of the origin and development of public utilities, franchises, regulation and legislation, valuation, rates and rate structures, public ownership and public relations. Professor CHAMBERLAIN.

450. *Electronics.* Required of juniors in Electrical Engineering. Second term. Credit four hours. Prerequisite courses 410, 411, and 431. Two lectures, one recitation, and one laboratory period a week. A study of the theory and application of electrical apparatus which involves electronic conduction in vacuum and gases with particular reference to high vacuum thermionic apparatus, gas conduction devices, photo-electric cells, mercury vapor converters and inverters and similar equipment. Professor BALLARD and Assistant Professor B. K. NORTHROP.

451. *Electrical Communication Engineering.* Elective for seniors in Electrical Engineering. First term. Credit three hours. Two lectures, one recitation, and one laboratory or computing period a week. Prerequisites, courses 411, 412, 431, and 450. Consideration of the theory of alternating currents as applied to telegraph, telephone, and radio communication. Special emphasis is placed upon the theory and the application of thermionic devices to electrical engineering. Professor BALLARD, Assistant Professor McLEAN, and Mr. MOEDER.

452. *Electrical Communication Engineering.* Elective. Open to seniors in Electrical Engineering. Second term. Credit four hours. Two lectures, one recitation, one laboratory period, and one report a week. Prerequisites, courses 450 and 451. Consideration of problems, apparatus, and measurements particularly applicable to electrical communication engineering. Professor BALLARD and Assistant Professor McLEAN and Mr. MOEDER.

453. *Theory of Communication Networks.* First term. Credit three hours. Three recitations a week, assigned problems and references. Must be accompanied by 451. Foundation laws of elements and circuits with variable frequency. General network theorems. Two and four terminal structures. Recurrent networks and wave filters. Equalizers. Distributed circuits including continuous and concentrated loading of long lines. Special networks for very high frequencies. Assistant Professor McLEAN.

456. *Elements of Broadcast Engineering.* Second term. Credit two hours. One recitation and one laboratory period a week. Must be accompanied by 452. The course includes the study of modern broadcast equipment including sound pickup equipment, amplifier design, sound reinforcement, sound recording as an adjunct to broadcasting, wire transmission, and radio transmitting equipment. The facilities of a modern broadcasting station will be at the disposal of the student to familiarize him with many standard tests made in the field. Mr. MOEDER.

462. *Industrial Application and Control of Electricity.* Elective. Second term. Credit two hours. Open to seniors and graduate students. A study of electric motor drive; selection of motors; study and selection of motor control; power requirements for various kinds of machinery; electric hoists, welding, heating. Professor CHAMBERLAIN.

463. *Electrical Transmission and Distribution.* Elective for E.E. seniors. First term only. Credit three hours. Two recitations and one computing period a week. This course is designed to give an understanding of the fundamentals of electric transmission and distribution. Prerequisites 411, 412, 431, 450. Assistant Professor M. G. NORTHROP.

465, 466. *Illumination.* Elective. Throughout the year. Credit two hours. Open to juniors and seniors in the College of Engineering. Prerequisite courses: Physics 11, 12. A study of the production, measurement, and utilization of light with emphasis on the latter. Recitation, discussion, and problem work. Oral reports on illumination topics of current interest are a feature of the course and supplement the textbook material. Assistant Professor STRONG.

481, 482. *Engineering Mathematics.* Elective. Open to juniors and seniors. Throughout the year. Credit two hours. Two recitations a week and home work. General methods by which engineering problems are expressed in mathematical form. The course consists of problems taken from mechanical,

civil, or electrical engineering, involving analytical geometry and the elements of differential and integral calculus. The topic will be selected to suit the class.

483, 484. *Special Electrical Engineering Problems.* Open to seniors and to qualified juniors. First or second term or both. Credit one or more hours. A course to meet the need of students who are not particularly interested in the other electives. Theoretical and experimental investigations on electrical apparatus. Each student selects his own subject, which, however must meet with the approval of the Director of the School of Electrical Engineering. Professors and instructors as required.

485, 486. *Heavyside's Operational Analysis.* Elective for seniors and graduate students. First and second terms. Credit three hours a term. Prerequisite course 420. Two lecture-recitations and one computing period a week. Mathematical introduction covering functions of real variables, functions of complex variables, infinite series, some special functions, integral equations, and Laplace and Fourier Transforms. Generalized expansion theorems for differential and difference equations. Application to transient problems in circuits with lumped and distributed parameters, and to ladder networks. Assistant Professor MALTI.

489. *Patents.* Elective for seniors and graduate students in Engineering. Credit one hour. One recitation a week. First term only. A consideration of the fundamental principles of United States and foreign patents and their relationship to the engineer. Professor BALLARD.

491. *Non-resident and Special Lectures.* Required. Credit one hour each year. Open to juniors and seniors. These lectures are primarily intended to include the technical addresses given during the academic year before the regular meeting of the local section of the A.I.E.E., and such other special lectures as may be designated. Notice of the lectures will be posted on the bulletin board of the School of Electrical Engineering. Credit of one hour may be obtained by attending at least fifteen of the lectures offered during the academic year. For credit a notebook giving a résumé of each lecture attended (not more than about one page for each lecture) must be handed in at the Director's office during block week at the end of the second term. The honor system applies to attendance at these lectures.

497, 498. *A.I.E.E. Seminar.* Elective for juniors and seniors who are members of the Student Branch of A.I.E.E. Throughout the year. Credit one hour a term. One period a week. Study and practice in the preparation and delivery of professional engineering papers. The organization, conduct, and purposes of the professional engineering societies. Assistant Professor STRONG, Counsellor of Cornell Branch A.I.E.E., Professor KARAPETOFF, and others.

School of Chemical Engineering

FIVE-YEAR COURSE Because a competent chemical engineer must be thoroughly familiar not only with the fundamentals of engineering and with the special field of chemical engineering but also with the science of chemistry, it is impossible to provide adequate preparation for professional work in Chemical Engineering in four years. The curriculum leading to the degree of Bachelor of Chemical Engineering outlines an integrated five-year course. Provision is made for a considerable amount of elective work. The elective work may be either in cultural subjects or in fields in which the student desires specialized or advanced instruction.

Here follows an outline of the regular five-year course of study leading to the degree of Bachelor of Chemical Engineering.

		COURSE	HOURS *First Term*	HOURS *Second Term*
FIRST YEAR 37 HOURS	Introductory Inorganic Chemistry	Chemistry 110	3	2
	Inorganic Chemistry Laboratory	Chemistry 115	3	0
	Introductory Qualitative Analysis	Chemistry 203	0	5
	Analytic Geometry and Calculus	Mathematics 7a, b	3	3
	English	English 2	3	3
	Introductory Experimental Physics	Physics 11, 12	4	4
	Drawing	M.E. 125a, b	2	2
SECOND YEAR 39 HOURS	Introductory Organic Chemistry	Chemistry 305	3	3
	Organic Chemistry Laboratory	Chemistry 310	3	3
	Introductory Quantitative Analysis	Chemistry 220	3	0
	Quantitative Analysis Laboratory	Chemistry 221	3	0
	Gas and Fuel Analysis	Chemistry 250	0	3
	General Physics	Physics 21, 22	3	3
	German	German 1c	3	3
	Differential Equations	Mathematics 7c, d	3	3
THIRD YEAR 34 HOURS	Introductory Physical Chemistry	Chemistry 405	3	3
	Physical Chemistry Laboratory	Chemistry 410	3	3
	Introductory Chemical Microscopy	Chemistry 530	0	3
	Elementary Mineralogy	Geology 311	3	0
	Mechanics	M.E. 3M21	5	0
	Strength of Materials	M.E. 3M22a, b	0	5
	Materials of Construction	M.E. 3X21	3	0
	Materials of Construction	M.E. 3X22	0	3
FOURTH YEAR 35 HOURS	Unit Operations of Chemical Engineering	Chem. E. 705	3	3
	Chemical Engineering Laboratory	Chem. E. 710	2	2
	Advanced Inorganic Chemistry	Chemistry 130	3	3
	Advanced Physical Chemistry	Chemistry 420	3	0
	Special Topics in Chemistry	Chemistry 910	1	0
	Advanced Quantitative Analysis	Chemistry 230	0	3
	Heat Power Engineering	M.E. 3P33	3	0
	Heat Power Engineering	M.E. 3P34	0	3
	Mechanical Laboratory	M.E. 3X33	3	0
	Mechanical Laboratory	M.E. 3X34	0	3

FIFTH YEAR 34 HOURS	Electrical Engineering Lectures	M.E. 405	4	0
	Electrical Engineering Lectures	M.E. 406	0	4
	Machine Design	M.E. 3D34	2	0
	Machine Design	M.E. 3D36	1	0
	Industrial Organization	M.E. 3I31	2	0
	Chemical Plant Design	Chem. E. 730	3	3
	Introduction to Economics	Economics 3	0	3
	Electives (hours per term variable)		5	7

Students who present two or three units of German at entrance may not take the first term of German 1b for credit. Students who present three units of German may, on recommendation of the Department of German, substitute German 8 for the second term of German 1b. The equivalent number of hours of electives will be substituted for the first term of German 1b, in the above cases.

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

A student who does not pass at least twelve hours in any term, with a grade of at least 70 in at least six of these twelve hours, may be dropped from the University or placed on probation. The same penalty may be imposed on students in the Summer Session who do not pass at least four hours, with a grade of 70 or better in two hours.

A student in Chemical Engineering is expected to maintain, term by term, a general average of 75.

If, in the opinion of the faculty of the School of Chemical Engineering, a student's general record is unsatisfactory, the student will be refused permission to continue his work for the degree of B. Chem. E., even though he has met the minimum requirements in respect to the number of hours of work passed and the grades in these hours.

THE COURSES OF INSTRUCTION

Following is a list of the courses of instruction which are prescribed for the course of study leading to the degree of Bachelor of Chemical Engineering. Some of them are given in other schools of the College of Engineering or in other colleges of the University. Those in Chemistry, Physics, English, Mathematics, Economics, German, and Geology are given in the College of Arts and Sciences. Those in Mechanics, Strength of Materials, Drawing, Materials of Construction, Heat-Power Engineering, Mechanical Laboratory, Industrial Organization, and Machine Design are given in the School of Mechanical Engineering, and those in Electrical Engineering in the School of Electrical Engineering, and any such courses, required or elective, will be found described elsewhere in this Announcement.

CHEMISTRY

110. *Introductory Inorganic Chemistry*. Throughout the year. Credit three hours first term, two hours second term. Prerequisite, entrance credit in chemistry, or course 101. Required of candidates for the degree of Bachelor of Chemical Engineering.

Lectures: Professor LAUBENGAYER. First term, M W F 8; second term, W F 8. *Baker* 200.

115. *Introductory Inorganic Chemistry*. Recitations and laboratory practice. First term. Credit three hours. Must be taken with the first term of Chemistry 110. Deposit, $20. Professor LAUBENGAYER and assistants.

Recitations: one hour a week, to be arranged. Laboratory: To be arranged. *Baker* 50.

130. *Advanced Inorganic Chemistry*. Throughout the year. Credit three hours a term. Prerequisite or parallel courses, Chemistry 405 and 410. Professor LAUBENGAYER. M W F 11. *Baker* 107.

Lectures. The chemical elements are discussed in the order in which they occur in the Periodic Table of Mendeléff, with special attention to the group properties of the elements and to the relations of the groups to one another. The rare elements are treated in as great detail as are the more common elements.

203. *Introductory Qualitative Analysis*. Second term. Credit five hours. Prerequisite, one term of Chemistry 110 or special permission. Deposit, $30. Must be taken with the second term of Chemistry 110. Required of students in the course in Chemical Engineering. Professor NICHOLS, Dr. LONG, and assistants.

Lecture or recitation: M 8. *Baker* 200. One other recitation, to be arranged. Laboratory: M W F 1:40–4 or T Th 1:40–4; S 8–10:30. *Baker* 50.

220. *Introductory Quantitative Analysis*. Repeated in the second term. Credit three hours. Prerequisite, Chemistry 203, or 205 and 206. Must be taken with Course 221. Professor NICHOLS and assistants.

Lectures: T Th 9. *Baker* 207.

Recitations: one hour a week, to be arranged.

A study of the fundamental principles of gravimetric and volumetric analysis with practice in stoichiometry.

221. *Introductory Quantitative Analysis*. Repeated in the second term. Credit three hours. Prerequisite, Chemistry 203, or 205 and 206. Must be taken with Course 220. Deposit, $20. Professor NICHOLS and assistants.

Laboratory sections: F 1:40–4, S 8–1; T Th 10–12:30, Th 1:40–4 (first term only). *Baker* 252.

Laboratory practice in the preparation and standardization of various volumetric solutions and the analysis of a variety of substances by volumetric and gravimetric methods.

230. *Advanced Quantitative Analysis*. Repeated in the second term. Credit three hours. Prerequisite, Chemistry 220 and 221 or special permission. Deposit, $20. Professor NICHOLS, and assistants. Recitation: one hour a week, to be arranged. Laboratory periods; first term, T Th 1:40–4; T Th 8–12:30; second term, T Th 1:40–4; T Th 8–12:30; S 8–1. *Baker* 294.

Students will be assigned to a combination of laboratory periods that will total seven and one-half hours a week.

The calibration of weights and volumetric apparatus; the analysis of ferrous and non-ferrous alloys, silicates and organic substances by various gravimetric, volumetric, and combustion methods.

250. *Gas and Fuel Analysis*. Second term. Credit three hours. Prerequisite, Chemistry 220 and 221. Fee, $10. Professor NICHOLS and assistants. Lectures: F 10. *Baker* 207.

Laboratory sections: M W 1:40–4; T 10–12:30, 1:40–4:00; Th 10–12:30, 1:40–4; S 8–1. *Baker* 282.

The complete analysis of coal gas, flue gas, and air, the determination of the heating power of gaseous, liquid, and solid fuels; the analysis of coal; standard methods of testing various petroleum and coal-tar products; the analysis of various substances by methods involving the use of different types of gas evolution apparatus. Problems are assigned which afford practice in the calculation and interpretation of results.

305. *Introductory Organic Chemistry*. Throughout the year. Credit six hours on completion of the course. Prerequisite, qualitative analysis. Open to those who are taking Course 220. Professor JOHNSON and Dr. MILLER. M W F 9. *Baker* 200.

Lectures and written reviews. The more important compounds of carbon, their occurrence, methods of preparation, relations, and uses.

310. *Introductory Organic Chemistry*. Throughout the year. Credit three hours a term. Prerequisite or parallel course, Chemistry 305. Deposit, $35. Professor JOHNSON, Dr. MILLER, and assistants. Laboratory sections, T Th 10–12:30; Th 1:40–4; F 1:40–4, S 8–1. *Baker* 250.

Laboratory practice and oral reviews. The student prepares a large number of typical compounds of carbon and familiarizes himself with their properties, reactions, and relations.

405. *Introductory Physical Chemistry*. Throughout the year. Credit three hours a term. Prerequisite, Chemistry 305. Mathematics 5a and 5b and Physics 11 and 12 (or their substantial equivalent). Professor BRIGGS and assistants. Lectures, M W F 9. *Baker* 7.

A systematic presentation of modern 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 and the concept of activity; chemical kinetics and catalysis; photochemistry; written problems in physical chemistry.

410. *Introductory Physical Chemistry*. Throughout the year. Laboratory and recitations. Credit three hours a term. Prerequisite or parallel course, Chemistry 405. Deposit, $20. Professor BRIGGS, and assistants. Laboratory sections: M T 1:40–4; Th F 1:40–4; and S 8–1. Baker 1. Recitations to be arranged.

Qualitative and quantitative experiments illustrating the principles of physical chemistry and practice in performing typical physico-chemical measurements. Recitations on the general principles of physical chemistry, based upon the lectures given in Course 405.

420. *Advanced Physical Chemistry*. First term. Credit three hours. Prerequisite, Chemistry 405. Required of candidates for the degree of Bachelor of Chemistry. Dr. HOARD. Lectures and recitations, M W F 12. *Baker* 7.

Exposition of the principles of physical chemistry from the mathematical standpoint, with emphasis on the solution of simple problems.

530. *Introductory Chemical Microscopy*. Repeated in the second term. Credit three hours. Prerequisite, or parallel courses, Chemistry 405 and Physics 21 and 22, or special permission. Fee, $5. Professor MASON and assistants.

Lecture: M 10. *Baker* 377.

Laboratory sections: M T 1:40–4; T Th 9–11:30. *Baker* 378.

Lectures and laboratory practice. The use of microscopes and their accessories in chemical and technical investigations. Micrometry; particle size determinations; quantitative estimations; microscopical characteristics and physical chemistry of crystals; illumination, ultramicroscopy and photomicrography; study of industrial materials such as textile and paper fibers.

Graduate students are advised to take this course the first term.

910. *Special Topics in Chemistry*. First term. Credit one hour. Required of candidates for the degree of Bachelor of Chemistry. Professors Rhodes and Mason. T 11. *Baker* 207.

The use of chemical literature; methods of research; administration of chemical laboratories; patent law; and other special topics.

Graduate students are advised to take this course before beginning thesis work.

For description of other courses in Chemistry, available as electives in the course in Chemical Engineering, see announcement of the College of Arts and Sciences.

PHYSICS

For description of Physics courses 11 and 12, see page 57 of this announcement. For courses 21 and 22, see page 111 of this announcement. For advanced courses in Physics available as electives, consult the announcement of the College of Arts and Sciences.

MATHEMATICS

7a, 7b. *Analytical Geometry and Calculus*. Throughout the year. Credit three hours a term. Prerequisites, Solid Geometry and Trigonometry.

7c, 7d. *Differential Equations*. Throughout the year. Credit three hours a term. Prerequisite, Mathematics 7a and 7b.

MECHANICAL ENGINEERING

Those courses required for the degree of Bachelor of Chemical Engineering that are given in the School of Mechanical Engineering are described in that section of this announcement that is devoted to a discussion of the work in Mechanical Engineering.

ELECTRICAL ENGINEERING

Courses 405 and 406 in Electrical Engineering are described on page 133 of this Announcement.

ENGLISH

2. *Introductory Course in Composition and Literature*. Throughout the year. Credit three hours a term. May not be entered the second term. Professor Sibley, Assistant Professor Tenney, and others. M W F 8, 9, 10, 11, 12; T Th S 8, 9, 10, 11. Rooms to be announced.

The course, open to freshmen who have satisfied the entrance requirements in English, is a training in the reading and writing of English. All those who elect this course must apply as follows for assignment to sections: the first term at the *Drill Hall;* the second term at *Goldwin Smith* A. Registration is in charge of Assistant Professor Tenney.

GERMAN

1c. *Course for Chemists: Grammar, Reading of Texts in Chemistry*. Throughout the year. Credit six hours on completion of the course, three hours for those taking it only the second term. Professor ANDREWS and Mr. MUELLER. M W F 11, 12. *Goldwin Smith* 177, 190.

CHEMICAL ENGINEERING

705. *Unit Operations of Chemical Engineering*. Throughout the year. Credit three hours a term. Prerequisite, Chemistry 405. Professor RHODES. M W F 10. *Baker* 177.

Lectures. A critical discussion of the important unit operations of chemical engineering: fluid flow, heat transfer, evaporation, distillation, filtration, gas absorption, crushing, and grinding, etc. In these lectures, particular emphasis is placed on the fundamental theory upon which the various unit operations are based.

710. *Unit Operations Laboratory*. Throughout the year. Credit two hours a term. Prerequisite, Chemistry 405. Fee, $10. Professor RHODES, Assistant Professors WINDING and SWENSON, and assistants. Laboratory period, day and hour to be arranged. *Baker* B-78. Conference period, Th 11. *Baker* 207.

The study in the laboratory, on a semi-plant scale, of the unit operations of chemical engineering, such as agitation, and mixing, filtration, fractional distillation, evaporation, drying, absorption of gases, and heat transfer.

715. *Unit Processes of Chemical Engineering*. Second term. Credit three hours. Prerequisite or parallel course, Chemistry 705. Assistant Professor WINDING. M W F 11. *Baker* 177.

Lectures. A discussion of the important typical unit processes of chemical engineering; as, for example, nitration, sulphonation, esterification, caustic fusion, chlorination, etc.

725. *The Chemistry of Fuels*. First term. Credit three hours. Prerequisite or parallel course, Chemistry 705. Assistant Professor WINDING. M W F 11. *Baker* 177.

Lectures. The chemistry of coal, coke, petroleum tars, and the fuel gases. Particular stress is laid upon the theoretical chemistry involved in the carbonization of coal, the gasification of coal, and the distillation and refining of petroleum and tar.

730. *Chemical Plant Design*. Throughout the year. Credit three hours a term. Prerequisite, Chemistry 705. Deposit, $10. Professor RHODES and Assistant Professors WINDING and SWENSON. Day and hour to be arranged.

One conference and two laboratory periods. Practice in the calculation and design of chemical plant equipment.

735. *Plant Inspections*. Second term. Credit one hour. Prerequisite or parallel course Chemistry 705.

Visits to plants typical of various chemical industries. Conferences and reports. A trip during spring vacation will be a feature of this course. Fee, covering expenses, to be announced.

The schedules of plant visits are so arranged that a different group of plants is visited each year, over at least a three-year cycle. All students in Chemical Engineering are expected to make at least one of the inspection trips.

740. *Chemical Engineering Computations*. Throughout the year. Credit two hours. Prerequisite or parallel course, Chemistry 705. Assistant Professor WINDING. Hours to be arranged.

Conferences and lectures. Problems in stoichiometric relationships, material balances and reaction rates, fluid flow and heat transfer, distillation, evaporation and drying, humidification and air conditioning, and filtration.

750. *Furnace Metallurgy*. Second term. Credit two hours. Prerequisite or parallel course, Chemistry 405. Professor RHODES. T Th 10. *Baker* 377.

Lectures. A discussion of the reactions involved in the smelting of ores and the furnace refining of metals. The discussion is accompanied by problems dealing with the various subjects discussed. (Given in alternating years. Not given in 1939–40.)

795. *Research for Seniors*. Throughout the year. Credit two or more hours a term. Fee variable. Professor RHODES and Assistant Professors WINDING and SWENSON.

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