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Comprising

The School of Civil Engineering
The Sibley School of Mechanical Engineering
The School of Electrical Engineering

1927-28

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A HISTORY OF THE COLLEGE OF ENGINEERING

CORNELL UNIVERSITY had its beginning in the Federal Government's grant, for the endowment of education in the several States, of a large portion of the public lands, under the authority of the Morrill Act, an Act of Congress approved by President Lincoln in 1862. The purpose of the Morrill Act was to endow in each State at least one college; by an express provision of the Act, a leading object of each of those colleges was to be the teaching of "such branches of learning as are related to . . . the mechanic arts." The State of New York devoted all the proceeds of its share of the land grant to Cornell University, which was established by charter in 1865 and was opened at Ithaca in 1868. In the very first plan of this University, therefore, was the foundation of a College of Engineering.

EZRA CORNELL, who had brought an eminent talent for practical affairs to the organizing and upbuilding of the telegraph business before and after the creation of the Western Union Telegraph Company, and who had retired in 1858, gave generously of his wealth and lavishly of his powers to the University's establishment. His wise management of New York's share of the land grant multiplied the endowment.

HIRAM SIBLEY OF ROCHESTER, the founder and first president of the Western Union Telegraph Company, a trustee of the University from 1865 until his death in 1888, was a liberal benefactor of the University's department of mechanical engineering. In 1871 he erected a building to house what was then called the college of mechanic arts, equipped it, and endowed the Sibley Professorship of Mechanic Arts to the amount of fifty thousand dollars. During the years from 1870 to 1887, Mr. Sibley gave more than \$180,000 for the building and equipment of lecture halls, shops, and laboratories. His benefactions have been continued by his son, Mr. Hiram W. Sibley, who has given about \$170,000 for construction and equipment.

When Cornell University began its work, in 1868, it included a College of Mathematics and Engineering and a College of Mechanic Arts. The former of these consisted of two schools, namely, a school of mathematics and a school of civil engineering. In 1871 mathematics was set apart, and architecture was associated with civil engineering in a single college until 1873, when another separation took place, and civil engineering was organized as a department; it retained that form until 1890, when the College of Civil Engineering was established.

The original College of Mechanic Arts offered instruction in shop work, drawing, and elementary engineering, in conformity with the provisions of the Morrill Act and the Charter, and provided a theoretical and practical course of four years leading to the bachelor's degree in mechanical engineering. In 1885, in recognition of the growth in importance of the profession of mechanical engineering,

the college was renamed The Sibley College of Mechanical Engineering and the Mechanic Arts.

Courses in electrical engineering were first established at Cornell in 1883, under the guidance of the Department of Physics. In 1889 the direction of the professional courses in electrical engineering was transferred to Sibley College and the present course in electrical engineering was developed within that college.

In 1919 the Board of Trustees, recognizing that all practice in engineering has a common groundwork, voted to consolidate all instruction in engineering at Cornell in a single institution to be called The College of Engineering. This single college comprises three schools, namely, the School of Civil Engineering, the Sibley School of Mechanical Engineering, and the School of Electrical Engineering. The last-named school has grown from the former department of electrical engineering in Sibley College. The combination has proved itself to be sound educationally, to be in harmony with the progress of industry, and to have administrative merit.

Besides the College of Engineering, Cornell University comprises the Graduate School, in which the student's work may lead to the degree of Doctor of Philosophy or to the master's degree in arts, science, agriculture, architecture, landscape architecture, forestry, chemistry, civil engineering, mechanical engineering, or electrical engineering; the College of Arts and Sciences, whose courses lead to the degree of Bachelor of Arts or that of Bachelor of Chemistry; the Law School; the Medical College, which gives most of its instruction in its main building at First Avenue and Twenty-eighth Street, New York City; the New York State Veterinary College; the New York State College of Agriculture; the New York State College of Home Economics; and the College of Architecture, in which a student may earn the degree of Bachelor of Architecture, Bachelor of Landscape Architecture, or Bachelor of Fine Arts. There are about nine hundred persons in the University's teaching staff and its students number about five thousand.

The College of Engineering has intimate relations with the rest of the University. Its students, constituting about one-fourth of the University's whole enrollment, are associated with the faculties and students of the other colleges. This is an association in which the student extends his intellectual horizon and gains a clearer understanding of the relation of engineering to other human interests.

The University is situated at Ithaca, in the central part of the State of New York, about seven hours by rail from the City of New York and about three hours from Buffalo. Ithaca is accessible by way of two trunk lines, the Lackawanna and Lehigh Valley Railroads, and it has connections by rail with several stations on the New York Central system. The University's campus and contiguous lands occupy about fifteen hundred acres. The campus is on a hill, overlooking the city of Ithaca and a good many miles of Cayuga Lake.

THE FACULTY

THE COLLEGE OF ENGINEERING

LIVINGSTON FARRAND, A.B., M.D., L.H.D., LL.D., President of the University.
DEXTER SIMPSON KIMBALL, A.B., M.E., LL.D., Dean of the College and Professor
of Industrial Engineering.
MAUDE S. NEWMAN, Secretary of the College.

THE SCHOOL OF CIVIL ENGINEERING

FRED ASA BARNES, M.C.E., Director of the School and Professor of Railroad
Engineering.
EUGENE ELWIN HASKELL, C.E., Professor of Experimental Hydraulics, Emeritus.
IRVING PORTER CHURCH, M.C.E., Professor of Applied Mechanics and Hydraulics,
Emeritus.
HENRY SYLVESTER JACOBY, C.E., Professor of Bridge Engineering, Emeritus.
HENRY NEELY OGDEN, C.E., Professor of Sanitary Engineering, in charge of
the College Library.
SIDNEY GONZALES GEORGE, C.E., Professor of Mechanics of Engineering.
JOHN THOMAS PARSON, Professor of Drawing.
ERNEST WILLIAM SCHODER, Ph.D., World War Memorial Professor of Experimental
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FRANCIS JOSEPH SEERY, S.B., Professor of Civil Engineering.
SAMUEL LATIMER BOOTHROYD, M.S., Professor of Astronomy.
ERNEST WILLIAM RETTGER, Ph.D., Professor of Mechanics of Engineering.
CHARLES LEOPOLD WALKER, C.E., Professor of Sanitary Engineering and Sec-
retary of the College Faculty.
PAUL HALLADAY UNDERWOOD, C.E., Professor of Surveying.
HERBERT HENRY SCOFIELD, M.E., Professor of Testing Materials. (On leave, first
term.)
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LEONARD CHURCH URQUHART, C.E., Professor of Structural Engineering.
MILES ALBION POND, Ph.B., Assistant Professor of Civil Engineering.
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 Railroad Engineering and Secretary
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JOHN EDWIN PERRY, B.S. in C.E., Assistant Professor of Railroad Engineering.
CHARLES EDWARD O'ROURKE, C.E., Assistant Professor of Structural Engineer-
ing. (On leave.)
ERIC VAIL HOWELL, M.C.E., Assistant Professor of Mechanics.
WILLIAM R. OSGOOD, M.S., Assistant Professor of Structural Engineering.
ROMEYN Y. THATCHER, C.E., Assistant Professor of Railroad Engineering.
CLAUDE M. PENDLETON, C.E., Marc Eidlitz Instructor in Surveying.
CHILTON A. WRIGHT, M.C.E., Instructor in Hydraulics.
ARTHUR F. BOYLES, C.E., Instructor in Surveying.

FRED J. SPRY, C.E., Instructor in Railroad Engineering.
JOHN M. GARRELS, C.E., Instructor in Structural Engineering.
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PAUL ERSKINE BROWN, Instructor in Surveying.

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GEORGE ROBERT McDERMOTT, Professor of Structural Design.
WILLIAM NICHOLS BARNARD, M.E., Professor of Power Engineering.
EDGAR HARPER WOOD, M.M.E., Professor of Mechanics of Engineering.
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 Power Engineering.
WILL MILLER SAWDON, M.M.E., Professor of Experimental Engineering, assigned to Engineering Research.
GEORGE BURR UPTON, M.M.E., Professor of Experimental Engineering.
SEYMOUR STANTON GARRETT, C.E., World War Memorial Professor of Mechanics of Engineering.
MILLARD CLAYTON ERNSBERGER, A.B., M.E., Professor of Power Engineering.
VICTOR RAYMOND GAGE, M.M.E., Professor of Experimental Engineering.
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WALTER RODNEY CORNELL, B.S., C.E., Professor of Mechanics of Engineering.
ROY EDWARDS CLARK, M.E., Assistant Professor of Power Engineering.
ENOCH FRANCIS GARNER, M.E., Assistant Professor of Machine Design.
WARREN HOWARD HOOK, M.E., Assistant Professor of Power Engineering.
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WILLIAM EMERSON MORDOFF, M.E., Assistant Professor of Machine Construction.
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SIMEON JOHN KOSHKIN, M.E. (E.C.P.), Assistant Professor of Machine Design.
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KARL DAWSON WOOD, M.E., M.S., Instructor in Mechanics of Engineering.
GEORGE RAYMOND HANSELMAN, M.E., Instructor in Engineering Drawing.
JAMES FOX, M.E., Instructor in Machine Design.

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ERNEST MERCER FERNALD, M.M.E., Instructor in Experimental Engineering.
BENJAMIN MARTIN SHAUB, M.E., Instructor in Machine Design.
CARROLL BROMLEY CLARK, M.E., Instructor in Experimental Engineering.
NORMAN LYLE EGBERT, M.E., Instructor in Experimental Engineering.
CHARLES OSBORN MACKEY, M.E., Instructor in Experimental Engineering.
EDWARD HAROLD WOODS, M.E., Instructor in Experimental Engineering.
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BENJAMIN WHITELEY CROSS, Instructor in Machine Design.
WINTHROP DOANE WASHBURN, Instructor in Experimental Engineering.
HAROLD FITCH KNEEN, M.E., Instructor in Industrial Engineering.
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ROGER WILSON BRETT, Assistant in Power Engineering.
THEODORE ELLSWORTH THOMPSON, Instructor in Engineering Drawing.

ASSISTANTS

BURDETTE N. HOWE, Foreman in the Machine Shop.
CHARLES E. PATTERSON, Foreman in the Foundry.
LEROY HOOPER, Foreman in the Pattern Shop.
WALTER LISTON HEAD, Assistant in Introductory Engineering Laboratory.
HOWARD STANLEY BUSH, Assistant in the Pattern Shop.
ERNEST STANLEY YAWGER, Assistant in the Pattern Shop.
GEORGE SANDERSON, Assistant in the Foundry.
RUDOLPH P. SCHALLOWITZ, Assistant in the Machine Shop.
RALPH W. HODGES, Assistant in the Machine Shop.

THE SCHOOL OF ELECTRICAL ENGINEERING

PAUL MARTYN LINCOLN, M.E. (in E.E.), Director of the School and Professor of Electrical Engineering.
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EVERETT MILTON STRONG, B.S. in E.E., Instructor in Electrical Engineering.
ERNEST WALTER STARR, E.E., Instructor in Electrical Engineering.

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RALPH HAMILTON BYRD, E.E., Instructor in Electrical Engineering.
HERSCHEL PAUL LEWIS, B.S. in M.E., Instructor in Electrical Engineering.
DONALD DIXON MACCARTHY, E.E., Instructor in Electrical Engineering.
WILBER ERNEST MESERVE, B.S., in E.E., Instructor in Electrical Engineering.
LOUIS CONRAD ROESS, E.E., Instructor in Electrical Engineering.
DIMITER RAMADANOFF, B.S. in E.E., Instructor in Electrical Engineering.
CHARLES LEGRAND BUNDY, B.S., Instructor in Electrical Engineering.

OTHER OFFICERS

ELSIE M. UPDIKE, Recorder.
LULU M. MARKELL, Secretary to the Dean.
MARY R. KORHERR, Librarian of the School of Civil Engineering.
HELEN R. LYNCH, Secretary to the Director of the School of Civil Engineering.
CLINTON D. CASS, Mechanician of the School of Civil Engineering.
JAMES H. NORTHPROP, Assistant Mechanician of the School of Civil Engineering.
LENA GERTRUDE MARSH, Librarian of the Sibley School of Mechanical Engineering.
DOROTHY H. WASHBURN, Secretary to the Director of the Sibley School of Mechanical Engineering.
GEORGE WASHINGTON RACE, Mechanician in the Sibley School of Mechanical Engineering.
EDWARD WARREN GREGORY, Mechanician in the Sibley School of Mechanical Engineering.
ALFRED WILLIAM NEIGH, Engineer in the Sibley School of Mechanical Engineering.
KATHERINE HANDLEN, Secretary to the Director of the School of Electrical Engineering.
Mrs. J. M. BATCHELLOR, Librarian of the School of Electrical Engineering.
GEORGE ALFRED CULLIGAN, Mechanician in the School of Electrical Engineering.

PURPOSE OF THE INSTRUCTION

THOROUGH TRAINING IN FUNDAMENTALS

The curricula of the Schools of the College of Engineering consist, primarily, of courses designed to teach the fundamental principles, theoretical and practical, that underlie the various branches of engineering. In addition, such work is required in pure and applied economics as is needed by the engineer of the present time. Late in the course some degree of specialization is permitted; but since the time allowed for this is quite limited, specialization cannot be carried very far. In fact, the Faculty of Engineering is strongly of the opinion that the duty of the technical school to its undergraduates is to train them thoroughly in the fundamental subjects and that the four-year course is not too long for this purpose. Hence the demand for the introduction of specialization early in the course has always been resisted.

It is well recognized that theoretical instruction must be supplemented by experience in practice and by contact with life before one can attain his greatest usefulness in the profession; hence an effort is made to bring the student into contact with teachers who are closely in touch with engineering practice, to the end that he may thus become familiar with problems encountered in modern engineering and with practical methods of solving them. It is hoped in this way to shorten somewhat the period of adjustment for the graduate when he begins actual engineering work.

FIVE AND SIX-YEAR COURSES RECOMMENDED

The success of an engineer has come more and more to depend upon his ability to meet men of education and culture on equal terms. Since the work in the regular four-year course in this College is largely technical, it is desirable that the student devote more time to his course in order to broaden the training. This may be done by devoting five or six years.

In a five-year course, the student enters the College of Engineering with the regular entrance, and pursues the regular work for two or three years. After having obtained the fundamentals in engineering in this way, he may then spread the rest of the engineering work of the regular four-year course over three or two years more and add, in the way of electives, the equivalent of one year's work in the field of liberal arts. See pages 33 and 67 for further details of a five-year Mechanical Engineering course.

A SIX-YEAR COURSE leading to the degrees of A.B. and C.E., or A.B. and M.E., or A.B. and E.E. is recommended for students who can afford the additional time and expense. The entrance requirements for this course include less mathematical preparation than is

specified for the four-year or five-year course, but the student must meet the entrance requirements specified by the College of Arts and Sciences, in which he will be enrolled for the first four years. The necessary arrangement of his studies in the course is set forth under the head of Admission to the Six-year Course, on page 33.

In addition to the prescribed courses in the College of Engineering, those students who have the necessary time available may elect, with the permission of their class adviser, any course in any college of the University, provided they have had the required preparation for the work.

THE 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, and electrical 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 and constructors.

The facilities for instruction, both fundamental and advanced, are extensive. The students entering upon the work of the first term in the College all take the same courses, it being recognized that the fundamental work should be the same for all engineers. At the beginning of the second term the work of the civil engineering students commences to be differentiated, while the work of the mechanical and electrical engineering students is the same for two years. At the beginning of the third year the courses for mechanical and electrical engineering students differentiate, and these students commence to specialize in their particular branches.

For the Courses of Instruction, covering the work of the first year for all engineering students, see pages 38-40 of this Announcement. The work of the last three years is outlined on pages 41-57 for civil engineers, on pages 58-77 for mechanical engineers, and on pages 78-84 for electrical engineers.

In general the work of the freshman students comprises fundamental training in mathematics, physics, chemistry, drawing, surveying, and shop work.

CIVIL ENGINEERING students follow this with as thorough a preparation as possible for the general purpose of the profession in the following subjects: the survey, design, and construction 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, harbours, 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 the irrigation and reclaiming of land; the application, and tests of hydraulic and electric motors and steam engines; 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 in an elementary manner with the questions of easements and servitudes, and the fundamental principles of the law of contracts and riparian rights.

MECHANICAL ENGINEERING students in the last three years of the course receive a thorough training in machine design, in shop methods and management, in thermodynamics and heat-power, in the fundamentals of electrical engineering, and in mechanical laboratory practice. They may in their last year specialize in heat-power work, steam or internal combustion engines, industrial engineering, or in naval architecture.

ELECTRICAL ENGINEERING students receive a thorough foundation in mechanical engineering principles before they specialize in their particular branch in the last two years of the course. Virtually all of the last year is devoted to advanced work in electrical engineering, and students have opportunity to follow either the straight electrical course or to specialize in radio work.

OPPORTUNITIES FOR EMPLOYMENT AFTER GRADUATION

A training in civil, mechanical, or electrical engineering opens wide opportunities for employment in all branches of industry.

CIVIL ENGINEERING graduates are in demand as surveyors, railroad engineers, sanitary engineers, water-works engineers, highway engineers, city engineers and managers, bridge designers, structural engineers, construction engineers, and contractors and builders. Some of the graduates enter the employment of the Government in the geological and the geodetic surveys, and in the reclamation and irrigation services.

MECHANICAL ENGINEERING underlies nearly all branches of the industries: its province includes the design, construction, operation and testing of steam engines, steam turbines, boilers and power-plant auxiliaries, gas and oil engines, with their auxiliaries, hydraulic machinery, pumping engines, railway equipment, compressed air machinery, ice-making and refrigerating machinery, equipment for heating and ventilation, machine tools, mill equipment and transmission machinery. The work of the mechanical engineer includes the planning of power plants and factories, the selection and installation of their equipment, the development of the systems of operation and of manufacturing processes, and the organization and administration of industries.

ELECTRICAL ENGINEERING includes the design, construction, operation, and testing of electrical equipment used for the generation, transmission, and utilization of electrical energy.

From the foregoing very brief outline of some of the fields covered by the branches of engineering for which the students of the College of Engineering are fundamentally prepared, it is seen that the opportunities for graduates to obtain employment are broad. Graduates, after gaining requisite experience in practice, usually occupy such positions as designers, supervisors of construction, inspectors, testers, research engineers, superintendents of departments, works managers, efficiency engineers, specialists in welfare work and in labor problems, consulting engineers, insurance investigators, commercial representatives, engineering salesmen, educators, and managers and presidents of commercial organizations.

There has always been a dearth of men fitted to fill the higher positions in the fields of engineering and business; and the salary and position that the graduate will eventually obtain depend not only on his special training but on his inherent ability, industry, initiative, capacity to recognize and seize opportunities as they arise, and on his other personal qualities. The young man who has just graduated from the College of Engineering has little difficulty in finding immediate employment with salary sufficient for self-support, and if he shows the proper qualifications he may rise eventually to the highest positions attainable in engineering and business fields.

Each school maintains an EMPLOYMENT BUREAU for its graduates. Correspondence should be addressed to the Director of the school concerned.

BUILDINGS, LABORATORIES, LIBRARIES AND OTHER EQUIPMENT

BUILDINGS

The building occupied by the School of Civil Engineering is LINCOLN HALL, a substantial brownstone structure, 200 feet long and 70 feet wide. In addition to the laboratories and museums, the building contains the working library of the School, aggregating over five thousand volumes, reading rooms, classrooms, and drafting rooms. The astronomical equipment and portions of the geodetic equipment are housed in the Fuertes Observatory, which contains all the instruments required for determining time, latitude, longitude, and azimuth. Several of the instruments are duplicates of those used by the United States Coast and Geodetic Survey. A large hydraulic laboratory is situated at the lower end of Beebe Lake in Fall Creek Gorge, near Lincoln Hall.

The Sibley School of Mechanical Engineering received its name from the late Hiram Sibley of Rochester, who between the years 1870 and 1887, gave \$180,000 towards its endowment and equipment. Mr. Hiram W. Sibley has added more than \$170,000 for later constructions and equipment. The SIBLEY BUILDINGS are situated at the north end of the Campus, and stand upon ground leased from the University for the purposes of the School, under an agreement with the late Hiram Sibley. There are five large buildings in the group.

The main building is 370 feet long, 50 feet wide, and threestories in height. It contains the reading room and reference library, drawing rooms, lecture rooms, offices, classrooms, and a large and well-lighted auditorium.

The Department of Experimental Engineering occupies two two-story buildings, each about 150 feet long by 40 feet wide, besides a boiler plant 30 by 40 feet, a refrigeration laboratory 30 by 40 feet, and the east basement of the main building.

RAND HALL was added to the Sibley School group (at a cost of \$60,000) through the generosity of Mrs. Florence O. R. Lang. This building is a memorial to Jasper R. Rand, Addison C. Rand, and Jasper R. Rand, jr., the father, uncle, and brother of the donor. It is a three-story building, the main portion of which is 170 feet long and 50 feet wide; it contains the machine shop and pattern shop, and a portion is used temporarily for the electrical laboratories.

The foundry and forge shops occupy a one-story building, 180 feet long and 40 feet wide.

The School of Electrical Engineering is housed in FRANKLIN HALL, but a portion of the electrical laboratory is temporarily situated on the second floor of Rand Hall.

LABORATORIES AND MUSEUMS

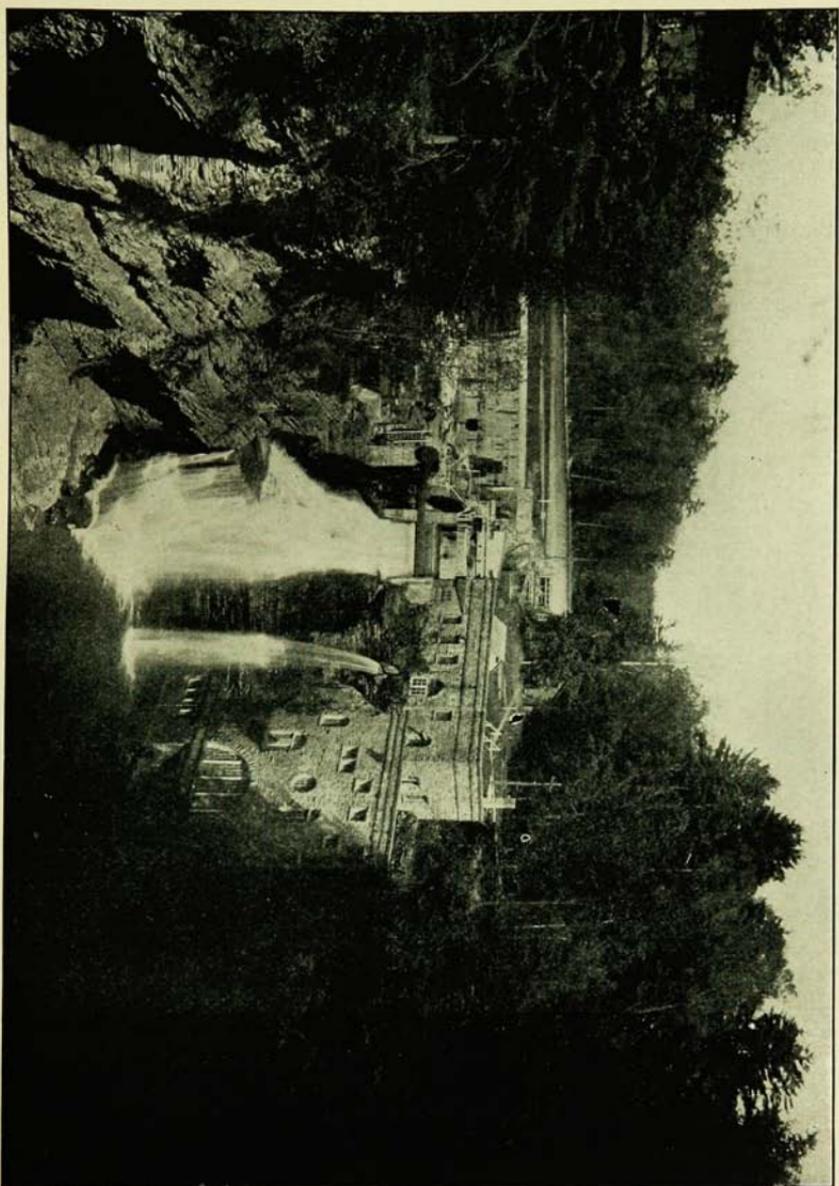
CIVIL ENGINEERING

The Civil Engineering Laboratories are housed in four distinct buildings and comprise the following:

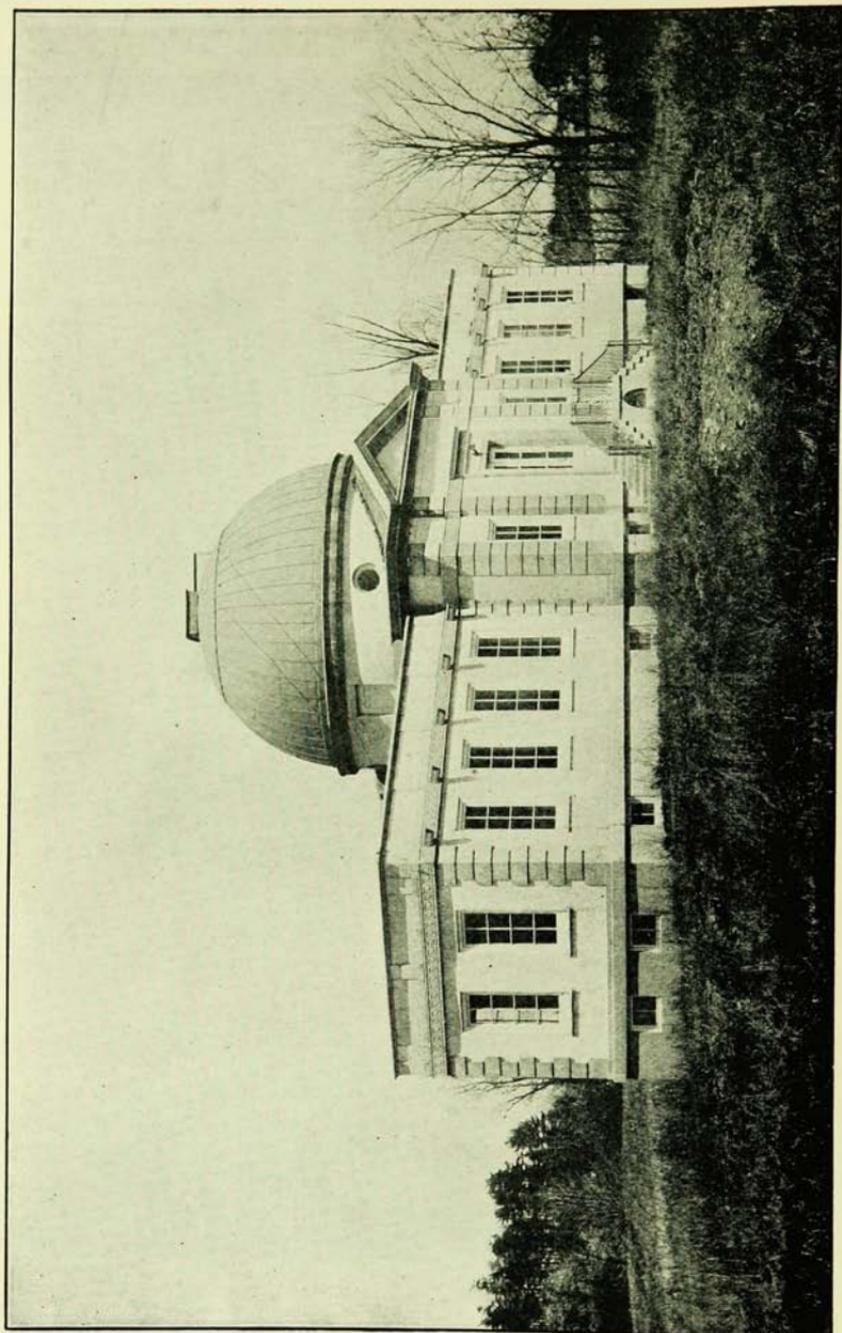
THE CEMENT LABORATORY. This laboratory contains machines for tension tests, compression machines of from two to two hundred tons capacity, and an impact machine. For direct experiment with cement there is also provided a large number of tension and compression briquette molds, a water tank with capacity for the storage of three thousand briquettes, a moist cabinet with a capacity of seven hundred briquettes, and a Freas automatic electric drying oven; scales, slates, and plateglass mixing tables, thermometers, permeability apparatus, several sets of apparatus for measuring linear and volume changes during setting, and apparatus for determining specific gravity, normal consistency, time of set, and constancy of volume by normal and accelerated tests; also standard sieves for determining fineness, a Ro-Tap Testing Sieve Shaker, and apparatus for determining voids in sand and stone.

THE TESTING LABORATORY. The equipment of this laboratory includes a Riehlé 400,000-lb. testing machine with a capacity for beams and girders up to 19 inches in width and 18 feet in length, and for specimens in tension and compression up to 12 feet in length; a Riehlé 50,000-lb. testing machine; an Olsen 100,000-lb. testing machine; an Olsen 50,000-lb. testing machine; an Olsen 10,000-lb. wire testing machine; a Thurston autographic torsion testing machine; a Riehlé torsion testing machine of 60,000 inch-pounds capacity for testing rods and shafts up to one and a half inches in diameter and six feet in length; a Riehlé 5,000-lb. transverse load testing machine for flexural tests of bars of wood and metal up to four feet in length; an Amsler-Laffon compression testing machine; a standard Page impact machine for tests of road material; a Riehlé grinder for stone specimens; a standard Deval machine for abrasion tests of road material; and a standard rattler for paving brick. The equipment also includes a set of torsion clinometers reading to single minutes for use with the Riehlé torsion machine; a Henning extensometer for tension tests of metals, and two self-indicating dial extensometers with fittings which adapt them for use in testing steel or iron tension or compression specimens, and also for testing full-sized concrete beams and columns and for tests of wire. Four Berry strain gages are available for practical measurements of deformation of steel and concrete structures. The Martens mirror extensometer is also available. Knock-down forms are provided for the molding of large concrete beams and columns, and an Austin Cube Mixer is available for making concrete.

THE HIGHWAY LABORATORY. This laboratory is equipped with apparatus for making all the standard tests on non-bituminous and bituminous materials used in highway construction and maintenance.



THE HYDRAULIC LABORATORY



THE FUERTES ASTRONOMICAL OBSERVATORY

The section of the laboratory for testing non-bituminous materials such as gravel, rock, etc., is in the basement of Lincoln Hall. It is equipped with a Deval machine for the abrasion test, diamond core drill, diamond rock saw, grinding lap, Page impact machine for the toughness test, ball mill and briquette molding machine for preparing specimens for the cementation test, impact machine for the cementation tests, Dorry machine for the hardness test, rattler for testing paving brick, and complete sets of sieves, scales, etc. The section of the laboratory for testing bituminous materials is in a special fire-proof building used entirely for testing asphalts, tars, soils, etc. This portion of the laboratory is equipped with a gas drying oven, electric oven, Engler viscosimeter, molds, and float for float tests, centrifuge and other apparatus for soil tests, penetration machine, apparatus for the determination of melting point, New York State Board of Health oil tester, crucibles, centrifugal bitumen extractor, New York Testing Laboratory bitumen extractor, ductility machine, apparatus for distillation tests, balances, scales, sieves, thermometers, hydrometers, etc.

THE HYDRAULIC LABORATORY. In addition to the usual equipment for the ordinary laboratory experiments, the unique location and construction of this laboratory render practicable investigations requiring a steady gravity water supply for long periods using relatively large flows of water. The water supply is obtained from Fall Creek with a water shed of 126 square miles. Beebe Lake, a pond of about 20 acres, has been formed by the construction of a concrete dam 26 feet high with a spillway crest length of 130.5 feet. At one end of the dam there is an additional flood spillway 141.5 feet long. A rectangular canal 420 feet long and 16 feet wide is supplied from Beebe Lake through six headgates for controlling the amount of flow. The upper portion of the canal is 17.7 feet deep and the lower portion is 10 feet deep. In this canal are two sharp crested weirs 16 feet long over which discharges as large as 400 cubic feet a second may be passed. The lower portion of the large 16-foot canal, 350 feet long between weirs, is used for measurements with floats and current meters. Models of dams may be built in the canal and the flow over them investigated with precision. An electrically operated car spans this canal and is used for rating current meters and Pitot tubes and for experiments that require the towing of floating or submerged objects through still or running water at various speeds. By means of a gear system the speed of the cable, which moves the car, may be varied through a range from $\frac{1}{4}$ to 12 feet a second. There are also two parallel concrete flumes with water supplied from Beebe Lake independently of the large canal. These are 2 feet wide, $2\frac{1}{2}$ feet deep, and 90 feet long extending downstream from a short canal 7 feet wide, 3 feet deep, and 40 feet long near the dam, to a 2000 cubic foot concrete measuring tank. Outdoor work is usually suspended from December 1 to April 1 because of the freezing weather.

The laboratory building is built against the south cliff of Fall Creek Gorge and extends vertically about 70 feet, from the pool below Triphammer Falls to the top of the gorge. A short branch canal six feet wide is housed by the upper portion of the laboratory building and may be supplied directly from Beebe Lake by means of a 48-inch cast-iron pipe line with a short 30-inch branch at its lower end. A 30-inch valve controls the flow from the 48-inch pipe into the 6-foot canal. The 6-foot canal discharges either to waste into the pool below Triphammer Falls (a sheer drop of 60 feet) or into the upper end of a steel stand-pipe 6 feet in diameter and 60 feet high. A suitable mechanism causes an instantaneous diversion of discharges as large as 60 cubic feet a second from the waste flume into the standpipe or vice versa. The 6-foot standpipe is provided at the bottom with a 36-inch discharge valve operated by hydraulic pressure. There is a float gage indicating accurately the height of the water surface in the standpipe, when used as a measuring tank. An independent 10-inch pipe line from the 30-inch pipe to the bottom of the laboratory supplies most of the pieces of apparatus used for class work and research. The 6-foot standpipe may also be used as a supply tank, water being supplied to it from either the 6-foot canal or the 10-inch pipe line. In the laboratory building there is also a concrete flume, 2 feet wide, 4 feet deep, and 25 feet long. Flows up to 11 cubic feet a second can be passed through this and measured volumetrically. This flume is arranged conveniently for experiments on small weirs, low-head orifices, etc. There are numerous flanged connections from 4 to 12 inches in diameter for the attachment of apparatus. The hydraulic machinery equipment at present includes only types of the turbine, Pelton-Doble wheel, Fitz Overshot wheel, multi-stage centrifugal pump and hydraulic ram, all arranged for testing.

Although the laboratory needs extensive additions to its equipment, the utility of this plant has been demonstrated by calls from all parts of the country for the performance of experiments of great importance. Among these may be mentioned the valuable results obtained for the United States Deep Waterways Commission, the Michigan Lake Superior Power Company, the City of New York in connection with its water supply, and the United States Geological Survey.

HAROLD I. BELL RESEARCH FUND. In memory of her husband, Harold Ingersoll Bell, C.E., 1905, Mrs. Ellen Foster Bell in 1922 gave the University five thousand dollars to establish the Harold I. Bell Research Fund. The income of the fund is used to purchase equipment and supplies for research in the field of hydraulic engineering and related fields, under the direction of the School of Civil Engineering.

THE SANITARY LABORATORY. This laboratory provides facilities for the physical, chemical, bacteriological, and biological analyses of water and sewage, and for the performance of such other tests as will

acquaint the student with current practice as affecting the control and operation of the various types of water purification and sewage disposal plants. The equipment includes microscopes and the necessary accessories for complete bacteriological and biological examinations of water; an autoclave, a hot-air sterilizer, one $37\frac{1}{2}^{\circ}$ and two 20°C . incubators, a chemical balance, a United States Geological Survey turbidity rod and color standards; four experimental sand filters, fitted with loss of head gages, and providing for a total depth of sand and water of nine feet, for determining the rate and efficiency of operation of sand filters, as well as various types of sewage nozzles. The laboratory is well equipped with such glassware, reagents, accessories, and apparatus as are needed for making the chemical analyses of water and sewage effluents.

THE FUERTES ASTRONOMICAL OBSERVATORY is situated north of Beebe Lake. It contains a transit room with four piers, a clock vault, a photographic darkroom, an office, a computing room, a classroom, and a dome for the 12-inch equatorial telescope, in addition to a comparator room and two constant temperature rooms for geodetic laboratory work. Besides the Irving Porter Church Telescope, a very superior 12-inch equatorial, the equipment includes a Howard mean time astronomical clock, chronometers by Negus and Nardin, four chronographs, a Troughton and Simms transit, two Fauth prismatic transits with latitude levels, a Fauth zenith telescope, an altazimuth by Troughton and Simms, a 4-inch portable equatorial telescope, as well as globes, sextants, surveyor's transits, clocks, collimators, micrometers, a spectra measuring apparatus, spherometer, planetarium, level-trie, and various meteorological instruments.

THE GEODETIC LABORATORY is housed in the new observatory building. Facilities are provided for work along the various lines relating to geodesy and advanced surveying, including geodetic astronomy. The standards of length include: Invar tapes standardized at the U. S. Bureau of Standards; a steel meter bar of the International type which has been compared with the International Prototype Meter of the U. S. Bureau of Standards; a Rogers speculum metal decimeter and 4-inch scale, combined, accurately divided and compared; and a 4-meter bar for subsidiary measures. The laboratory equipment also includes a Mendenhall half-second pendulum apparatus for the determination of the acceleration of gravity—the standard type used by the U. S. Coast and Geodetic Survey; a Kew magnetometer, a dip circle, and a declinometer, for observation of terrestrial magnetism; a dividing engine by the Société Générale; precision thermometers by Tonnelot and Boudin standardized at the International Bureau in Paris; a small comparator for calibrating thermometers; and the usual auxiliary apparatus. A 100-foot tape comparator is located on the fourth floor of Lincoln Hall.

MECHANICIAN'S ROOM. This room is used in connection with the laboratories for the construction of special apparatus and instru-

ments and for the maintenance of the equipment. It is well supplied with tools and special machines for the purpose, and is in charge of a mechanician.

THE MUSEUMS AND DRAWING ROOMS of the School of Civil Engineering contain the following collections: (1) The Muret collection of models in descriptive geometry and stone cutting. (2) The DeLagrange general and special models in topography and geology. (3) The Schroeder models in descriptive geometry and stereotomy with over 50 brass and silk transformable models made in the college after the Olivier models. (4) The M. Grund collection of bridge and roof details, trusses, and masonry structures, such as right, oblique, and annular arches and domes, and several intricate models in stone cutting, supplemented by similar models by Schroeder and other makers. (5) A model railroad bridge of 25-foot span, one-fourth natural size, and a numerous collection of models of track details. (6) The Digeon collection of moveable dams, artificial harbors, and working models in hydraulic engineering. (7) Working models of water wheels, turbines, and other water engines. (8) Several large collections of European and American progress photographs of engineering work showing the progress of construction, and many other photographs, blue-prints, models, and diagrams. (9) A collection of typical geodetic and surveying instruments of historical interest, including a secondary base-line apparatus made under the direction of the United States Coast and Geodetic Survey, a pair of base-bars constructed in this college, solar and magnetic compasses, levels, transits, theodolites, omnimeters, tacheometers, sextants, telemeters, altimeters, hypsometers, odometers, meteorological instruments, etc., with a large number of auxiliary and special instruments such as planimeters, pantographs, elliptographs, calculating devices, and computing machines.

THE LABORATORIES OF MECHANICAL ENGINEERING

The Mechanical Engineering Laboratories and Work Shops comprise the following:

THE MATERIALS TESTING LABORATORY. This laboratory is equipped for tension and compression tests with an Olsen 3,000,000-lb. machine, a Riehlé 100,000-lb. machine, a 2,000,000-lb. Emery hydraulic machine, an Olsen 150,000-lb. three-screw machine, together with several other machines varying in capacity from 10,000 to 100,000 pounds. For transverse test there is a Riehlé machine of 200,000 pounds capacity and a Fairbanks machine of 10,000 pounds capacity. There are one Thurston autographic torsion machine, one Olsen torsion machine of 200,000 inch-pounds capacity, two Upton-Lewis fatigue testing machines, and an Amsler-Charpy-Izod impact testing machine. The equipment includes extensometers, a cathetometer, gas furnaces, tempering baths, and all other apparatus required for the determination of the physical qualities of engineering materials under tensile,

compressive, transverse, and torsional stress, and under different kinds of heat treatment.

THE STEAM LABORATORY. In this laboratory there is a 150-HP triple expansion Allis-Corliss engine so fitted up that it may be operated as a simple, compound, or triple expansion engine, condensing or non-condensing. There are also several smaller engines, including a Russell, a Harris-Corliss, a Payne, a Fitchburg uniflow, and a Troy steam engine. There are three surface condensers and one jet condenser which may be connected with these engines as desired. There are two 35-kw. horizontal Curtis turbines, and a 15-kw. De Laval turbine which drives electric generators and may be run condensing or non-condensing, and a Lee turbine driving a Goulds centrifugal pump. A two-stage Worthington air compressor driven by a Uniflow engine and one airbrake pump, together with meters, nozzles, and other instruments, may be used for routine tests. This part of the laboratory also has several fans that can be arranged and equipped for testing. The apparatus and instruments used for engine testing comprise about eighty indicators of different types, about seventy-five steam gauges, a number of calorimeters for determination of the quality of steam, speed counters, tachometers, planimeters, etc., besides a number of dynamometers of various kinds. The boiler section of this laboratory has one 150-HP Babcock and Wilcox water-tube boiler of the marine type, one 100-HP Babcock and Wilcox water-tube boiler of the standard type, both of which are fitted with internal superheaters, and an 80-HP Heine water-tube boiler. The auxiliary apparatus consists of a Cochrane open heater, a Wainwright closed heater, steam pumps, traps, injectors, etc. A full set of scales, measuring tanks, gauges, flue gas apparatus, separating and throttling calorimeters, pyrometers, etc., complete the boiler equipment.

THE GAS ENGINE LABORATORY. The equipment in this laboratory is chosen with a view to providing a great variety of types as to fuel used, governing, etc. It includes an 8-HP Fairbanks gasoline engine, an 8-HP Olds gasoline engine, a 6-HP Ingeco oil engine, a 6-HP and a 15-HP Hornsby-Akroyd oil engine, a 30-HP Westinghouse gas engine with gas producer, a 25-kw General Electric Co. gas motor set, and a 45-HP Diesel engine. High speed engines are represented by a variety of auto and airplane engines. The testing equipment includes a full set of indicators and a Midgley indicator. Dynamometers are represented by a 150-HP Sprague Electric, a 60-HP Diehl Electric, and two Wheeler hydraulic, good for 100-HP at 4000 r.p.m.

THE HYDRAULIC LABORATORY. This Laboratory contains the following machines and apparatus: a 6-inch single-stage De Laval centrifugal pump; a 2½-inch two-stage Worthington centrifugal pump; a 12-inch Doble water wheel; a 10-inch Trump turbine; several Pelton wheels and hydraulic rams; sets of weir boxes with various types of weirs and nozzles for the determination of coefficients of discharge; various types of water meters and other apparatus for measur-

ing the flow of water, such as Pitot tubes, Venturi meters, current meters, etc.

THE OIL TESTING LABORATORY. This laboratory contains a Cornell oil-testing machine, a Thurston standard railway-testing machine, and several smaller Thurston machines. The rest of the equipment consists of several viscosimeters of different types, flash and burning test apparatus, together with the necessary hydrometers and thermometers.

THE REFRIGERATION LABORATORY. For the study of refrigeration the mechanical laboratory possesses a 2-ton York absorption machine and a very complete York refrigerating compression plant having a capacity of 15 tons of ice.

THE CEMENT LABORATORY. This laboratory not only contains the ordinary apparatus for the testing of cement, and concrete but in addition is equipped with crushing and grinding machinery and a small vertical kiln for making investigations on the manufacture of cement from raw material.

THE FUEL TESTING LABORATORY. This laboratory contains a complete equipment of fuel calorimeters and other apparatus needed for the determination of the composition and calorific value of fuel, whether gaseous, liquid, or solid.

The Work Shops of the Sibley School of Mechanical Engineering comprise the following units:

THE FOUNDRY occupies floor space of about 4,800 square feet, and has an equipment for the production of iron and composition castings. The methods of producing duplicate work are demonstrated by molding machines of different types selected to illustrate the production of castings of various kinds at lowest labor cost.

THE PATTERN SHOP occupies the top floor of Rand Hall with floor space of 8,440 square feet. The work given the students in this department includes the use of hand and power operated tools under instructors who are skilled in the trade of pattern making.

THE MACHINE SHOP is located on the ground floor of Rand Hall with the same floor area as the pattern shop. It is equipped with an electric traveling crane and representative modern machine tools selected with a view to demonstrating manufacturing methods. A part of the work-shop equipment is installed to illustrate the latest practice in production with specialized labor-saving machinery. The students are not expected to become skilled operators of the machines of this class, but to acquire a general knowledge of their possibilities in the kinds of work to which they are adapted. The equipment is arranged in groups, each under the charge of an instructor who has made a special study of the machinery in his group.

THE INTRODUCTORY ENGINEERING LABORATORY contains the necessary equipment to demonstrate the principal operations in the forge shop, forging (hand and machine), welding, soldering, brazing,

etc. The equipment also includes numerous examples of common engineering appliances such as valves, traps, gages, etc., and an example of a simple steam engine, a gas engine, and a steam pump. There is also a complete equipment to teach the principles of oxy-acetylene and electric welding.

THE LABORATORIES OF ELECTRICAL ENGINEERING

The equipment of the laboratories of the School of Electrical Engineering is distributed as follows:

THE LECTURE EQUIPMENT. The lecture room is exceptionally well provided with display apparatus and with apparatus especially designed for demonstration purposes. All types of electrical machinery may be operated on the lecture table and a 60,000 volt transformer is provided for insulator testing.

THE DYNAMO LABORATORIES. These laboratories are provided with a great variety of standard and special machines for both direct and alternating current work, along with the necessary meters and control equipment. Among the special pieces of equipment are street car trucks with motor and also a complete outfit for exhibiting in actual operation the multiple unit system of electric car control. The laboratory has recently been provided with a large number of new machines, including an alternating-current generator, which may be connected as a two-phase, three-phase or six-phase machine; a modern rotary converter provided with brush-lifting device; a squirrel-cage and phase-wound induction motor; a sine-wave generating set; also a constant current transformer and a high-voltage testing transformer with a kenotron tube from which 100,000 volts d. c. may be obtained.

THE STANDARDIZING LABORATORY. This laboratory is equipped with the necessary potentiometers, galvanometers and standards for the calibration of instruments, and the testing of materials used in electrical work. There is also a G. E. oscillograph for work on wave form.

THE ELECTRICAL COMMUNICATION LABORATORY. This laboratory is well equipped with apparatus to illustrate present day methods of electrical communication. The wire telegraph section includes various types of commercial apparatus illustrative of simple, duplex, quadruplex, and repeater circuits. The telephone section includes representative telephone equipment of various types. A complete machine switching exchange is installed in the laboratory. The radio section comprises various transmitting and receiving sets including spark telegraph, continuous wave telegraph, and radio telephone apparatus. The vacuum tube equipment is unusually complete and includes thorough facilities for the manufacture and exhaustion of experimental tubes of various designs.

LIBRARIES: GENERAL AND DEPARTMENTAL

The Cornell University Library comprises about 750,000 volumes, being one of the largest collections of its kind in the country. Most of the books are in a general library building.

For convenience of reference, the University Library maintains DEPARTMENT LIBRARIES—in Lincoln Hall for the School of Civil Engineering, in Sibley Dome for the School of Mechanical Engineering, and in Franklin Hall for the School of Electrical Engineering. These libraries are under the supervision of the authorities of the several schools. They contain the standard reference and text books and the current files of the important engineering periodicals.

Of special importance is the KUICHLING MEMORIAL LIBRARY, of the School of Civil Engineering, a collection of about fifteen hundred books and pamphlets on hydraulic and municipal engineering, formerly the professional library of the late Emil Kuichling, A.B., C.E., of Rochester, N. Y. It was given to the school in 1919 by Mrs. Sarah L. Kuichling, with an endowment of one thousand dollars, the income of which is to be used to extend the collection and to maintain it as a separate library.

The library in Franklin Hall for the School of Electrical Engineering is known as the ALEXANDER GRAY MEMORIAL LIBRARY. The nucleus of the library was the personal library of the late Alexander Gray, for some years Professor of Electrical Engineering at Cornell University and executive head of the School of Electrical Engineering. The McGraw Hill Book Company bought this collection and gave it to Cornell University for the use of the School of Electrical Engineering.

SCHOLARSHIPS: PRIZES: LOANS

The University has no means of remitting the usual tuition charges in any instance except to students of certain classes which are exempted by statute of New York State or the Board of Trustees. Those classes are defined in the General Circular of Information. There are no undergraduate free-tuition scholarships available to residents of the State of New York except the Padgham Scholarship (which is described below) and the Cornell Free-Tuition Scholarships, which are awarded annually by the State Commissioner of Education after a competitive examination; and there are none available to non-residents of the State.

More particular information is given about undergraduate scholarships and loans in the General Circular of Information; about graduate scholarships and fellowships in the Announcement of the Graduate School; and about prizes in a pamphlet entitled Prize Competitions. Any of these publications may be obtained from the Secretary of the University.

FELLOWSHIPS AND GRADUATE SCHOLARSHIPS

Fellowships and graduate scholarships are awarded by the Graduate School. Students interested in them should consult the Announcement of the Graduate School. Blank forms of application are to be obtained from the Dean of the Graduate School, to whom correspondence should be addressed.

OPEN TO GRADUATE STUDENTS IN THE SCHOOL OF CIVIL ENGINEERING

THE MCGRAW FELLOWSHIP: \$400 a year and free tuition; offered to graduates of the School of Civil Engineering and similar schools of equivalent rank.

A GRADUATE SCHOLARSHIP: \$200 a year and free tuition; offered under similar conditions.

THE ELON HUNTINGTON HOOKER FELLOWSHIP IN HYDRAULICS: \$510 a year; offered for research in experimental hydraulics in Europe or America; open to graduates of the School of Civil Engineering and similar schools of equivalent rank. This fellowship was founded in 1919 by E. H. Hooker, a graduate of the School of Civil Engineering of the class of 1894. (*Not available in 1927-28.*)

OPEN TO GRADUATE STUDENTS IN THE SCHOOL OF MECHANICAL ENGINEERING

THE SIBLEY FELLOWSHIP: \$400 a year and free tuition.

THE EDGAR J. MEYER MEMORIAL FELLOWSHIP: \$400 a year and free tuition.

OPEN TO GRADUATE STUDENTS IN THE SCHOOL OF ELECTRICAL ENGINEERING

THE CHARLES BULL EARLE MEMORIAL FELLOWSHIP: \$400 a year and free tuition.

UNDERGRADUATE SCHOLARSHIPS

THE CORNELL FREE-TUITION SCHOLARSHIPS: Open only to residents of the State of New York; awarded by the State Commissioner of Education. For particulars, see the General Circular of Information.

THE UNIVERSITY UNDERGRADUATE SCHOLARSHIPS: Eighteen in number, each paying \$200 a year for two years; awarded by the University each year to members of the incoming freshman class. For particulars, see the General Circular of Information.

THE EUDORUS C. KENNEY SCHOLARSHIPS: Two in number, each paying \$250 a year for four years; open annually to *bona fide* residents of the town of Truxton, Cortland County, New York; in case of a vacancy in any scholarship the value of the scholarship may be awarded by the University Faculty's Committee on Scholarships in such manner as it may deem best. For particulars, see the General Circular of Information.

UNDERGRADUATE SCHOLARSHIPS IN ENGINEERING

THE JOHN McMULLEN SCHOLARSHIPS: Open to undergraduates in Civil, Mechanical, or Electrical Engineering. These scholarships were founded by a bequest of John McMullen of Norwalk, Conn., to Cornell University "for the purpose of creating and maintaining free scholarship or scholarships for the education of young men as engineers, the details as to the amounts of said scholarships and the qualifications of the beneficiaries to be left to said institution to determine, said scholarships to be known as the John McMullen Scholarships." With the avails of this bequest the Board of Trustees established nine scholarships of an annual value of \$500 each and divided them among the three schools of the College of Engineering. The President of the University awards the scholarships to candidates selected by a committee of each school and approved by the Faculty of the College. Each committee of selection consists of the Dean of the College, the Director of the School, and one member of the Faculty.

THE FRANK WILLIAM PADGHAM SCHOLARSHIP: Open to undergraduates in Mechanical or Electrical Engineering. This scholarship, founded in 1892 by Amos Padgham of Syracuse, New York, in memory of his son Frank William Padgham, a graduate of Sibley College of the class of 1888, entitles the holder to free tuition and fees in the regular course 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. The Frank William Padgham Scholarship is awarded to the candidate who has had his preparatory education wholly or in part in the public schools of Syracuse, New York, and who, having been admitted to the regular course in either of the Schools named, passes the best examination in a competitive examination on the following studies selected from those that may be offered for admission to the College of Engineering: (1) Solid Geometry, Advanced Algebra, Plane Trigonometry; (2) Third Year German; (3) Third Year French; (4) English. Of these subjects the candidate must take three, including mathematics. The examination for the Padgham Scholarship is held at the same time as the University Undergraduate Scholarship examinations; it is, however, a special examination and the candidate must declare his intention to enter the Padgham Scholarship examination and state his qualifications therefor to the Registrar, who will issue the usual permit to enter the examination. In case no one qualifies for this scholarship in the foregoing manner, the Faculties of the Schools may, with certain restrictions, recommend the awarding of the scholarship to some worthy applicant, preferably one from Syracuse. Upon request, detailed information regarding the examinations and the awarding of this scholarship will be furnished by the Dean of the College of Engineering or by the Registrar of Cornell University.

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, under the following rule: "Scholarships arising out of this bequest shall be awarded by a committee consisting of the President of the University, the Dean of the College of Engineering, and one other person chosen by them; and in making such awards the following attributes shall be given the weight indicated; scholarship, evidenced by written examination, 30 per cent; character, in the broadest sense, 30 per cent; probable usefulness in the world at large, 30 per cent; proficiency in mechanic arts, 10 per cent; it being understood that these scholarships are intended to assist such students as are in need of financial aid to complete their courses."

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. The award is determined by a committee approved by the President of the University from the Faculty of the College of Engineering, and is reported to the University Faculty for the purpose of record.

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 \$50 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.

THE JUDSON N. SMITH SCHOLARSHIP: Open to upperclassmen in the School of Civil Engineering; pays \$200 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 before May 1.

PRIZES IN THE COLLEGE OF ENGINEERING

THE FUERTES MEDALS: Established by the late Professor E. A. Fuertes; two gold medals, each of the value of one-half the amount of income provided by the endowment fund. One of these medals is awarded annually by the University 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 medal 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. Candidates are recommended to the University Faculty by the School of Civil Engineering annually.

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 \$125, one of \$35, and one of \$20, are awarded annually to members of the junior and senior classes in the Colleges of Engineering and Architecture, for proficiency in public speaking. The conditions of the award are as follows: (1) The competition shall be open to seniors and juniors in the Colleges of Engineering and Architecture. (2) The competition shall be held on the evening of the third Friday in April. (3) A preliminary contest shall be held before a com-

mittee of four, representing each of the three Schools of Engineering and the College of Architecture, at such time and place as this committee may decide. Each contestant in this preliminary contest shall (a) submit a letter of not more than 400 words outlining the purpose and argument of his proposed address; (b) speak from a platform, without notes, for not more than five minutes, either on the subject of the proposed address or on some other subject, at the contestant's option. From the contestants at this preliminary contest not more than seven candidates shall be selected by the committee for the final contest. (4) The speeches delivered in the competition must be on technical subjects original in character. Any technical subject may be chosen by the competitor that may seem to him best suited to furnish an opportunity for persuasive argument. Questions relating to his profession that would naturally come before semi-technical or non-technical commissions, boards of directors, and conventions are of peculiar fitness. In making the award, both the character of the argument and the manner of presentation shall be considered. Each speech shall be limited to fifteen minutes. (5) The delivery must be without notes, but illustrative material such as diagrams, plans, models, or lantern slides may be used. (6) The judges of the final contest shall be six in number—one selected by the College of Architecture, one selected by each of the three Schools of the College of Engineering, one selected by the Department of Oratory and one selected by the President of the University from men prominent in business life in the city of Ithaca. (7) A student who has already received the first prize is not eligible for subsequent competition.

THE CHARLES LEE CRANDALL PRIZES: Founded in 1916 by alumni of the School of Civil Engineering; a first prize of \$100, and a second prize of about \$25 or the balance of the yearly income from the fund. They are awarded each year, by a committee appointed by the Director of the School of Civil Engineering, for the best paper written by a senior or junior in that school on a suitable subject, provided both the substance and the written form of the paper submitted show real merit. If, in any year, no papers of sufficient merit are presented for these prizes, the income from the fund for that year is added to the principal and the additional income used from time to time to increase the amount of the prizes. The fund was established to provide prizes 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 15 of each year.

THE SIBLEY PRIZES IN MECHANIC ARTS: Awarded to undergraduates in Mechanical or Electrical Engineering. Under a gift of the late Hiram Sibley, made in 1884, the sum of one hundred dollars is awarded annually in five 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 required in the course and done in the schools named. The prizes are \$30, \$25, \$20, \$15, and \$10.

AMERICAN BUREAU OF SHIPPING PRIZE: The American Bureau of Shipping (American "Lloyds") has placed at the disposal of the Department of Naval Architecture and Marine Engineering an annual cash prize of one hundred dollars, to be awarded to the student taking the Senior Option in Naval Architecture and Marine Engineering, who in the judgment of the instructors of the department has shown the greatest ability and promise.

In awarding this prize, scholastic ability will be given due weight, but in addition other personal qualities, which a good engineer must possess to a greater or less extent, will be given proper consideration in making the award.

LOAN FUNDS: AWARDS: OTHER PECUNIARY AIDS

Cornell University has two general funds that are used to make loans to students. They are (1) the F. W. GUTEAU STUDENT LOAN FUND, established by the will of Frederick William Guiteau and augmented by the will of his sister,

Mrs. Nancy Guiteau Howe, both of Irvington-on-Hudson, the income of which fund is by the terms of the bequest available for loans to young men; and (2) **THE WOMEN STUDENTS' LOAN FUND**, consisting of a former student loan fund, increased in 1913 by \$7,000 assigned to this fund by the late President Andrew D. White from funds placed at his disposal by the late Trustee Andrew Carnegie.

Both these funds are administered for the Trustees of the University by a standing committee. Applications for loans are received by the Secretary of the University for submission to that committee. The benefits of these funds are reserved to undergraduate students who have been in attendance at Cornell University for at least one year, and preference is given to seniors and juniors. Account is taken of the applicant's character, scholastic record, and need of financial assistance. Loans are made ordinarily to assist students who would otherwise be unable to meet the tuition charges. The student must not regard the loan fund as a normal or assured resource. No student should enter upon a year at the University with the expectation of paying a part of the year's expenses with money yet to be borrowed. The use of the loan fund is a privilege reserved to the industrious student of proved worth and earning power whose means are so nearly exhausted and whose training is so nearly completed as to warrant going into debt in order to complete the training without delay. Money borrowed from either of the funds is to be repaid to the fund with interest at five per cent per annum.

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 ALAN PARK TOMS AWARD was founded in 1924 by Dr. and Mrs. S. W. S. Toms in memory of their son, Alan Park Toms, M.E., 1923, who lost his life in an untimely manner while practicing his profession. The value of the award is about \$250 annually and is available only for undergraduates in the Sibley School of Mechanical Engineering. Awards from this fund are made on the recommendation of the Dean of the College and the Director of the Sibley School of Mechanical 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 Sibley School of Mechanical 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. This fund is administered for the Trustees by the University's standing committee on loans, and applications are received by the Secretary of the University for submission to that committee.

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., 1909, who lost his life in the performance of his duties as a civil engineer, 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 by the Treasurer of the University upon the recommendation of the Director of the school, preference being given to underclassmen.

The Cornell Clubs of **BUFFALO** and **ROCHESTER** have each made provision for the loan of a small sum of money each year to an undergraduate student coming from the club's own neighborhood.

ADMISSION TO THE COLLEGE

All correspondence concerning admission to the College of Engineering should be addressed to The Registrar, 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 in the Registrar's hands as early as possible, in no case later than the first day of September. A prospective applicant should read carefully the paragraph headed Rules Governing Admission, a page or so further on. He should also read the General Circular of Information, for which application should be addressed to The Secretary, Cornell University, Ithaca, N. Y.

ADMISSION TO THE FRESHMAN CLASS

THE REQUIREMENTS FOR ENTRANCE

For admission to the freshman class in the regular four-year course, the applicant must offer fifteen specific units of entrance subjects, as follows: English, 3 units; History, 1 unit; Elementary Algebra, 1 unit; Intermediate Algebra, $\frac{1}{2}$ unit; Advanced Algebra, $\frac{1}{2}$ unit; Plane Geometry, 1 unit; Solid Geometry, $\frac{1}{2}$ unit; Plane Trigonometry, $\frac{1}{2}$ unit; foreign language equivalent to 3 units in either Greek, Latin, German, French, Spanish, or Italian, or 2 units in each of two of them; and in other entrance subjects, elected by the applicant, 3 or 4 units. Applicants offering fifteen units which do not differ materially from the specific list may present their credentials for consideration.

It is recommended that French or German be offered to satisfy the language requirement for the reason that a knowledge of either of these tongues gives the student immediate access to a large part of the standard literature in the theory and practice of engineering.

The student preparing to enter the college is strongly advised to offer at least three of his elective units in Language and History. He can very well defer his introduction to Physics and Chemistry until after his admission to the college. But his work in the four-year course in engineering will necessarily be almost entirely scientific or technical and will leave him little opportunity for instruction in other fields. He will do well, therefore, during 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, if they can afford the additional time and expense involved.

Students who have had some practical experience in engineering usually gain more than others from the courses offered by the College of Engineering; hence it is recommended that prospective students spend at least one summer vacation in practical work in connection with some kind of engineering.

Students entering the courses in engineering will find it of advantage to have had some instruction in free-hand sketching.

The applicant must be at least sixteen years of age. Under special circumstances the committee on admissions will admit students who lack not more than one-half unit in Advanced Mathematics (Advanced Algebra, Solid Geometry, Plane Trigonometry), if fifteen units are offered and all other requirements are met. Such students may so arrange the course as to graduate in four years plus attendance in one Summer Session. More detailed information about courses requiring more than four years for graduation will be furnished upon application to the Secretary of the College of Engineering.

SUBJECTS THAT MAY BE OFFERED FOR ENTRANCE

The subjects that may be offered for admission to the College of Engineering are named in the following list. The figure in parenthesis opposite the name of each subject indicates its value expressed in units and shows the maximum and minimum amount of credit allowed in that subject. A unit represents five prepared recitations a week for one year of study. Two hours of laboratory work are counted the equivalent of one hour of prepared recitation, but in Drawing or Manual Training 300 hours of actual work are required for one unit. If an applicant counts Biology (1) he may not also offer Botany ($\frac{1}{2}$) or Zoology ($\frac{1}{2}$).

1a. English 1	(1 $\frac{1}{2}$)	7c. Third Year Italian	(1)
1b. English 2	(1 $\frac{1}{2}$)	8a. Ancient History	($\frac{1}{2}$ -1)
1c. English (elective)	(1)	8b. Modern History	($\frac{1}{2}$ -1)
2a. First Year Greek	(1)	8c. American History, Civics	($\frac{1}{2}$ -1)
2b. Second Year Greek	(1)	8d. English History	($\frac{1}{2}$ -1)
2c. Third Year Greek	(1)	9a. Elementary Algebra	(1)
3a. First Year Latin	(1)	9b. Intermed. Algebra	($\frac{1}{2}$)
3b. Second Year Latin	(1)	9c. Advanced Algebra	($\frac{1}{2}$)
3c. Third Year Latin	(1)	9d. Plane Geometry	(1)
3d. Fourth Year Latin	(1)	9e. Solid Geometry	($\frac{1}{2}$)
4a. First Year German	(1)	9f. Plane Trigonometry	($\frac{1}{2}$)
4b. Second Year German	(1)	9g. Spherical Trigonometry	($\frac{1}{2}$)
4c. Third Year German	(1)	10. Physics	(1)
4d. Fourth Year German	(1)	11. Chemistry	(1)
5a. First Year French	(1)	12. Physical Geography	($\frac{1}{2}$ -1)
5b. Second Year French	(1)	13. Biology	(1)
5c. Third Year French	(1)	14. Botany	($\frac{1}{2}$ -1)
5d. Fourth Year French	(1)	14a. Zoology	($\frac{1}{2}$ -1)
6a. First Year Spanish	(1)	15. Bookkeeping	($\frac{1}{2}$ -1)
6b. Second Year Spanish	(1)	16. Agriculture	($\frac{1}{2}$ -1)
6c. Third Year Spanish	(1)	17. Drawing	($\frac{1}{2}$ -1)
6d. Fourth Year Spanish	(1)	18. Manual Training	($\frac{1}{2}$ -1)
7a. First Year Italian	(1)	19. Any high school subject or subjects not already used	($\frac{1}{2}$ -1)
7b. Second Year Italian	(1)		

WAYS OF OBTAINING ENTRANCE CREDIT

There are four ways in which credit for entrance subjects may be obtained. They are:

1. By passing the required Cornell University entrance examinations held in September in Ithaca and New York City, and in January in Ithaca.
2. By passing the College Entrance Examination Board examinations (not comprehensive except for English, Latin, French, German, and Spanish) held in June in various places. Address the Secretary of the College Entrance Examination Board, 431 West 117th St., New York City.
3. By passing the Regents' examinations (for students who have prepared in New York State).
4. By presenting an acceptable school certificate.

RULES GOVERNING ADMISSION

Besides satisfying the entrance requirements, candidates for admission must comply with the following rules:

1. Every candidate for admission to an undergraduate course must deposit twenty-five dollars with the Treasurer, not later than August 1 if he is to be admitted in September, or not later than January 1 if he is to be admitted in February. A check, draft, or order should be payable to Cornell University and should be sent to The Treasurer, Cornell University.

If the candidate matriculates, the deposit will be credited to his account, \$10 for the matriculation fee and \$15 as a guaranty fund, which every undergraduate student is required to maintain and which is to be refunded upon his graduation or permanent withdrawal, less any indebtedness to the University.

If the application is withdrawn before the due date (August 1 or January 1, as the case may be) the deposit will be refunded in full; if it is withdrawn within the month of the due date (August or January) \$10 will be charged to cover accrued expenses and \$15 will be refunded; after that month no refund will be made. If admission is denied a candidate who has complied with all these rules his deposit will be refunded in full at any time.

2. Every candidate for matriculation must submit to the Registrar a satisfactory certificate of vaccination against smallpox, not later than August 1 if he is to be admitted in September, or not later than January 1 if he is to be admitted in February. It will be accepted as satisfactory only if it certifies that within the last five years a successful vaccination has been performed or three unsuccessful attempts at vaccination have been made.

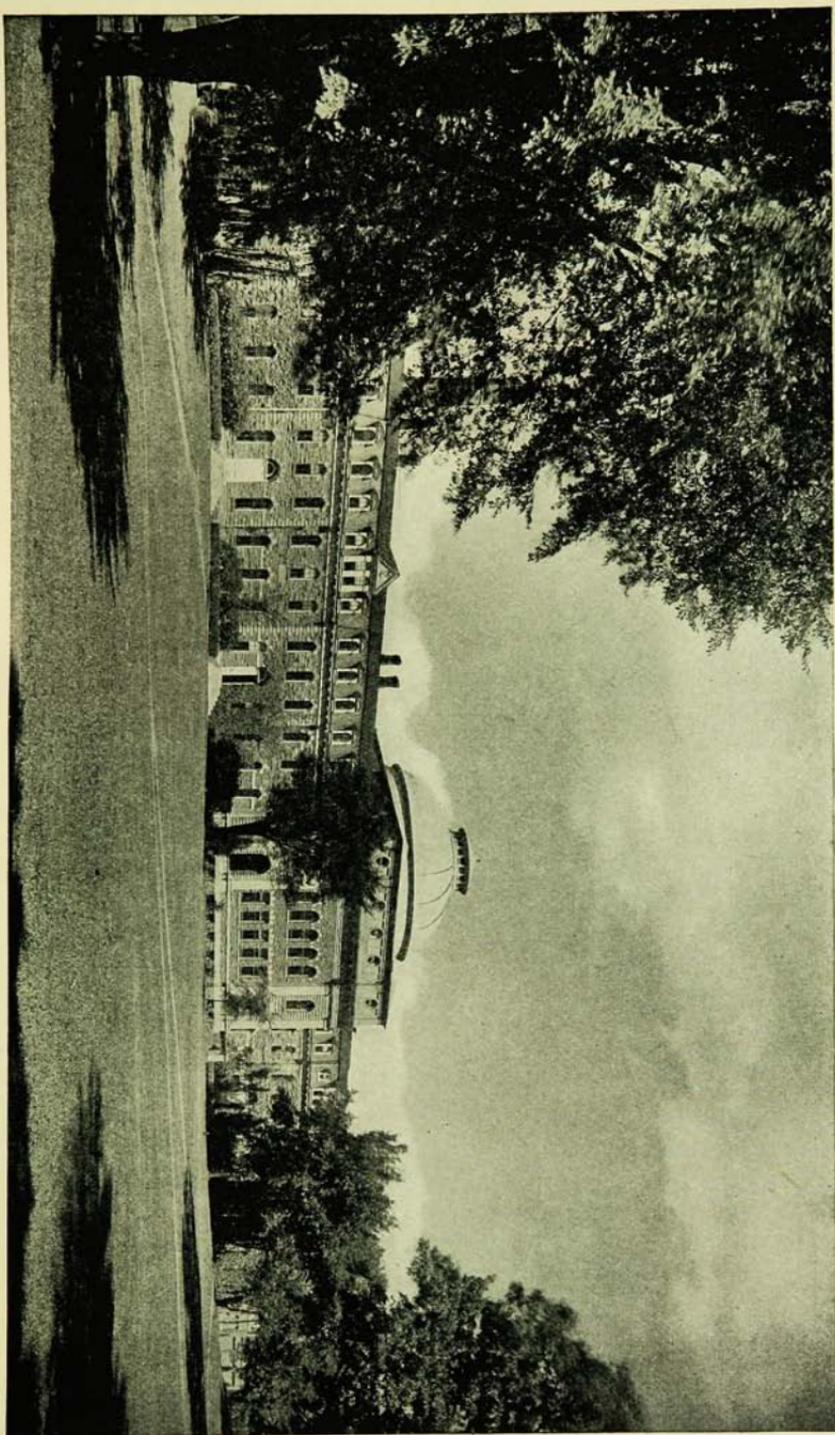
3. Every candidate for admission to an undergraduate course must file with his application at the Registrar's office either a certificate of good moral character or, if he has attended some other college or university without graduating from it, a certificate of honorable dismissal from it.

A NECESSARY PRECAUTION

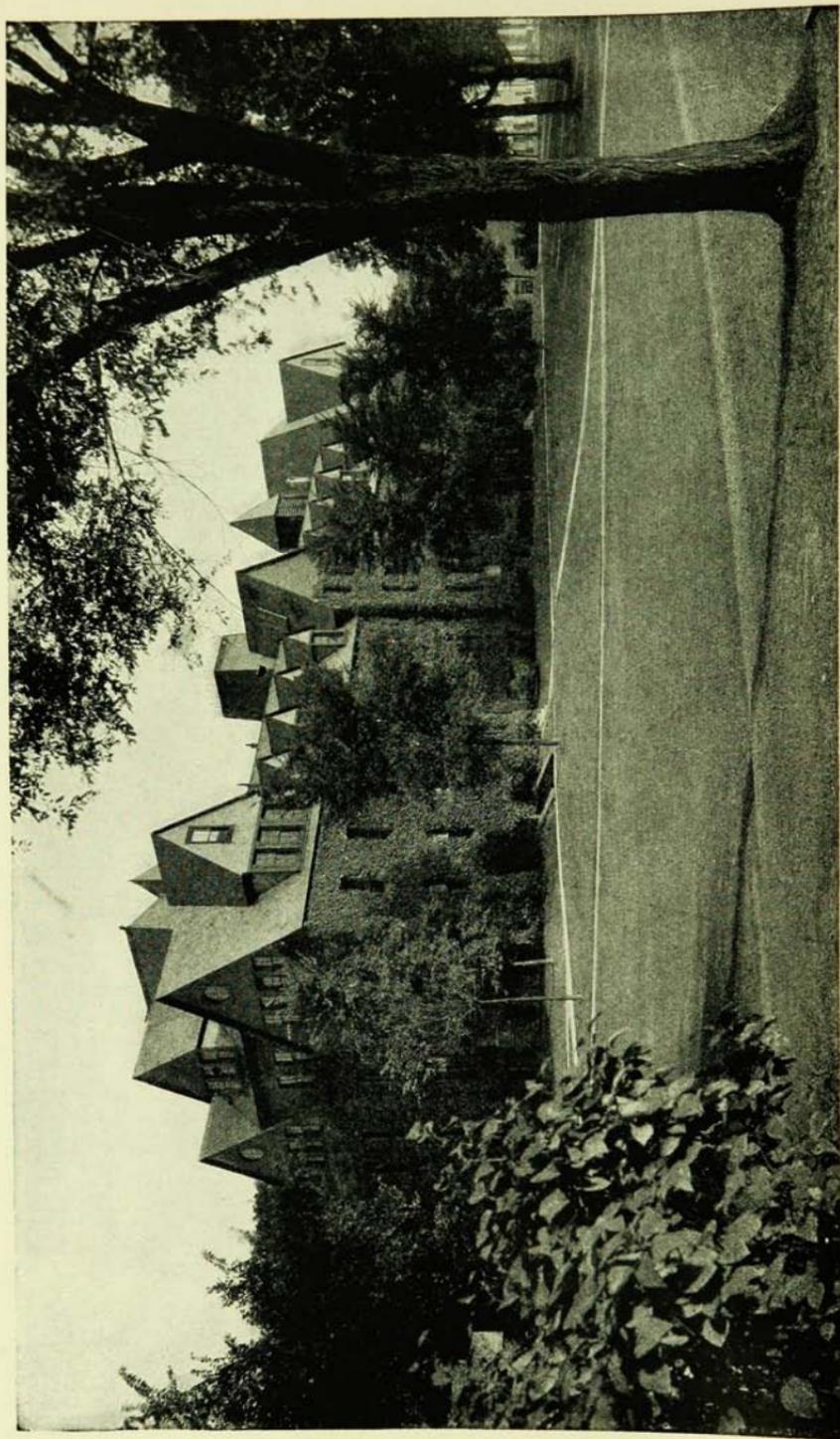
Before coming to the University, the student should consult an oculist and have any defect of vision corrected. Unless he does so, he may begin his work under a disadvantage and run the risk of failure. The large amount of close work that is required in reading and drafting puts a strain on farsighted or otherwise imperfect eyes. Such a weakness, unless discovered and remedied before the student begins his work, may delay his progress and impair his health.

ADMISSION AS A GRADUATE STUDENT

Graduates of this college or of other colleges may enter the Graduate School of Cornell University and pursue work in the College of Engineering. Such a student may enter either as a candidate for a degree (M.C.E., M.M.E., M.E.E., M.S., or Ph.D.) or not, according to the character of his previous training. A prospective student should consult the Announcement of the Graduate School and apply to the Dean of the Graduate School. See also page 36.



THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING



LINCOLN HALL
The Main Building of the School of Civil Engineering

ADMISSION TO THE FIVE-YEAR COURSE

For admission to this course, the entrance requirements are those of the four-year course. The schedule requires the student to pursue the regular engineering work for two or three years, spending more time on the advanced engineering work, and adding the equivalent of about one year of liberal arts work. A definite schedule for such a course has so far been laid down only by the Sibley School of Mechanical Engineering (see p. 67) but similar arrangements can be made in the schools of Civil and Electrical Engineering. The degrees of C.E., M.E., or E.E. are conferred for these courses.

ADMISSION TO THE SIX-YEAR COURSE

For admission to the six-year course, leading to the degrees of A.B. and C.E., or A.B. and M.E., or A.B. and E.E., the requirements are those of 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 C.E., M.E., or E.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 and to the Dean of the College of Arts and Sciences.

ADMISSION FROM ANOTHER COLLEGE

A student who has attended another college may be admitted to advanced standing, provided he is in good standing in the college from which he comes and provided also that he meets the full entrance requirements of the College of Engineering. An applicant for admission in this way should file by mail with the Registrar of Cornell University, on an official blank to be obtained from him, a formal application for admission stating definitely the branch of engineering desired, along with an official certificate, from the college or university already attended, of his honorable dismissal; his entrance credits in detail; his terms of attendance and the amount of work that he has completed; a detailed statement of the courses pursued; and the drawings and reports for which credit has been secured. He should also send a catalogue of the institution, writing on it his name and marking the entrance requirements that he has satisfied and each subject that he has completed.

ADMISSION AT THE BEGINNING OF THE SECOND TERM

Certificates and credentials for admission at midyear should be in the hands of the Registrar not later than January 15. Admission at midyear is possible only under the following conditions. (a) A student must meet the regular entrance requirements. (b) If a student enters as a freshman without advanced college credit the time required for his graduation may be more than four years, and may require attendance during one or more Summer Sessions at Cornell University. On application made to the Registrar on or before January 15 in any year, special entrance examinations in any of the University entrance subjects may be arranged for students who must be examined in one or more subjects to complete their requirements for admission at midyear. These special entrance examinations are held in Ithaca on or about January 25 of each year.

SPECIAL STUDENTS

The College of Engineering admits special students, that is to say, applicants who have not fifteen acceptable units of entrance credit, only under exceptional circumstances. They must have had equivalent training satisfactory to the committee on admissions.

TUITION AND OTHER FEES

Information about the amount and the manner of payments to be made by a student to the University should be looked for in the General Circular of Information.

Tuition. The University charges students registered in the College of Engineering tuition at the rate of three hundred dollars a year, payable \$160 at the beginning of the first term and \$140 at the beginning of the second term.

A student enrolled only for the second term of the academic year is required to pay tuition at the rate of the first term. The installment for any term becomes a liability at once when the student registers.

A Matriculation Fee of \$10 is required of every student upon entrance into 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 need not make an additional payment of the matriculation fee, because the Treasurer will draw on the deposit for this fee.

A Laboratory Fee is required of all students registered in the College of Engineering, one-half of the fee at the beginning of each term, at the following rates: Freshmen in the College of Engineering, \$25 a year; sophomores, juniors, and seniors in Mechanical Engineering and Electrical Engineering, \$25 a year; sophomores, juniors, and seniors in Civil Engineering, \$8 a year. Students taking a five-year course in the college pay this fee for only eight terms. Students in the College of Engineering who take laboratory courses in other colleges of the University are required to pay to the Treasurer a fee or deposit for materials used in the work. Students not registered in the College of Engineering but taking work in the shops are required to pay a laboratory fee at the rate of \$3.50 a record hour. (A student who has taken, while in a non-engineering college of the University, part of the work required for an engineering degree shall, before receiving such technical degree, be required to pay to the University Treasurer such amount as would have been necessary if he had taken all such work while registered in the College of Engineering.)

An Infirmary Fee of \$5 a term is required, at the beginning of each term, of every student. For a statement of the privileges given in return for this fee, see the General Circular of Information.

A Willard Straight Hall Membership Fee of \$4 a term is required, at the beginning of each term, of every undergraduate student. Its payment entitles the student to a share in the common privileges afforded by the operation of Willard Straight Hall, subject to regulations approved by the Board of Managers of the Hall. Membership on the same terms is open to students in the Graduate School upon payment of a fee of \$8 a year at the office in Willard Straight Hall.

A Locker Fee of \$2 a term is required, at the beginning of each term, of every male undergraduate student. A locker fee of \$1 a term is required of every woman in the freshman and sophomore classes. Payment of this fee entitles the student to the use of the Gymnasium and the University Playgrounds, and to the use of a locker, together with the use of bathing facilities and towels, in the Gymnasium, or in the New York State Drill Hall, or in the Schoellkopf Memorial Building.

A Graduation Fee is required, at least ten days before the degree is to be conferred, of every candidate for a degree. For a first or baccalaureate degree the fee is \$10; for an advanced degree it is \$20. The fee will be returned if the degree is not conferred.

Tuition and other fees become due when the student registers. The University allows twenty days of grace after the last registration day of each term. The last day of grace is generally printed on the registration coupon which the student is required to present at the Treasurer's office. Any student who fails to pay his tuition charges, other fees, and other indebtedness to the University, or who, if

entitled to free tuition, fails to claim it at the Treasurer's office and to pay his fees and other indebtedness, within the prescribed period of grace, is hereby dropped from the University unless the Treasurer has granted him an extension of time to complete payment. For the conditions and terms of any such extension, see the General Circular of Information.

A tuition fee or other fee may be changed by the Trustees at any time without previous notice.

CHARGES FOR MINOR DELINQUENCIES

Every student is held responsible for any injury done by him to any of the University's property.

Assessments are levied upon the student in certain circumstances, under the following rules of the University:

A student desiring to be reinstated after being dropped from the University for delinquency in scholarship or in conduct shall first pay a fee of \$25.

A matriculated student desiring to register after the close of registration day shall first pay a fee of \$5. [Students in the Graduate School are excepted.]

A student desiring to file his registration of studies after the date set by his college for filing the same shall first pay a fee of \$2.

A student desiring to take an examination or other test for the removal of a term condition (including the making up of a mark of "absent" or "incomplete") shall first pay a fee of \$2 for each examination or other test.

A student desiring to make an appointment for the required medical examination or conference after twenty days from the last registration day of the term shall first pay a fee of \$2.

For reasons satisfactory to the proper authority any of the above-mentioned assessments (except that levied for examination or other test to remove a condition) may be waived in any individual case if the student's failure to comply with the regulation was due to ill health or to other reasons beyond his control.

COURSES OF STUDY IN THE COLLEGE

THE REGULAR FOUR-YEAR COURSES

Regular four-year courses are offered in the schools of the college, leading to the degrees of Civil Engineer, Mechanical Engineer, and Electrical Engineer.

The first year of all the courses is common, except for the second term's work in Drawing, so that no student need make his choice of Civil Engineering, Mechanical Engineering, or Electrical Engineering until near the end of the first term of residence. The curriculum of the first year is given below, under the head of The Freshman Year.

The last three years of each regular four-year course are spent by the student under the direct supervision of one of the three schools. Further on in this Announcement there will be found, under the appropriate head, a particular statement of the curriculum 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 electives are clearly defined in the announcement of each school, on subsequent pages.

GRADUATE STUDY AND ADVANCED DEGREES

The facilities for study and research offered by the various laboratories of the College of Engineering are available for graduate students; they will also find among both the regular and the elective courses given in the College many that are suitable for graduate study.

The degrees of Master of Civil Engineering (M.C.E.), Master of Mechanical Engineering (M.M.E.), Master of Electrical Engineering (M.E.E.), Master of Science (M.S.), and Doctor of Philosophy (Ph.D.) are granted upon fulfillment of the conditions prescribed by the Faculty of the Graduate School.

In general, admission to candidacy for the degree of M.C.E., M.M.E., and M.E.E. presupposes the preceding training of the applicant to be the substantial equivalent of the undergraduate courses in Civil, Mechanical, and Electrical Engineering, respectively. Any applicant whose training falls short of this standard will be required to make up the deficiencies, and thus it may take more than one year of residence to fulfill the requirements for the master's degree. Any applicant whose previous training is the substantial equivalent of a year, or more, short of the undergraduate degree of C.E., M.E., or E.E. must register in the undergraduate school.

For further and more detailed information on the Graduate School, see the Announcement of that school.

MILITARY SCIENCE: PHYSICAL TRAINING

All men in the first two years of undergraduate courses must take, in addition to the scholastic requirements for the degree, three hours a week in the Department of Military Science and Tactics. This de-

partment is a unit of the Reserve Officers' Training Corps of the United States Army. For details of the work in the Department of Military Science and Tactics, see the General Circular of Information.

All women in the first two years of undergraduate courses, and all men of those two classes who are excused from military drill, must take, in addition to the scholastic requirements for the degree, three hours a week in the Department of Physical Training. For details of this work in the Department of Physical Training, see the General Circular of Information.

HYGIENE AND PREVENTIVE MEDICINE

All students are required, upon entering, to report to the medical office of the University for a physical examination.

All students in the first two years of undergraduate courses are required to attend lectures on Hygiene and Preventive Medicine given once a week throughout the college year.

THE REQUIREMENTS FOR GRADUATION

The degree of Civil Engineer, Mechanical Engineer, or Electrical Engineer is 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 at least two terms and must have satisfied the University requirements in Military Training (or Physical Training), in Hygiene and Preventive Medicine, and in the payment of tuition and fees.

2. If admitted to the four-year course, he must have completed to the satisfaction of the Faculty of the College of Engineering all the subjects, including elective hours, prescribed in the four-year curriculum as outlined by that faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements for graduation that would have applied if he had been registered in this college from the time he matriculated in the University.

THE HONOR CODE IN EXAMINATIONS

Under a constitution proposed and adopted by the students, and approved by the University Faculty on March 9, 1921, all students of Cornell University are put upon their honor with respect to their conduct in examinations and in other tests of work by which they are earning academic credit. The students have made themselves responsible for maintaining the code. For the trial of charges of breach of honor they elect committees of their own—a central committee for the University, and a committee in each of the colleges. Every student is expected to do his share in upholding the code, not only by honorable conduct on his own part, but also by refusal to conceal or condone fraud on another's part. A fraud observed in any college should be reported to a member of the student honor committee of that college.

THE FRESHMAN YEAR

THE SCHEDULE OF STUDIES

There is a single schedule of studies for all students in the freshman year of the College of Engineering, except that freshmen expecting to work for the C.E. degree take Drawing 200 and 201; those expecting to work for the M.E. or E.E. degree take Drawing 123 and 124. The prescribed schedule for freshmen is as follows; the numbers of the courses refer to the lists of courses printed on the next two pages:

<i>Course</i>	<i>Hours 1st Term</i>	<i>2nd Term</i>
Analytical Geometry and Calculus, 5a, 5b	5	6
Physics 6	6 or 0	0 or 6
Chemistry 101, Lectures	0 or 3	3 or 0
Chemistry 105, Recitations and Laboratory	0 or 3	3 or 0
Drawing 123 and 124, or 200 and 201	3	3
Elementary Surveying 110	0 or 3	3 or 0
Wood Working 102	2 or 0	0 or 2
Introductory Engineering Laboratory 103	1 or 0	0 or 1
Introductory Lectures 130	1	0
Total number of hours each term	18	18

In addition to taking the courses named in the above schedule, all freshmen must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Circular of Information), and must also attend lectures in Hygiene and Preventive Medicine given once a week throughout the year.

For the schedules of the sophomore, junior, and senior years in civil engineering, mechanical engineering, or electrical engineering, consult the announcement of the appropriate school in following pages.

THE COURSES OF INSTRUCTION, FRESHMAN YEAR

The following courses of instruction are those prescribed for all students in the freshman year of the four-year course leading to the degree of Civil Engineer, Mechanical Engineer, or Electrical Engineer. The courses in Mathematics, Physics, and Chemistry are given in the College of Arts and Sciences; the other courses in the list 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 six 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, Advanced Algebra, and Trigonometry.

PHYSICS

6. **Introductory Physics.** First term. Credit six hours. Repeated in second term. Required of candidates for C.E., M.E., E.E. Prerequisites, Mathematics 1-3, or the equivalent. Entrance Physics is desirable but is not required. Three lectures and three recitations. *Rockefeller Hall*, as assigned. Professor BIDWELL, Assistant Professor COLLINS and instructors.

CHEMISTRY

101. Introductory Inorganic Chemistry. Lectures. Repeated in the second term. Credit three hours.

Two sections: M W F 11; T Th S 11. *Main Lecture Room.* Professor BROWNE and Assistant Professor MCKINNEY.

Entrance credit in chemistry does not carry with it University credit in Course 101 or 105. 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 New York City and in Ithaca on the same day in September as the entrance examination. University credit in Courses 101 and 105 that is obtained by passing this examination does not carry with it entrance credit in Chemistry.

Examinations for those who were unavoidably absent from the final examination in courses 101 and 105 will be held at 2 p. m. on the day before instruction begins in the fall.

105. Introductory Inorganic Chemistry. Recitations and laboratory practice. Repeated in the second term. Credit three hours.

Recitations, one hour a week, to be arranged.

Laboratory sections: M F 2-4:30; T Th 2-4:30; W 2-4:30; S 8-10:30; M W 8-10:30. Room 150. Professor BROWNE, Assistant Professor MCKINNEY, and assistants.

Chemistry 101 and 105 must be taken simultaneously unless permission is obtained by the student from the Dean of his college and from the Department of Chemistry to take either course alone.

DRAWING, LETTERING, SURVEYING, SHOPWORK,
INTRODUCTORY LECTURES

123. Engineering Drawing (for M.E. and E.E. students). First term. Repeated in second term. Credit three hours. General course for all freshmen in engineering. This course includes such subdivisions as use of instruments, simple projections, free-hand sketching, lettering, conventional signs, tracing, blue-printing, etc. Professor TOWNSEND and others. *East Sibley.*

124. Descriptive Geometry (for M.E. and E.E. students). Regularly given second term. Make-up section first term. Credit three hours. Two drawing periods and one recitation. Lectures and demonstrations during the drawing periods. The course includes points, lines, planes, solids, tangents, intersections, and developments, with solutions in all quadrants; isometric projections with practical applications. Professor TOWNSEND and others. *East Sibley.*

200. Drawing (for C.E. students). First term. Credit three hours. Use of instruments, free-hand lettering, titles, geometrical problems, simple projections, conventional signs, tracing, and blue-printing. Professor PARSON.

201. Drawing (for C.E. students). Second term. Credit three hours. Lettering—Roman, Gothic, and other styles of letters, with practice in forming the letters and combining them into appropriate titles; orthographic projection, with sections; use of different scales, scale drawings, practical problems, using working drawings; plotting contours. Professor PARSON.

110. Elementary Surveying. Freshmen. Either term as assigned. Credit three hours. Use of steel tape, level and transit; fundamental surveying methods; measurement of lines, angles, and differences of elevation; land surveying, areas and plotting. Recitations, field work, computations, and mapping. Text-book: Breed and Hosmer's *Elementary Surveying*. First Term, one recitation and two field or computation periods a week; Second Term, three recitations a week for the first six weeks and three field or computation periods a week for the remainder of the term. Professors UNDERWOOD and WALKER, Assistant Professor LAWRENCE, and Messrs. PENDLETON, BOYLES, BROWN, and NEWTON. *Lincoln Hall.*

102. **Woodshop.** Freshmen. Two hours 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. HOOPER, 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. Demonstration, followed usually by practice in forging, welding, hardening, and tempering, drop forging, soldering and brazing, oxy-acetylene cutting and welding, 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 Mr. HEAD.

130. **Introductory Lectures.** Freshmen. Credit one hour. One lecture a week throughout the first term. 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.*

SCHOOL OF CIVIL ENGINEERING

OUTLINE OF THE INSTRUCTION

The regular four-year course in Civil Engineering includes instruction in the fundamental subjects of Mathematics, Physics, Chemistry, Drawing, and Surveying. This preparatory training is supplemented by required instruction in the allied subjects of Geology, English, Public Speaking, and Economics. In addition to these, technical instruction is provided in the fundamental principles of Heat-Power and Electrical Engineering, together with cultural courses indicated in the curriculum which may be elected by the student subject to the approval of his class adviser. The purpose of this arrangement is to provide a broad general foundation for the professional work of the civil engineer.

In addition to these subjects, all of which except Surveying are taught in departments or colleges outside of the School of Civil Engineering, the curriculum includes fundamental technical instruction within the School in Materials, Mechanics, Graphics, Hydraulics, Structural Design and Construction, Surveying, and applied or related subjects.

Further provision for elective study in certain technical subjects affords individual opportunity for specialization to as full an extent as experience has shown to be justified under the time limitation of the four-year course. As a result, without neglecting required general instruction in the important branches of Civil Engineering, each student may specially qualify in a branch of engineering to which his ability, interest, and probable future opportunity particularly direct him.

With the assistance of faculty advisers, by following a plan carefully prearranged, emphasis may accordingly be placed upon studies in any one of the following branches of Civil Engineering: Railroad, Highway, Hydraulic, Water Supply, Water Power, Structural, Concrete, Bridge, Municipal, Sanitary, Topographic, Testing or Experimental Engineering.

On the other hand, a general course including subjects from several branches of engineering may be taken. The experience of many of the graduates in Civil Engineering at Cornell University warrants the statement that such a course has proved to be an excellent preparation for work in the fields of business, finance, or engineering contracting.

COURSES LEADING TO THE DEGREE OF CIVIL ENGINEER

I. THE REGULAR FOUR-YEAR COURSE THE FRESHMAN YEAR

There is a single schedule of studies prescribed for all students alike, except as stated in Drawing, in the freshman year of the College of Engineering, whether they expect to graduate in civil, mechanical, or electrical engineering. That schedule is set forth in full under the head THE FRESHMAN YEAR, beginning on page 38.

THE SOPHOMORE YEAR

Public Speaking 1	3 or 0	0 or 3
Engineering Geology 501	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 202	1	0
Drawing 203	0	1
Descriptive Geometry 205	2	0
Descriptive Geometry 206	0	2
Surveying 211	2	0
Surveying 212	0	2
Mechanics 220	6	0
Mechanics Laboratory 220A	1	0
Mechanics 221	0	4
Mechanics Laboratory 221A	0	1
Engineering Construction 264	3 or 0	0 or 3
Technical Reports 294	0 or 3	3 or 0
	<hr/>	<hr/>
Total number of hours each term	18	18
Summer Survey 213 (four weeks in summer vacation)		4

In addition to these courses, sophomores are required to take Military Drill and Hygiene.

THE JUNIOR YEAR

Railroad Location 260A (one week in summer vacation)		1
Modern Economic Society 1	0 or 5	5 or 0
Survey Computations 214	1	0
Engineering Problems 223	0	2
Materials 225	3 or 0	0 or 3
Materials Laboratory 226	3 or 0	0 or 3
Hydraulics 240	4	0
Municipal Sanitation 252	0	4
Railroad Surveying and Drawing 260	0 or 3	3 or 0
Structural Design and Bridge Stresses 270	4	0
Structural Design 271	0	3
Concrete Construction 280	3 or 0	0 or 3
	<hr/>	<hr/>
Total number of hours each term	18 or 17	17 or 18

Students, desiring to specialize in a field requiring it, may, subject to the approval of their class adviser, defer certain courses of the junior year 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.

THE SENIOR YEAR

Heat Engines and Auxiliaries 341	0 or 3	3 or 0
Essentials of Electrical Engineering 417*	4 or 0	0 or 4
Water Supply 230	0 or 3	3 or 0
Highway Engineering 265	3 or 0	0 or 3
Engineering Law 290	3 or 0	0 or 3
Cost-Keeping and Management 293	0 or 3	3 or 0
Elective**	9	9
	<hr/>	<hr/>
Total number of hours each term	19 or 18	18 or 19

*Any qualified student in Civil Engineering who wishes to take a more extended course than E 417 may substitute for it E 415, 416, and E 435, 436. See the description of courses in Electrical Engineering on pages 80-84.

**Of the elective hours, at least one-half 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.

Not more than four hours credit in Advanced Military Science and Tactics will be accepted toward meeting the requirements for the C.E. degree.

2. A SIX-YEAR COURSE LEADING TO THE DEGREES OF A.B. AND 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. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the School of Civil Engineering and to the Dean of the College of Arts and Sciences.

LIST OF THE COURSES OF INSTRUCTION

The courses in the following list are designed for sophomores, juniors, and seniors. Those courses which are designed for freshmen are described under the head The Freshman Year, page 38. The following courses in Geology, Economics, and Public Speaking are given in the College of Arts and Sciences.

GEOLOGY

501. **Engineering Geology.** Required of sophomores in Civil Engineering. Either term as assigned. Credit three hours. Registration by special permission. Lectures and laboratory work. 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. *McGraw Hall.* Professor RIES.

ECONOMICS

1. **Modern Economic Society.** Either term. Credit five hours. Daily except S, 8, 9, 10, 11, 12. An introduction to Economics, including a survey of the principles of value; money, banking, and prices; international trade; protection and free trade; wages and labor conditions; the control of railroads and trusts; socialism; principles and problems of taxation. In the first term the registration will be limited to four hundred. Assignment of sections will be made on registration days at *Goldwin Smith* 260. Professor DAVENPORT.

PUBLIC SPEAKING

1. **Public Speaking.** Either term. Credit three hours. *Goldwin Smith* 24. 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. Professor DRUMMOND.

MECHANICAL ENGINEERING

341. **Heat Engines and Auxiliaries.** Required of all seniors in Civil Engineering. For a description of this course see page 74 of this Announcement.

342. **Small Power Plants.** Elective. For a description of this course see page 74 of this Announcement.

ELECTRICAL ENGINEERING

417. **Essentials of Electrical Engineering.** Either term. Required of all seniors in Civil Engineering. For description of this course see page 82 of this Announcement.

ASTRONOMY

181. General Astronomy. Elective. Throughout the year. Credit three hours a term, but no credit for the first term alone. Not open to Freshmen. Lectures and recitations: Section (a) M F at 9; Section (b) T Th at 9; Section (c) W F at 10. *Lincoln* 31. Laboratory: M T W or Th afternoon 2-4, *Lincoln* 37, assignment to sections to be made on day of registration. Observations at Observatory: one clear evening each week before Thanksgiving and after Easter vacation with four observation periods between Thanksgiving and Easter vacation. This course satisfies the requirement for Group 4 in the College of Arts and Sciences.

A study of the facts and principles of the Science of Astronomy, together with a review of its history as illustrating the gradual development of the scientific method. Professor BOOTHROYD.

182. Elements of Field Astronomy. Sophomores. Second term. Credit two hours. Prerequisite Surveying 110. Before Easter vacation two laboratory periods each week and after Easter vacation one computing period and one observing period each week.

The course is designed to acquaint the student with the principles underlying the practical applications of Astronomy in Surveying and Navigation and to train him in methods of making the observations and computations necessary in determining time, latitude, longitude, and azimuth with the sextant and the surveyor's transit. Professor BOOTHROYD and Mr. PENDLETON.

183. Modern Astronomy. Elective. First term. Credit three hours. Prerequisite courses, Astronomy 181 and Physics 3. An elementary exposition of gravitational astronomy followed by a consideration of spectroscopic and other methods as applied to the study of sun, comets, stars, stellar systems, and nebulae. Lectures, assigned readings, and discussions. Professor BOOTHROYD.

184. Geodetic Astronomy. Elective. First term. Credit three hours. Prerequisite courses, Calculus and Astronomy 181 or 182. A study of precise methods of determining time, latitude, longitude, and azimuth, together with practice at the observatory in determining the instrumental constants and in making and reducing the observations. Professor BOOTHROYD.

185. Practical Astronomy. Elective. First term. Credit three hours. Prerequisite course, Astronomy 184. Study of the use and adjustments of the equatorial and of the various instruments used in connection therewith. Practical problems chosen by the student in consultation with the head of the department will be carried through to completion. Professor BOOTHROYD.

DESCRIPTIVE GEOMETRY AND DRAWING

200 and 201. **Drawing.** Freshmen. Credit three hours each term. See page 39.

202. **Drawing.** Sophomores. First term. Credit one hour. Isometric drawing, line shading, topographic signs, including practice with the different standard topographic signs for mapping. Professor PARSON.

203. **Drawing.** Sophomores. Second term. Credit one hour. Projections, and intersections, using practical problems, practice with water colors in the rendering of flat and curved surfaces, and in the use of crayon. Professor PARSON.

204. **Advanced Drawing.** Elective. Juniors and seniors. Second term. Credit three hours. Perspective drawings, rendered in pencil, ink, and washes, of architectural buildings (exterior and interior) concrete bridges, dams, and other engineering works; building details of window frames, doors, cornices, moulding, stairs, and other simple details, to give the student some insight into detailing parts of plans, and to familiarize him with reading working drawings; engineering drawings, rendered in crayon and color, to enable the student to supplement ordinary working drawings with artistic representations so portrayed as to be readily intelligible to non-technical committees, etc. Professor PARSON.

205. **Descriptive Geometry.** Sophomores. First term. Credit two hours. A study of the representation of lines, planes, surfaces, and solids, with practical applications. Two two-hour exercises each week. Assistant Professor POND.

206. **Descriptive Geometry.** Sophomores. Second term. Credit two hours. A continuation of Course 201. A study of surfaces and solids; tangencies, intersections, and developments; warped surfaces; perspective. When feasible practical problems are introduced throughout the course. Two two-hour exercises each week. Assistant Professor POND.

207. **Advanced Descriptive Geometry.** Elective. Juniors and seniors. Either term. Credit three hours. A continuation of courses 201 and 202. Problems in intersections, developments, warped surfaces, shade, shadows, and perspective. A considerable portion of the time is devoted to stereotomy, with practical problems in stone cutting and the making of accurate templet drawings. Assistant Professor POND.

SURVEYING

110. **Elementary Surveying.** Freshmen. Either term. Credit three hours. See page 39.

211. **Advanced Surveying.** Sophomores. First term. Credit two hours. Prerequisite course 110. City, topographic, and mine surveying; surveys of the United States Public Lands; precise measurements; subterranean surveys; city planning; earth volumes. Professors UNDERWOOD and WALKER, Assistant Professor LAWRENCE, and Mr. NEWTON.

211-A. **Advanced Surveying.** For students in Forestry and Landscape Architecture. Second term. Credit three hours. Prerequisite course 110. Topographic, hydrographic, mine and geodetic surveying and field astronomy; United States Public Land Surveys; precise measurements; transit and stadia; plane table; sextant; stream measurement; topographic reconnaissance; road location; circular curves; triangulation for the control of local surveys; base lines; field determinations of time, latitude, and azimuth. Recitations and field work. Textbook: Breed and Hosmer's *Higher Surveying*. Professor UNDERWOOD and Assistant Professor LAWRENCE.

212. **Advanced Surveying.** Sophomores. Second term. Credit two hours. Prerequisite course 211. Topographic, hydrographic, and geodetic surveying; transit and stadia; plane table; sextant; soundings; triangulation; base lines; precise leveling. Recitations, and field and office work. Textbook: Breed and Hosmer's *Higher Surveying*. Professor UNDERWOOD, Assistant Professor LAWRENCE, and Mr. PENDLETON.

213. **Summer Survey; Topographic, Hydrographic, and Geodetic Survey; Camp.** Sophomores. Four weeks in summer. Credit four hours. Date of beginning to be announced in second term. Prerequisite course 212. Open also to students in Forestry and Landscape Architecture who have had Course 211-A, for whom the work is modified to meet their special needs. 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 Cayuga 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. Professors UNDERWOOD and BOOTHROYD, Assistant Professor LAWRENCE, and others.

214. **Survey Computations.** Juniors. First term. Credit one hour. Prerequisite course 213. Reduction of the observations made at the Camp during the previous summer in Course 213, embracing base-line measurements, triangulation and leveling. The work results in a set of permanent records which include the descriptions of stations and benchmarks with their elevations, and the geographic positions, azimuths, and distances of the triangulation stations. Professor UNDERWOOD and Assistant Professor LAWRENCE.

214-A. Mapping. Elective. Upperclassmen. Required of students in Forestry. 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. Professor UNDERWOOD.

215. Problems in the Adjustment of Observations. Elective. Upperclassmen. Second 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 method of least squares. Lectures and problems. Textbook: Leland's *Notes on the Adjustment of Observations*. Professor UNDERWOOD.

216. Least Squares; Adjustment of Observations. Elective. Second term. Credit two hours. Prerequisites, Calculus and Physics. Lectures and recitations. 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. Two hours 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. Upperclassmen. First term. Credit three hours. Prerequisite courses 182 and 212. 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.

MECHANICS OF ENGINEERING

220. Mechanics of Engineering. Sophomores. First term. Credit six hours. Repeated in one section, second term. Prerequisite course, Mathematics 5b. Statics of material point and of rigid bodies by graphic and by algebraic methods of analysis; chains and cords; centers of gravity; moments of inertia of plane figures; dynamics (kinetics) of a material point; impact; virtual velocities; centrifugal and centripetal forces; pendulums; moments of inertia of rigid bodies; dynamics (kinetics) of rigid bodies. Five recitations and one computing period a week. The computing period will be devoted to the solution of mechanics problems, the use of the slide rule, planimeter, etc. Emphasis will be placed upon correct numerical work and consistent use of proper units. Each student is required to provide himself with a slide rule of approved type. Professors GEORGE and RETTGER and Assistant Professor HOWELL.

220-A. Mechanics Laboratory. Credit one hour. One two-and-one-half hour period a week. This course consists of experiments (both qualitative and quantitative) designed to illustrate the principles of Mechanics studied in Mechanics 220, the experiments to be performed by the students themselves. Working models will be used when practicable. Courses 220 and 220-A are closely correlated and must be taken concurrently. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

221. Mechanics of Engineering. Sophomores. Second term. Credit four hours. Continuation of Mechanics 220. Prerequisite course, Mechanics 220. Work; power; energy; fly-wheels; friction; dynamometers; general theorem of work and energy applied to machines; 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 of Engineering Design. Four recitations a week. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

221-A. Mechanics Laboratory. Credit one hour. One two-and-one-half hour period a week. Experiments designed to illustrate the principles of mechanics studied in Course 221. Courses 221 and 221-A are closely correlated and must be taken concurrently. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

222. Advanced Mechanics. Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite courses 220 and 221. Linear arches; curved beams; special cases of flexure; problems in the mathematical theory of elasticity; thick hollow cylinders and spheres; plates; Castigliano's theorem of least work; internal work and its derivatives. Recitations, three hours a week. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

223. Engineering Problems. Juniors. Second term. Credit two hours. Prerequisite 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. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

MATERIALS OF CONSTRUCTION

225. Materials of Construction. Juniors. 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. Textbook: Mills' *Materials of Construction*. Professor SCOFIELD.

226. Materials Laboratory. Juniors. 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 test 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 and Mr. WRIGHT.

HYDRAULIC ENGINEERING

230. Water Supply. Seniors. Either term. Credit three hours. Prerequisite course 240. Three recitations a week from assigned texts and the working of assigned problems. 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 or the ground water; 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; probable dependable draft; flow into wells, etc. The second half of the term is devoted to a review of the methods of developing public water supplies from the several 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. Professor SEERY.

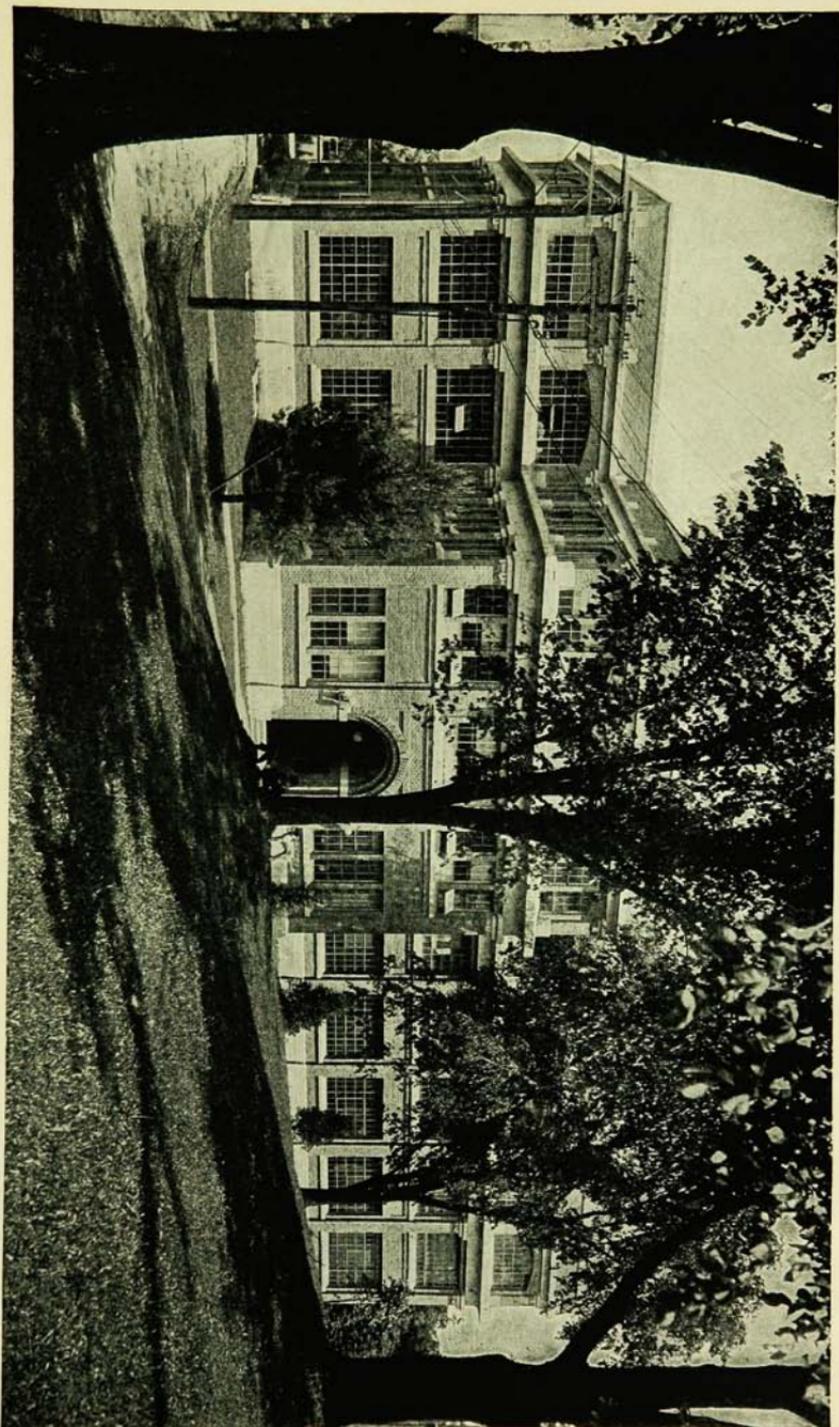
231. Hydraulic Construction. Elective. Seniors and graduates. First term. Credit three hours. Repeated second term. Should be taken after, or concurrently with Water Supply 230. One recitation from assigned texts and two long computing periods a week for working problems. The course is devoted largely to a study of water storage and the engineering investigations and design of structures associated with stream regulation for the public water supplies, water power, irrigation, or navigation. Extensive problems are worked out involving the preliminary investigation of a project, exploration of dam sites, surveys of reservoir sites, the economics of storage, manipulation of storage and pondage, the preparation of an estimate of quantities, costs, plan of progress in construction, etc., for a particular project. The stability of weir dams by graphics, and the analytic design of high masonry dams by Wegmann's method, together with a study of all the factors affecting the stability and form of section of a dam, and the methods of construction are fully covered by text and in problems. Earthen dams and embankments, timber weirs, movable dams, and flashboards are also considered. Professor SEERY.

232. Water-Power Engineering. Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 240, and must be taken after or concurrently with Course 230. Recitations from assigned text and the working of lengthy problems. The course is devoted to a general study of the problems of water power development, the factors affecting the economics of a project, the engineering and commercial feasibility of developing power and the value of a mill site. A detailed study of the characteristics of modern turbine types, the selection of mechanical equipment suited to the conditions of installation and operation, the effects of load factors, pondage, storage and steam auxiliary on the capacity and cost; together with an analysis of the power capacity of a low-head mill site, the speed regulation of a plant under medium head fed by a long penstock, and a thorough study of the phenomena of unsteady flow and surging, with and without surge tanks, are covered by the text and incorporated into numerical problems taken from existing plants. Professor SEERY.

233. Pumps and Pumping. Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 240, and should be preceded by, or taken concurrently with Course 230. Recitations from assigned texts and working of problems. The course deals with types and characteristics of pumps with particular reference to adaptation of the mechanical equipment of a pumping station to the working conditions as indicated by the load curve of pumping stations for public water supplies, irrigation and drainage projects, special fire protection systems, etc. A thorough study of centrifugal pumps and their characteristic curves, the interpretation of tests, methods of making tests, and the forecasting of the results and costs of operation of pumps for the several purposes above mentioned will be made by text and exemplified by numerical problems to be worked by the student. Professor SEERY.

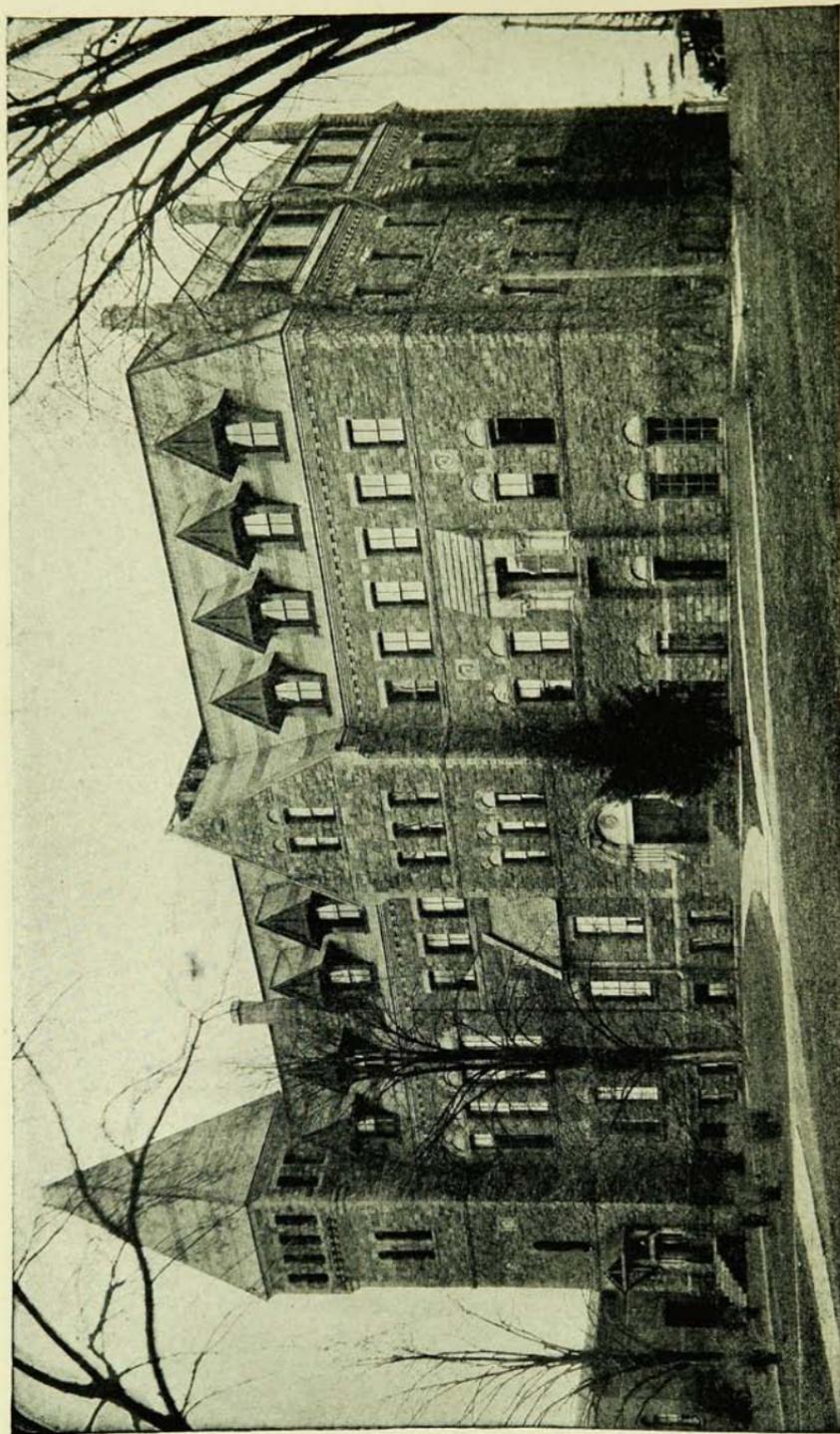
234. Hydraulic Engineering. Elective. Seniors and graduates. Second term. Credit three hours. Lectures, recitations, and readings. This course is an elementary course dealing with the hydraulic, engineering, and economic problems relative to navigable waterways, river improvements, and harbor construction. Professor SEERY.

235. General Hydrology. Elective for graduate students. Second term. Credit three hours. Lectures, readings, recitations, and working of problems. The course is designed primarily as an aid to the interpretation of stream flow data in the light of elemental factor. It includes a review of the related physics, physical geography, and meteorological physics, geology, statistical methods, etc. Professor SEERY.



RAND HALL

Containing the Machine Shop, the Pattern Shop, and an Electrical Laboratory



FRANKLIN HALL

The Main Building of the School of Electrical Engineering
The Senior Electrical Laboratory occupies the second floor of Rand Hall (see plate facing page 48).

236. **Hydraulic Power and Pumping Stations.** Elective. Seniors and graduates. Second term. Credit three hours. A computing period three afternoons a week for the term, devoted to the solution of problems arising in the design of hydraulic power plants and pumping stations. Required to be taken simultaneously with or after Courses 230 and 232.

THEORETICAL AND EXPERIMENTAL HYDRAULICS

240. **Hydraulics.** Juniors. First term. Credit four hours. Prerequisite courses 220 and 221. Two recitations and two computing periods a week; some of the computing periods are utilized for experimental demonstrations. 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. Professor SCHODER and Mr. WRIGHT.

241. **Advanced Hydraulics.** Elective for juniors and seniors. Second term. Credit three hours. Prerequisite course 240. One recitation and two long periods a week. One period is devoted to problems and the other to laboratory work and preparation of reports. The recitations and problems take up topics in stability of flotation; overflow dams, free and submerged; backwater and variable flow in open channels; standing waves; water hammer and surges; flow of air in pipes; impulse wheels and turbines; centrifugal pumps; hydraulic rams; logarithmic plotting. The laboratory experiments include gage testing, orifices, nozzles, pipes, current meter rating, Pitot tubes, Venturi meters. Professor SCHODER.

242. **Hydraulic Measurements.** Elective for seniors and graduates. First term. Credit three hours. Prerequisite course 240. Three periods a week in laboratory or computing room. In addition to more thorough experimental investigations on some of the laboratory topics mentioned under Course 241 (e. g. weirs, Pitot tubes, pipes and current meters), the work includes fire hose and nozzles, ordinary water-meters, floats in open channels, actual measurement of river discharge (on a week-end trip) and such occasional tests as opportunity offers in the laboratory or the immediate neighborhood of Ithaca. Professor SCHODER.

243. **Experimental Hydraulic Motors and Pumps.** Elective for seniors and graduates. Second term. Credit three hours. Prerequisite course 240. Three periods a week. The determination of efficiency, capacity, and characteristics of hydraulic machinery by tests. Professor SCHODER.

MUNICIPAL AND SANITARY ENGINEERING

250. **Sanitary Biology.** Elective. Juniors and seniors. Second term. Credit three hours. The course is designed to familiarize the student with current standard practice in the bacteriological control of water and sewage treatment plants. The use of the microscope; preparation of media; bacteriological analyses of water; sewage, sewage effluents and sewage sludge; efficiency of disinfectants; and that part of the science of bacteriology related to sanitary engineering. Textbook: Buchanan's *Household Bacteriology*. One recitation and two laboratory periods a week. Professor WALKER.

251. **Sanitary Biology.** Elective. Juniors and seniors. First term. Credit one hour. The collection and microscopical examination of the various forms of algae most prevalent in water supplies; the methods of their identification and control; and a study of the biological forms most prevalent in sewage wastes and sludges. Lectures, notes, and various references. One laboratory period a week. Professor WALKER.

252. **Municipal Sanitation.** Juniors. Second term. Credit four hours. Prerequisite course 240. Three recitations and one computing period a week. Sewer design and construction, and sewage disposal. Problems illustrating the matter taken up in the recitations such as problems on sewage flow, both domestic and storm water; hydraulic problems; construction problems dealing with various details of disposal plants. Textbook: Metcalf and Eddy's *Sewerage and Sewage Disposal*. Four sections. Professors OGDEN and WALKER.

253. **Purification and Control of Water Supplies.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 240. Examination of water (physical, chemical, and bacteriological); normal quality of surface and subterranean waters, with effects of storage; communicable diseases and water supplies; epidemics of typhoid fever and cholera with studies of etiology etc.; purification of water, sedimentation, and coagulation; slow sand filtration (theory, construction and operation, with examples); rapid sand filtration (theory, construction, and operation, with examples); miscellaneous purification processes (aeration, softening, iron removal, sterilization, distillation, and purification by chemicals.) Professors OGDEN and WALKER.

254. **Sewerage Works.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 252. Three hours a week for fifteen weeks, divided between lectures and recitations. The work is upon the construction and operation of sewers and sewage disposal works, illustrated by lantern slides and by reference to recent descriptions of sewage-disposal plants in the current literature. There are, generally speaking, three recitations or one week's work on each of the following topics: disposal by dilution (salt and fresh water); chemical precipitation; broad irrigation, with special reference to institutions; natural and artificial filtration beds; sedimentation and septic tanks; Imhoff tanks; contact beds; sprinkling filters; and activated sludge. It is intended to differentiate this course from the junior work by making the latter chiefly a discussion of principles involved, while the senior course is a detailed investigation of the methods of construction with the reasons involved. Textbook: Kinnicutt, Winslow, and Pratt's *Sewage Disposal*. Professor OGDEN.

255. **Treatment of Wastes.** Elective. Seniors and graduates. Credit two hours. Prerequisite course 252. First term. The treatment of municipal and industrial wastes such as from garbage plants, tanneries, slaughter-houses, mines, canning factories, sugar factories, dye plants, pulp mills, creameries, cheese factories, milk bottling stations, condensaries, is considered.

Flow or process charts for each industry are used to show the general character and composition of the wastes, and methods of treatment applicable including results of experimental work, are considered. Professor WALKER.

256. **Municipal Engineering.** Elective. Seniors and graduates. Credit three hours. A study of the relationships that exist between the practising municipal engineer and the various state and city commissions and other organizations with which he comes in contact. Financing of municipal operations including bond issues and sinking funds; special assessments; the limitations and restrictions placed by State Departments on municipal enterprises; town planning and public utilities; municipal housekeeping. Lectures, reports, and readings. Professor OGDEN.

257. **Purification of Water.** Elective. Graduates. Credit three hours. Specific problems in water purification; control of watersheds; effect of sedimentation on waters of different compositions; treatment of waters for particular requirements, such as removal of hardness, sediment, bacteria, etc. A report on some existing water system will be required from each student. Professor OGDEN.

258. **Conference on Present Methods of Sewage Disposal.** Elective. Graduates. Credit three hours. A critical study of the construction and operation of plants now in existence. Inspections and reports. Professor OGDEN.

259. **A Laboratory Course for Graduates.** Devoted to some special problem of sewage or water, such as the operation of a water-filtration plant, a sewage-disposal plant, the purification of trade wastes, the value of disinfection, etc. Professors OGDEN and WALKER.

RAILROAD AND HIGHWAY ENGINEERING

RAILROAD ENGINEERING

260-A. Railroad Location. Juniors. One week during summer vacation, opening date to be announced. Credit one hour. Prerequisite course 213. 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. Professors BARNES and CONWELL, Assistant Professors PERRY, CRANDALL and THATCHER, and Mr. SPRY.

260-B. Railroad Surveying and Drawing. Juniors. Either term. Credit three hours. One recitation and two field or drawing periods a week. Prerequisite courses 213 and 260-A. The recitations cover the theory of simple, transition, and vertical curves, and earthwork computation; with applications to practical problems for purposes of illustration. The field periods take up about two-thirds of the term and are devoted to computing, laying out and checking simple, transition, and vertical curves. The 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 the preliminary line surveyed by his section in 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 as determined by the cross sections. Professors BARNES and CONWELL, Assistant Professors PERRY, CRANDALL, and THATCHER, and Mr. SPRY.

261. Railroad Maintenance of Way. Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 260. 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 both by 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. Lectures and recitations three hours a week. Professor BARNES and Assistant Professor PERRY.

262. Railroad Operation and Management. Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 260. 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. Railroad Location. Elective. Juniors and seniors. Second term. Credit three hours. A detailed study is made of the economic principles governing the location of new railroads, both steam and electric, and the revision or relocation of existing lines to make them most efficient as transportation machines. Some of the topics treated are estimation of revenue, expenses and rates and steam and electric locomotive performance and train operation; gradients, distance and

curvature; line and grade revisions; grade crossing elimination and additional facilities; location surveys and estimates. Lectures and recitations with problems involving investigations of projects, revisions and comparisons of alternate locations. Three hours a week. Professor BARNES.

264. **Engineering Construction.** Sophomores. Second term. Credit three hours. A course in the fundamentals of construction with special reference to field methods, equipment and tools, plant layouts, and costs. The course includes estimates and analyses of costs with reference to planning, preparatory and construction periods; earth and rock excavation; haulage; tunneling; foundations; masonry; trestles; falsework, etc. The foregoing are applied to the various types of engineering construction to which they are best adapted. Frequent problems are given to bring out these applications and lantern slides are used to illustrate current practice. Attention is also given to the economic selection of structures, etc. Lectures, recitations, and problems, three hours a week. Professors BARNES and CONWELL, Assistant Professors PERRY, CRANDALL, and THATCHER.

HIGHWAY ENGINEERING

265. **Highway Engineering.** Seniors and graduates. Either term. Credit three hours. Prerequisite, first term of 260. The course consists of recitations and lectures on the economics of location of highways and selection of type of surface, and the methods of construction and maintenance of earth, gravel, sand-clay, and top-soil roads, and water bound macadam; character of non-bituminous and bituminous highway materials; construction and maintenance of Portland cement concrete roads, brick pavements, bituminous macadam, bituminous concrete, sheet asphalt, wood block, stone block, etc. Problems are assigned in road location, street intersections, and in estimating the cost of construction of various types of roads and pavement construction. Professor CONWELL and Assistant Professor THATCHER.

266. **Highway Laboratory.** Elective. Juniors, seniors, and graduates. Either term. Credit three hours. Prerequisite course 265, or may be taken concurrently with Course 265. Students are required to make the standard tests for non-bituminous materials such as sand, clay, top-soil mixtures, gravel, and rock; standard tests of asphalts and tars used for bituminous highway construction and maintenance; and gradation of aggregates for bituminous concrete and sheet asphalt mixtures. One lecture and two laboratory periods a week. Professor CONWELL and Assistant Professor THATCHER.

267. **Advanced Highway Engineering.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 265. Recitations and lectures dealing with the economics of location and selection of type of surfaces, methods of financing; study of the materials available with special emphasis on the interpretation of tests, particularly those pertaining to bituminous highway materials and their characteristics; the development of the more modern types of surfaces and current practice in regard to their construction and maintenance; investigation of the labor and plant organization for various kinds of highway work; street cleaning; highway legislation, etc. Problems are assigned in writing specifications, in road and street location and improvement, in planning the contractor's organization, and in estimates of cost of various proposed highway projects. Professor CONWELL.

268. **Advanced Highway Laboratory.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite courses 265 and 266. Testing of all kinds of non-bituminous and bituminous highway materials and a study of their characteristics; testing of aggregates, bituminous concrete, sheet asphalt and asphalt paving block mixtures; study of specifications. Special investigations and tests will be made to determine the properties of various combinations of materials and the effects of modifications in design. One lecture and two laboratory periods a week. Professor CONWELL.

STRUCTURAL ENGINEERING

270. **Structural Design and Bridge Stresses.** Juniors. First term. Credit four hours. Prerequisite courses 220 and 221.

Structural Design. The recitations cover the graphic analysis of simple beams and roof trusses. The computations and drawings include complete detail designs and working drawings of wooden joints to resist large tensile stresses, and of a wooden roof truss for given specifications. The object of the course is to show how to apply the principles of mechanics to the design of every detail of the simple structures named, and to study the forms and strength of joints and fastenings used in heavy timber framing. The computations required are to be arranged in systematic order in the form of reports. Textbook: Jacoby's *Structural Details*. Computation and drawing, two and one-half hours a week.

Bridge Stresses. Stresses due to dead, live and wind loads, initial tension, and impact; pannelloads and locomotive axleloads; determination of the position of live loading for greatest stresses; maximum and minimum stresses; analytic and graphic methods are used. The principal types of simple trusses employed in modern construction are considered, in several cases both with and without counterbracing; historical notes on truss bridges. The solution of many numerical examples taken from practice forms a prominent part of the class work. Three recitations a week. Professor URQUHART, Assistant Professors BURROWS and OSGOOD.

271. **Structural Design.** Juniors. Second term. Credit three hours. Prerequisite course 270. An elementary course in Steel Design. Complete design, detail drawing, bill of material and estimate of weight of a steel roof truss and of a through and deck railroad plate girder bridge. Textbook: Johnson, Bryan and Turneure's *Modern Framed Structures, Part III*. Three computation and drawing periods a week. Professor URQUHART, Assistant Professors BURROWS and OSGOOD.

272. **Higher Structures.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite courses 220, 221, and 270. Determination of the loading and stresses in continuous girders and trusses, and metallic arches. The arches include arch ribs and trussed arches with three and two hinges respectively. Both analytic and graphic methods are used; the latter include displacement diagrams to find the deflection of trusses and the reactions of statically indeterminate structures, and the use of influence lines to find their loading and stresses. Recitations three hours a week. Professor URQUHART and Assistant Professor OSGOOD.

273. **Steel Buildings.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite courses 220, 221, and 271. This course comprises the design of the steel framework for building 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: Ketcham's *Steel Mill Buildings*. Report and drawings. Three two-hour periods a week. Assistant Professor BURROWS.

274. **Bridge Design.** Elective. Seniors and graduates. 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, 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 and Turneure's *Modern Framed Structures, Part 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 according to standard specifications. Assistant Professor BURROWS.

280. **Concrete Construction.** Juniors. Either term. Credit three hours. Prerequisite courses 220, 221, 225, and 226. Concrete materials, properties of plain concrete, its making and deposition; elementary theory of reinforced concrete as applied to columns, rectangular beams and slabs; T-beams and beams reinforced for compression; direct stress combined with flexure. Three two-hour periods a week. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures*. Professor URQUHART, Assistant Professor OSGOOD, and Mr. GARRELTS.

281. **Masonry and Foundations.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite courses 220 and 221. Piles and pile driving, including timber, concrete, tubular and sheet piles; cofferdams; box and open caissons; pneumatic caissons for bridges and buildings, caisson sinking, and physiological effects of compressed air; pier foundations in open wells; freezing process; hydraulic caissons; ordinary bridge piers; cylinders and pivot piers; bridge abutments; spread footings for building 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. Professor URQUHART and Mr. GARRELTS.

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. Seven and one-half hours a week. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures*. Professor URQUHART and Mr. GARRELTS.

283. **Reinforced Concrete Arch.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 280. The design of an arch of reinforced concrete and its abutments; investigation of the arch ring in accordance with the elastic theory (the live loading for maximum unit-stresses in the arch ring, as well as the direction and magnitude of abutment thrusts, being determined by the influence-line method.) Computation and drawing. Seven and one-half hours a week. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures*. Professor URQUHART and Assistant Professor OSGOOD.

284. **Highway Bridges.** Elective. Seniors and graduates. 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 drawing. Professor URQUHART and Assistant Professor O'ROURKE.

285. **Reinforced Concrete Design.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 280. Theory and design of gravity, cantilever, and counterfort retaining walls. Design of footings: single and multiple column of reinforced concrete, I-beam grilliages. Design of bins and tanks: subsurface and supported on towers. Reports and sketches. Three two-hour periods a week. Professor URQUHART and Assistant Professor O'ROURKE. (First given in 1927-28.)

SPECIFICATIONS, DESIGNS, ETC.

290. **Engineering Law.** Seniors. Juniors admitted by special permission only. Either term. Credit three hours. Development of contract principles; agency, tort, and independent contractor; contracts of association, and of sale and transportation; preparation of engineering contracts; relation to commercial contracts; practical suggestions for general condition clauses, as extras, alteration,

time limit, payments, arbitration, etc.; specifications and methods of studying them; skeletons of important examples of contracts and specifications; practice in analyzing and in writing specifications; acquisition, ownership, and conveyance of land; rights and liabilities in streams, surface, and underground waters; property rights defined by boundaries; determination of boundaries of land. Tucker's *Contracts of Engineering* is used as a text. Lectures and recitations, two hours a week. Professor BARNES, Assistant Professors CRANDALL, PERRY, and THATCHER.

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 courses 240 and 223. For best results Hydraulic Design should be preceded by Course 230, but the two may be taken concurrently. Courses 231 or 232 may be substituted for Engineering Design. One or both of these courses should be elected by the student specializing in hydraulics unless he has a good reason for electing independent design instead. The purpose of the course is not to duplicate in large part work regularly given in Courses 231, 232, and 241 or in the courses in structural engineering. Professor SCHODER.

(d) **Sanitary Engineering.** First term. This course must be preceded by or taken at the same time as Course 254, and may not be elected otherwise. The following problems indicate the scope of the work: (1) Computations, design, and detail drawings for the wooden forms needed for brick or concrete sewers of various diameters and forms of cross sections. (2) Computations, design, and detail drawings for a pile foundation to support sewers from three to ten feet in diameter. (3) Design and detail drawing for patterns of cast-iron manhole covers. (4) Computations, designs, and detail drawings for flap valve as outlet of settling tank, the design involving a lifting device. (5) Design and detail drawings of a sewage screen, involving a device for raising screen for cleaning. (6) Computations, designs, and a detail drawing for an inverted siphon for sewage flow; the problem involves a flushing gate and overflow as well as manholes. (7) Design of disposal plant for a small community as an asylum or school. Professor OGDEN.

(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, Assistant Professors PERRY and CRANDALL.

(f) **Bridge Engineering.** Second term. Course 271 is required as general preparation for engineering design in bridges and buildings. Course 272 is required in preparation for designs relating to draw, cantilever, suspension, and metallic arch bridges. Course 280 is similarly required for designs of bridges and buildings in reinforced concrete. Courses 273, 274, 282, 283, and 284 may be substituted for Engineering Design. Professor URQUHART and Assistant Professor BURROWS.

(g) **Highway Engineering.** Second term. The problems are those encountered in the location and construction of highways and include the following: Economic location; selection and design of different types of highway surfaces for various traffic conditions; culverts, 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 and Assistant Professor THATCHER.

292. **Thesis.** Elective. Seniors. Credit three hours. The thesis is intended to demonstrate the ability of the student for independent investigation, or his ability to apply the fundamental principles acquired in this course to the study of some special problem related to civil engineering. The latest date for filing the subject with the Director of the School is October 15 for the first term, and January 15 for the second term. The plan of work is to be submitted to the professor having charge of the subject, to whom also regular reports are to be made showing the progress of the investigation. The latest date for presenting the complete thesis is June 1. A pamphlet containing instructions in regard to theses in Civil Engineering is available and should be consulted by students registered for this course.

293. **Cost-Keeping and Management.** Seniors. Either term. Credit three hours. An elementary course on the principles which govern the organization and management of laborers on construction; selection of plant and equipment; systems of payment; measurement of efficiency, cost-keeping, and accounting on construction with illustrative examples. Professor BARNES and Assistant Professor CRANDALL.

294. **Technical Writing.** Credit three hours. This course is intended to aid the student in finding the application of his high school training in English to writing technical reports. One lecture, one recitation, and one exercise for the discussion of written work each week. Textbook: Sypherd's Watt and McDonald's *Composition of Technical Papers* and Greever and Jones's *Century Collegiate Handbook*. Mr. BOYLES.

295. **Valuation Engineering.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite courses 264 and 290. Lectures, recitations and reports. Theory and practice of the preparation of valuation reports on public utilities, industrial plants and other properties. The topics taken up include the purpose of the valuation; the fundamentals such as franchises, stock and bond issues, amortization, depreciation, cost data, analysis of cost, value, rates and theory of valuation; outline of typical valuation reports; sample forms; organization and methods of procedure; discussions of special features; detailed examples of valuation reports. Assistant Professor CRANDALL.

296. **Earthwork Computations.** A special course for students in landscape architecture. Not open to students in civil engineering. See Announcement of the College of Architecture. Assistant Professor LAWRENCE.

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. Prerequisite courses 184 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. Prerequisite 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) **Experimental Hydraulics.** Either term. Prerequisite course 240 or its equivalent. The subject and scope of the investigations 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 OGDEN 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) **Bridge 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. The laboratory for testing and investigating bituminous materials is available for research, and other materials may be tested in the laboratories in Lincoln Hall. Special problems in location and design and in economic selection of types of surfaces give opportunity for a wide variety of research. Professor CONWELL.

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 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

OUTLINE OF THE INSTRUCTION

The instruction in Mathematics, Chemistry, Physics, English, and Economics is given in the College of Arts and Sciences. All other regular subjects in the course are of an engineering nature and are given in the Sibley School of Mechanical Engineering in the following departments: (1) Mechanic Arts; (2) Machine Design; (3) Naval Architecture and Marine Engineering; (4) Mechanics of Engineering; (5) Power Engineering; (6) Experimental Engineering; (7) Industrial Engineering; or in the School of Electrical Engineering.

The following is a brief outline of the scope and purposes of instruction in the various departments of the School of Mechanical Engineering.

I. 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 forge shop operations, like welding, hot working, etc.

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 student

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.

2. MACHINE DESIGN

In this department, instruction is given in empirical design, kinematics, and machine design, to sophomores and juniors in mechanical and electrical engineering. The department also offers elective courses and an option in general engineering design, open to seniors in mechanical engineering.

Instruction is given by means of recitations and work over the drawing board. First, a study is made of the common machine parts and their uses and the empirical proportioning and assembling of such parts. The study of kinematics is then taken up and applied to the solution of cam, gear, linkage, instant center, velocity, and acceleration problems. These courses are followed by recitations and drawing room courses in general machine design. The theory and principles developed are applied to the solution of many short problems and to the design of complete machines in the drawing room. Only such machines 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.

The general engineering option offered by the department is intended to meet the requirements of seniors in mechanical engineering who do not wish to devote the year to specialized design work. A fundamental grounding in structural work, foundations, reinforced concrete, etc., is given.

3. NAVAL ARCHITECTURE AND MARINE ENGINEERING

Under this head, the School offers a Senior Option in ship design, and in marine machinery. The work consists of lectures and drafting room work bearing on the theoretical and practical design of ships, taking up the important features in the resistance, proportioning and powering of ships, while another course of lectures is devoted to marine machinery.

4. MECHANICS OF ENGINEERING

In this department instruction is given in theoretical and applied mechanics and hydraulics, beginning with a course for sophomores in the fundamental principles of statics, kinetics, and the strength of materials. In weekly computation periods problems are solved under the guidance and supervision of the instructors. 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 juniors a course in hydraulics is given. A broad knowledge of the fundamental principles is deemed of more value than familiarity with special formulas or numerical coefficients. The accompanying lectures give a short description of water power plants, in order to enable the student to read reports on power projects intelligently. 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 hydro-electric work. The laboratory instruction in hydraulics is given in the Department of Experimental Engineering.

5. HEAT-POWER ENGINEERING

Instruction in this department is given to all students of Mechanical Engineering in their junior and senior years, with the object of training them in the methods of solution of problems involved in the theory, design, and economics of heat engines and their auxiliary apparatus, considered both separately and in combination in power plants.

The work begins with lectures and recitations on the elements of Heat-Power Engineering, including the study of the elementary thermo-dynamics of gases and vapors, ideal and actual cycles, air compressors, internal combustion engines, and steam engines. This is followed by a study of steam turbines, fuels and combustion, furnaces, boilers, draft apparatus, producers, heat transmission, condensers, feed-water heaters and other power-plant auxiliaries, the flow of gases and vapors, the utilization of waste heat, refrigeration, and other topics.

In addition to taking these required courses, the student in his senior year may specialize in power plants by taking the lecture and drafting courses specially devoted to that subject. He may also attend special lecture courses on steam turbines, steam boilers, gas-power machinery, refrigeration, pumping and pneumatic machinery and power plant auxiliaries.

6. EXPERIMENTAL ENGINEERING

A. MECHANICAL LABORATORY

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 very completely equipped mechanical laboratories (described on page 20), not only to familiarize him with the various types of testing apparatus and to give him skill in their use, but to teach him the best methods of research. Briefly, the courses include: the use of computing machines; 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; valve setting; tests of boilers, steam engines, turbines, pumps, heaters, condensers, injectors, and other steam apparatus; tests of air compressors and refrigerating machines; tests of external and internal combustion gas and oil engines; and tests of hydraulic machinery.

B. ENGINEERING RESEARCH

Engineering research by graduate and undergraduate students is carried on in this department under the supervision of a separate corps of specialists who devote their entire time to this work. Students who have shown proficiency in experimental engineering may have opportunity to conduct original investigations under expert guidance, and as occasion offers, may assist in commercial tests, made at the University or elsewhere, of materials, prime movers, power plants, etc. The equipment of every department is available for this work and the specialists in any department may be consulted.

In case the investigation or research is sufficiently extended, the student is encouraged to embody the work in a thesis. Research, or Thesis, may be elected during the senior year by a limited number who have shown special ability for investigation. Arrangements for this work should be made with the department during the junior year if possible.

This department will cooperate in every way to assist graduate students in mechanical, electrical, and industrial engineering, and will aid in providing apparatus and other facilities for graduate work.

7. INDUSTRIAL ENGINEERING

Until recently the field of the mechanical engineer was a comparatively narrow one, comprising little more than the design, construction, and operation of machinery. As industry has developed, however, many technically trained men have entered the fields of manufacturing, selling, and administration. This is a natural and increasing tendency, since industrial development rests mainly upon a scientific basis. There are few lines of human activity today that are not connected in some way with applied science, and this is particularly true of those lines known by the general term of engineering.

The success of the engineer in times past in meeting these commercial requirements, for which he had received no special training, was probably due to the method of attack characteristic of the engineer and to superior knowledge of the technical side of the work. But the commercial demands upon the engineer are now becoming so great that special training is necessary to equip him more completely for this larger field. This becomes more evident when it is considered that a large number of the graduates of mechanical engineering colleges go into the commercial side of engineering.

Therefore, in addition to training in the fundamental principles of engineering, every student in the regular courses in the School of

Mechanical Engineering has some work in industrial organization and administration before he is graduated; but in the Department of Industrial Engineering a more complete provision is made in the senior year for those who wish to specialize in manufacturing or the commercial side of engineering.

The work of the department begins in the junior year, when all students in the School take a course of instruction in the basic principles of industrial organization. An optional group of studies is offered in the senior year for those who wish to specialize somewhat in this line of work. This option consists of the engineering subjects required in all senior options with courses in plant arrangement, industrial organization and administration, time and motion study, cost finding, corporation finance, industrial relations, etc.

NON-RESIDENT LECTURERS

Supplementing the regular course of instruction, lectures are delivered from time to time by non-resident specialists in the profession on various subjects relating to the many branches of mechanical engineering. Seniors are required to attend these lectures. The student may also attend the many public scientific lectures given in other departments of the University by non-resident lecturers.

COURSES LEADING TO THE DEGREE OF MECHANICAL ENGINEER

I. THE REGULAR FOUR-YEAR COURSE

One hour of credit in the following schedules corresponds to about three hours of actual work a week for the term of fifteen weeks. Thus, from two and one-half to three hours a week of actual work in shop, laboratory, computing room, or drawing room count as one hour of credit, and each recitation hour assumes about two hours of outside preparation.

THE FRESHMAN YEAR

There is a single schedule of studies prescribed for all students alike, except as stated in Drawing, in the freshman year of the College of Engineering, whether they expect to graduate in civil, mechanical, or electrical engineering. That schedule is set forth in full under the head THE FRESHMAN YEAR, beginning on page 38.

THE SOPHOMORE YEAR

Mechanics 330, 331	6	5
Physics, Recitations, 28, 29	2	2
Physics, Laboratory, 34	2	2
Empirical Design 311	3	0
Kinematics, Recitations, 313	0	3
Kinematic Drawing 314	0	2
English 2	2	2
Engineering Chemistry 775	2 or 0	0 or 2
Foundry 300	2 or 0	0 or 2
Materials 360	0 or 3	3 or 0
Total number of hours each term	19 or 18	19 or 20

In addition to taking the courses named in the above schedule, all sophomores must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Circular of Information), and must also attend lectures in Hygiene and Preventive Medicine given once a week throughout the year.

Students having previous training in English of like character, or students whose first term in this English course is satisfactory, may substitute Public Speaking for English, provided the Department of Public Speaking approves.

THE JUNIOR YEAR

Heat-Power Engineering 340a, b.....	3	3
Mechanical Laboratory 365, 366.....	4	4
Machine Design 316a, 316b.....	2	2
Machine Design 317a, 317b.....	2	2
Electrical Engineering 415, 416.....	3	3
Machine Shop 305a, b.....	3 or 0	0 or 3
Industrial Engineering 380.....	0 or 2	2 or 0
Hydraulics 334.....	2 or 0	0 or 2
Economics 3.....	0 or 3	3 or 0
	<hr/>	<hr/>
Total number of hours each term.....	19	19

THE SENIOR YEAR

In the senior year the regular student must complete one of the options (A to F inclusive) outlined in the following pages. All these options include courses in Heat-Power Engineering, Mechanical Laboratory, and Electrical Engineering, and, under each, lecture and drafting courses are devoted to the special work of the option. In addition, provision is made in the options for limited election of courses given in any college of the University.

OPTION A: POWER-PLANT ENGINEERING

The object of the special courses in this option is to acquaint the student with the design and application of the various types of steam power-plant equipment and to train him in problems connected with the layout, construction and equipment of the plant as a whole. After studying the details of the design and the selection of steam prime movers and their auxiliaries, the time is devoted to consideration of load curves, station factors, variable load economy, cost of equipment and of power, principles of economic selection of machinery with respect to the load curve and local conditions, arrangement of equipment, plant location, and similar topics.

The work is taught by lectures supplemented by a drafting course in which the student first makes layouts of the more important machines and constructs their characteristic curves, after which he takes up a power plant project.

In addition to the prescribed courses, the student may elect such related courses as Boiler Design, Steam Turbines, Power-Plant Auxiliaries, Internal Combustion Engines, Pumping and Pneumatic Machinery, Refrigerating Machinery, Heating and Ventilating, Motor Car Construction and Industrial Administration; or he may elect courses in other colleges.

Following is the schedule of the senior option in Power-Plant Engineering:

Heat-Power Engineering 345a, b.....	4	4
Mechanical Laboratory 370, 371.....	4	3
Electrical Engineering 435, 436.....	2	2
Steam Power-Plant 346a, b.....	4	4
Drawing and Design 347a, b.....	2	2
Elective.....	3	4
	<hr/>	<hr/>
Total number of hours each term.....	19	19

In addition to the schedule above, Seniors in Option A must take, as a requirement for graduation, the non-resident lectures in M.E. 391, and such non-resident lectures as may be assigned in E.E. 491. Announcement of these lectures will be made in advance.

OPTION B: 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 courses relating to 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.

Following is the schedule of the senior option in Industrial Engineering:

Heat-Power Engineering 345a, b	4	4
Mechanical Laboratory 370, 371	4	3
Electrical Engineering 435, 436	2	2
Industrial Engineering, Lectures, 382a, b	2	2
Industrial Engineering Problems, Computing, 383a, b	2	2
Cost Finding 384	3 or 0	0 or 3
Corporation and Investment Finance 385	0 or 3	3 or 0
Industrial Relations 386	2	0
Elective	0	3
	19	19
Total number of hours each term	19	19

In addition to the schedule above, Seniors in Option B must take, as a requirement for graduation, the non-resident lectures in M.E. 391, and such non-resident lectures as may be assigned in E.E. 491. Announcement of these lectures will be made in advance.

OPTION C: NAVAL ARCHITECTURE AND MARINE ENGINEERING

The primary purpose of Option C is the training of men who intend to enter ship and marine engineering works, but it can be very profitably elected by men who may follow other lines of engineering.

In this option the application of the fundamental principles of engineering to the design and construction of all types of mercantile, naval, and other vessels, and their machinery, is productive of problems in statics, hydro-, aero-, and thermo-dynamics, the solution of which are of interest and value not only to the naval but to the mechanical engineer. These problems are fully dealt with from both theoretical and practical standpoints. The structural and economic values of the materials employed in the construction of vessels, their machinery, and equipment, are discussed and determined. The speed and powering of vessels are investigated along lines which the latest experimental research and the trained observation of the performance of vessels in actual service have indicated. The different types of propelling machinery and their adaptability to various types of vessels are critically examined.

The men taking the work are divided into groups of two, and to each group is assigned a distinct type of vessel having an installation of machinery different from that of the other groups, thus ensuring to the whole class a broad and comprehensive study of the latest practice. The principal features underlying the writing of specifications and contracts, as well as the organization of shipyards and engineering shops, are brought up for discussion throughout the course.

Following is the schedule of the senior option in Naval Architecture and Marine Engineering:

Mechanical Laboratory 370, 371	4	3
Naval Architecture 325a, b (lectures)	3	4
Naval Architecture 326a, b (office work)	3	2
Marine Engineering 327a, b	4	4
Electrical Engineering 435, 436	2	2
Elective	3	4
	<hr/>	<hr/>
Total number of hours each term	19	19

In addition to the schedule above, Seniors in Option C must take, as a requirement for graduation, the non-resident lectures in M.E. 391, and such non-resident lectures as may be assigned in E.E. 491. Announcement of these lectures will be made in advance.

OPTION D: GENERAL ENGINEERING DESIGN

The construction and operation of modern power and industrial plants and enterprises present a great variety of problems. While most of the problems confronting the mechanical engineer fall within his field, they often present aspects and features demanding a knowledge of the elements of structural and concrete work and of building construction. It is the purpose of this option to cover this border land between the distinct fields of civil and mechanical engineering.

The lectures and recitations of the option are devoted to a discussion of graphics and structural design relating to columns, beams, crane frames, girders, trusses, walls and floors, and to concrete construction as applied to foundations and industrial buildings. The drawing room work consists of deflection and continuous beam problems, the design of a plate girder, crane frame, roof truss and building bent, and problems in reinforced concrete. In addition problems covering the fundamental principles of engine and machinery balancing are taken up.

Following is the schedule of the senior option in General Mechanical Engineering:

Heat-Power Engineering 345a, b	4	4
Mechanical Laboratory 370, 371	4	3
Electrical Engineering 435, 436	2	2
General Engineering Design 318a, b	2	2
General Engineering Design, Drawing 319a, b	4	4
Elective	3	4
	<hr/>	<hr/>
Total number of hours each term	19	19

In addition to the schedule above, Seniors in Option D must take, as a requirement for graduation, the non-resident lectures in M.E. 391, and such non-resident lectures as may be assigned in E.E. 491. Announcement of these lectures will be made in advance.

OPTION E: WATER POWER ENGINEERING

The work of the water power engineer includes subjects from the fields of civil, mechanical, and electrical engineering. The special courses in this option aim to cover all topics essential to an intelligent cooperation between those engineers engaged in either the design, construction, or operation of water power developments or in the transmission and distribution of energy. Special emphasis is placed upon financial and economic phases of the work. Those elements of design and construction which affect economical operation are carefully discussed. Courses in electrical engineering cover the electrical power plant and the transmission and distribution engineering. The object is to present a complete picture of the problem from the water in the stream to the sale of energy to the ultimate consumer. As opportunity offers, the students in this option are taken on inspection trips to water power plants under construction or completed. These trips are not compulsory.

Those students who can spend five years are urged to combine this option with the course in electrical engineering. Since the present day power system usually includes thermal plants also, elective courses in the Department of Heat-Power Engineering are recommended. In the five-year period both the M.E. and E.E. degrees may be obtained. For 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 third year.

Heat-Power Engineering 345a, b	4	4
Mechanical Laboratory 370, 371	4	3
Electrical Laboratory 435, 436	2	2
Elec. Power Plant Design 441	3	0
Elec. Transmission and Distribution 463	0	3
Hydraulic Power Plants 336a, b	3	2
Hydraulic Power Plants, 337a, b	2	3
Engineering Geology Problems 503	1	0
Elective	0	2
	<hr/>	<hr/>
Total number of hours each term	19	19

In addition to the schedule above, Seniors in Option E must take, as a requirement for graduation, the non-resident lectures in M.E. 391, and such non-resident lectures as may be assigned in E.E. 491. Announcement of these lectures will be made in advance.

OPTION F: AUTOMOTIVE ENGINEERING

The wide variety of theoretical and practical problems arising in automotive design and operation, and the great industrial importance of this field of engineering, make the analysis of automotive machinery one of the most interesting of ways to introduce a student to engineering work. The "Automotive option" for seniors makes a study of the fundamentals of construction and operation of automotive vehicles. First term work studies the vehicle as a whole, the functions of steering, driving, braking; load distributions, framing, body design; and makes detailed analysis of power required for operation. Second term work studies power plant theory, design and operation. Two lectures are given a week, and three computing periods; the latter may also be used for drawing, or for laboratory work or demonstration.

Following is the schedule of the senior option in Automotive Engineering:

Heat-Power Engineering 345a, b	4	4
Mechanical Laboratory 370, 371	4	3
Electrical Laboratory 435, 436	2	2
Motor Car Construction, Lectures 328a, b	2	2
Motor Car Construction, Computing 329a, b	3	3
Elective	4	5
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Total number of hours each term	19	19

In addition to the above schedule, Seniors in Option F must take, as a requirement for graduation, the non-resident lectures in M.E. 391, and such non-resident lectures as may be assigned in E.E. 491. Announcement of these lectures will be made in advance.

ELECTIVE COURSES OF STUDY

A student may elect any course of study offered by any department of the University, provided he have the necessary preparation for that course and the approval of his class adviser.

Not more than four hours credit in Advanced Military Science, in addition to the required military training of the freshman and sophomore years, will be accepted toward meeting the requirements for the M.E. degree.

Following is a list of the technical electives given in the Sibley School of Mechanical Engineering, for seniors only:

Thesis 376	0 or 8	8 or 0
Steam Boiler and Boiler Plants 352	0	2
Steam Turbines 350	0	2
Steam Power-Plants 346a, b	3	3
Internal Combustion Engines 351	2	0
Pumping and Pneumatic Machinery 353	0	2
Refrigeration 354	2	0
Power-Plant Auxiliaries 355	0	2
Motor Car Construction 328a, b	2	2
Heating and Ventilating 378	2	0
Engineering Research 375	1 or 3	1 or 3
Applied Metallography 379	2	0
Hydraulic Power-Plants 338	2	0
Sibley Journal Credit 390	0 or 2	0 or 2
Industrial Relations 386	2	0
Advanced Industrial Engineering 387	1 or 3	1 or 3
Advanced Heat-Power Engineering 359	2	2
Graphical Computation and Representation 392	0	2
Ordnance Problems 333	2	2
A.S.M.E. Credit 393	0	1
Sibley Readings in English Literature 394	0	1
Advanced Kinematics and Kinetics 321	0	2
Materials Handling 322	0	2
Gearing 320	0	2

2. A FIVE-YEAR COURSE

The requirements for admission to this course are the same as those for the four-year course, and the work of the first two years is the same. Without detailing the liberal arts electives, the rest of the course is tentatively as follows. Minor changes can be made after personal conference with the director of the school.

III

Heat-Power Engineering 340a, b	3	3
Mechanical Laboratory 365, 366	4	4
Machine Design 316a, b	2	2
Machine Design Drawing 317a, b	2	2
Machine Shop 305	3	0
Economics 3	0	3
Electives	4	4
Total number of hours each term	18	18

IV

Electrical Engineering 415, 416	3	3
Industrial Engineering 380	2	0
Hydraulics 334	0	2
Mechanical Laboratory 370, 371	4	3
Heat-Power Engineering 345a, b	4	4
Electives	5	6
Total number of hours each term	18	18

V

Group Lectures	4	4
Group Design	2	2
Electrical Engineering 435, 436	2	2
Electives	10	10
	<hr/>	<hr/>
Total number of hours each term	18	18

3. A SIX-YEAR COURSE LEADING TO THE DEGREES OF A.B. AND 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.

A LIST OF THE COURSES OF INSTRUCTION FOR FRESHMEN

A description of the course of instruction for freshmen is given under the head **THE FRESHMAN YEAR**, beginning on page 38.

FOR SOPHOMORES, JUNIORS, AND SENIORS

The following courses in Physics, Chemistry, English, and Economics are given in the College of Arts and Sciences. The rest are given in the College of Engineering.

For information about examinations for the removal of conditions in Mathematics, Physics, or Chemistry, students are referred to the Announcement of the College of Arts and Sciences or told to inquire of the department in which the examination is given.

PHYSICS

28. General Physics. Theory and problems covering selected topics in wave motion, light, sound and heat. Required of candidates for the degree of M.E. or E.E. First term. Credit two hours. Prerequisites, Physics 6 and Mathematics 5a, b. Two classroom periods as arranged. *Rockefeller*, as arranged. Professor BIDWELL and instructors.

29. General Physics. Continuation of Physics 28. Selected topics in electricity and magnetism. Required of candidates for the degree of M.E. or E.E. Second term. Credit two hours. Prerequisites, Physics 6 and Mathematics 5a, b. Two classroom periods, as arranged. *Rockefeller*, as arranged. Professor BIDWELL and instructors.

34. Physical Measurements. Required of candidates for the degree of B.Chem., M.E., or E.E. Throughout the year, beginning either term. Credit two hours a term. One three-hour laboratory period a week. Prerequisites, Mathematics, 5a, b, and Physics 6. Physics 28 must precede or parallel the first half, and Physics 29 the second half, of Physics 34. Physical measurements in properties of matter, mechanics, heat, light, sound, magnetism and electricity; the adjustment and use of instruments of precision. Results and errors are carefully discussed. Professor RICHTMYER and instructors. Eight sections as assigned. *Rockefeller* 250.

CHEMISTRY

775. **Engineering Chemistry.** Repeated in second term. Two lectures a week. Credit two hours. Prerequisite courses Chemistry 101 and 105. Chemistry in its relation to engineering. Among the topics discussed in this course are heat insulators and refractories, wood preservation, boiler water softening, the corrosion of iron and steel, paints and varnishes, the refining of petroleum, the manufacture of coal tar products, etc. Mr. JOHNSON.

ENGLISH

2. **English.** Required of sophomores in Mechanical or Electrical Engineering. Throughout the year. Credit two hours each term. A course designed to give engineering students practice in writing and an intelligent interest in good books. Essays, reports, and assigned reading. Hours as assigned by class adviser.

ECONOMICS

3. **Modern Economic Society.** Repeated in second term. Credit three hours. A survey of the existing economic order, its more salient and basic characteristics, and its operation. Mr. HUDGINS.

ELECTRICAL ENGINEERING

Courses 415, 416, 435, 436, are required of all candidates for the M.E. degree. For a description of these courses, see pages 82-83 of this Announcement.

MACHINE CONSTRUCTION

(For courses in Wood Working and Introductory Engineering Laboratory, see Courses 102 and 103 under courses offered to freshmen, page 39.)

300. **Foundry Work.** Either term. Credit two hours. Five hours of work a week. Moulding, core making, mixing, and casting of metals; use of moulding machines. Demonstrations of large work and production in quantities. Messrs. PATTERSON and SANDERSON.

305a, b. **Machine Work.** Juniors. Credit three hours one term. Nine hours of work a week. Prerequisite courses 103, 102, and 300. 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, SCHALLOWITZ, and HODGES.

DRAWING

(For the course in Engineering Drawing and Descriptive Geometry, see Courses 123 and 124 under courses offered to freshmen, page 39.)

125. **Drawing.** This course is given in the College of Engineering, but is designed only for students registered as candidates for the degree of Bachelor of Chemistry. First term. Credit three hours. Eight hours of drawing a week. Lettering, mechanical drawing, working drawings, including conventions, standards, etc. Professor TOWNSEND and instructors. *East Sibley.*

MACHINE DESIGN

311. **Empirical Design.** Sophomores. First term. Credit three hours. Prerequisite courses 123, 124. Three three-hour drawing periods a week throughout the term, with time taken out of the drawing periods for recitations and lectures in connection with the work. The course consists of further work in mechanical drawing, the study and use of standard parts, the application of the empirical method to the proportioning of common machine elements, and the assembling of such elements. Assistant Professor KOSHKIN and Messrs. CROSS, INGERSOLL, and SHAUB.

313. Kinematics. Sophomores. Second term. Credit three hours. Must be taken with Course 314. Prerequisite courses, Physics 6, and 330 and 311. Three recitations a week throughout the term on the theory of mechanisms, instant centers, cams, gears, linkages, velocity and acceleration diagrams, etc. Professor ROGERS, Assistant Professor KOSHKIN and Messrs. CROSS, INGERSOLL, and SHAUB.

314. Kinematic Drawing. Sophomores. Second term. Credit two hours. Must be taken with Course 313. Prerequisite courses, Physics 6, and 330 and 311. Two three-hour drawing periods a week throughout the term, making drawing board application of the theory and principles of Course 313 in the construction of cams and gears, the solution of linkage and instant center problems, and the determination of velocity and acceleration diagrams, etc. Professor ROGERS, Assistant Professor KOSHKIN and Messrs. CROSS, INGERSOLL, and SHAUB.

315. Mechanical Technology as Related to Design. An elective primarily for Sophomores. First or second term. Credit two hours. Two recitations a week throughout the term. 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 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 processes to design work. Professor ALBERT and Mr. WEISS.

316a, b. General Machine Design Theory. Juniors. Throughout the year. Credit two hours each term. Prerequisite courses 311, 313, 314, 330, and 331. Two recitations a week throughout the year on the theoretical and practical applications of kinematics and mechanics to the design of machines and machine elements with due regard to such considerations as lubrication, cost, construction, appearance, etc. Professor ALBERT and Messrs. WEISS, MORRIS, and FOX.

317a, b. Machine Design. Juniors. Throughout the year for Mechanical Engineers; first term for those in Electrical Engineering. Must be taken in conjunction with 316a and b. Prerequisite courses, 311, 313, 314, 330, and 331. Credit two hours each term. Two three-hour drawing and computing periods a week. The student for the first time undertakes the design of a complete machine. Orderly systematic computations are insisted upon, and working drawings of the most important details and a finished assembly drawing of each machine are made. Professor ALBERT and Messrs. WEISS, MORRIS, and FOX.

318a, b. General Engineering Design. Required of seniors in Option D. Two recitations and discussion periods a week throughout the year. Credit four hours a term. Prerequisite courses 316 and 317. Elements of balancing of engines and machines; elements of structural work, of building construction, of foundations, and of reinforced concrete work. Graphical and algebraic determination of stresses, influence diagrams, structural members and details, trusses, building bents, and steel framing, plate girders, crane frames, chimneys, foundations, plain and reinforced concrete, etc. Professor ALBERT.

319a, b. General Engineering Design, Drawing. Required of seniors in Option D. Two lectures and two three-hour drawing periods a week throughout the year. Credit four hours a term. Prerequisite courses 316 and 317. Notes, computations, and drawing board work. Practical solution of certain problems discussed in 318; balancing of simple and multiple cylinder engine, deflection and continuous beam problems, design of plate girder, jib-crane frame, roof truss, building bent, reinforced concrete building element, dynamics of a hoist, etc. Professor ALBERT.

320. Gearing. An elective for seniors and for a limited number of juniors. Second term. Two lectures a week. Credit two hours. Prerequisite courses 316a, 371a, 330, and 331. History and development. Applications to machinery. Systems, with reference to tooth form and strength and wearing characteristics. Types of gears and tooth proportions. Gear rims, arms and hubs. Bearing reactions due to tooth pressures. Manufacture and operation of gears. Assistant Professor GARNER.

321. Advanced Kinematics and Kinetics. An elective for seniors and a limited number of juniors. Second term. Credit three hours. Prerequisite courses, 311, 313, and 314. Two lectures and one three-hour drawing period a week throughout the term. 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 so far as time permits. Assistant Professor KOSHKIN.

322. Material Handling. An elective for juniors and seniors. Second term. Credit two hours. Prerequisite courses, 313, 314. 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. Professor ALBERT.

323. Elements of Structural Work. An elective for juniors and seniors who are not taking or do not intend to take Option D. Either term. Credit, two hours. Prerequisite courses, 313 and 314. Two three-hour drawing periods a week throughout the term, with time taken out of drawing periods for lectures and discussions. Elements of structural steel work. Graphical and algebraic determinations of forces and stresses in trusses and frame work. Design of tension and compression members, trusses, girders, crane frames, etc. Professor ALBERT.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

325a. Ship Design and Construction. Seniors. First term. Credit three hours. Lectures. Derivation and conception of the "Elements of Form;" methods of laying down and fairing of the lines; discussion of the general arrangement plans, cargo space, passenger and crew accommodation and location of fuel spaces; the selection of the suitable type of propelling machinery and its location; application of hydrostatic principles to design of vessels, and methods of computing the quantities—displacement, centers of buoyancy and of gravity, metacenters, and the initial stability. The lines of selected vessels are laid down and the necessary computations performed in application of the lectures. Static and dynamical stability, rolling in a seaway, the steering and maneuvering power of vessels; elements of construction peculiar to the leading types of vessels; the materials employed, and the methods whereby the sizes or scantlings of the different members of the construction are determined; comparison of the rules of the various classification organizations; laws for tonnage, loadlines, subdivision and safety of life at sea, the influence they have on the efficient design of vessels and their effect on the commercial efficiency of the mercantile marine, domestic and foreign-going, of the United States. Professor McDERMOTT.

325b. Strength, Resistance and Propulsion. Seniors. Second term. Credit four hours. Lectures. The strength of vessels and the methods employed in the determination of the required amount of material, and its distribution so as to successfully withstand the forces of longitudinal bending, transverse racking, impact and other forces which act upon the structure in a seaway; the fundamental hydrodynamic principles involved in the resistance of vessels and of the propelling agents—chiefly that of the screw propeller; the determination of the required horsepower to overcome the resistance of the different types of vessels; the most suitable dimensions of screw propellers, the number, form, and strength of blades. The concluding lectures round up the course in reviewing the vessels in the completed state, and in discussing methods of estimating weights, cargo carrying and other efficiencies, and of estimating the cost of production. Professor McDERMOTT.

326a. Ship Design and Construction. Seniors. First term. Credit three hours. Office work. Three three-hour periods a week. Drawing and computations, in application of the subject matter of the lectures given in Course 320a, supplemented by personal discussion of the problems arising in the design of the individual vessels in hand. Professor McDERMOTT.

326b. **Strength, Resistance, etc.** Seniors. Second term. Credit two hours. Office work. Two three-hour periods a week. Drawing and investigations covering the work as discussed in the lectures of Course 320b. Professor McDERMOTT.

327a. **Marine Engineering, Applications.** Seniors. First term. Credit four hours. Prerequisite courses, 340a and b. Three lectures and one group discussion period a week. The lectures will deal primarily with the discussion of the problems confronting those responsible for the selection of the propelling machinery, which the experience of operation under service conditions, in the various geographic zones of commerce, has proved to be the most suitable for different types of vessels. Consideration is also given to the allowable space, weight, and cost, and economic operation, taking into account the characteristics of the personnel commonly available.

The underlying principles as applied in the peculiar service of marine machinery will be dealt with in full. *Engines*:—(1) Reciprocating steam engines; (2) steam turbines, direct drive and with reduction gears; (3) Diesel and similar types of engines; (4) combination machinery, including direct and alternating current types. *Condensing Equipment*:—Surface and jet condensers, with various types of air ejectors, air pumps, condensate pumps, and circulators. *General Auxiliaries*:—Bilge, ballast, sanitary and other pumps with their piping and manifolds. *Boilers*:—Scotch and watertube, superheaters, air, feed and oil heaters.

Each discussion group will comprise those working on similar installations of machinery. Each group, prepared with sketches and other information obtained from indicated sources, will discuss the details of their particular types of machinery more fully than time will permit in the lectures. Mr. KEARNEY.

327b. **Essentials of Marine Power Engineering.** Second term. Credit four hours. Three lectures and one office period a week. Lectures to center on established practice in the application of fundamental principles—thermal, mechanical, electrical, and hydraulic—which will give the best all-round efficiency, in the production and transmission of mechanical energy under the conditions which surround marine installations. The office work will parallel the lectures. The major part of the time will be spent in determining the more important values required in the choice and design of power development, including a comparative study of combustion; dimensions of boilers, furnaces, smoke-stacks; required heating and grate surfaces; performance of steam turbines; electric propulsion motors. Empirical design of important parts of the different types of engines, etc. Mr. KEARNEY.

AUTOMOTIVE ENGINEERING

328a, b. **Motor Car Construction.** Required of seniors taking the Automotive option. Credit two hours each term. Two lectures a week, illustrated. Two preliminary examinations, term problem, and a final examination. Either term's lectures may be used as a senior elective. First term work deals with design of chassis and body, and power requirements for operation; second term deals with power plant design and operation. Professor UPTON.

329a, b. **Motor Car Construction.** Required of seniors taking the Automotive option. Drawing room, computing, or laboratory work paralleling the lecture courses 328a, b. Two preliminary examinations and a final examination. Professors UPTON and GARNER.

MECHANICS OF ENGINEERING

330. **Theoretical and Applied Mechanics.** Sophomores. First term. Credit six hours. Five recitations and one computation period a week. Prerequisite courses, 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: friction; brakes, dynamometers; power, efficiency, and regulation of machines. Professors WOOD and GARRETT, Assistant Professors CORNELL and PERKINS, and instructors.

331. Strength of Materials. Sophomores. Second term. Credit five hours. Four recitations and one computation period a week. Prerequisite course 334. 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; combined loads; resultant stresses; curved bars; continuous beams; impact loads. Professors WOOD and GARRETT, Assistant Professors CORNELL and PERKINS, and instructors.

333. Ordnance Problems. Two lectures a week throughout the year. Credit two hours each term. Prerequisite courses 330 and 331. Lieutenant WOODBURY.

334. Hydraulics. For juniors in Mechanical Engineering. First or second term. Credit two hours. Prerequisite courses 330 and 331. Two recitations a week. Hydrostatics: pressures and centers of pressure. Hydrokinetics: general equation of energy; orifices, weirs, nozzles, Venturi meters, etc.; losses of head; flow in pipes and open channels. Hydrodynamics: forces on stationary and moving bodies. Professors SWITZER and GARRETT.

335. Hydraulics. For juniors in Electrical Engineering. Second term. Credit three hours. Prerequisite courses 330 and 331. Two recitations and one lecture a week. Hydrostatics: pressures and centers of pressure. Hydrokinetics: general equation of energy; orifices, weirs, nozzles, Venturi meters, etc.; losses of head; flow in pipes and open channels. Hydrodynamics: forces on stationary and moving bodies. Lectures on the essential features of water power plants. Professor SWITZER and others.

WATER-POWER ENGINEERING

336a, b. Hydraulic Power Plants. Required of seniors in Option E and may be taken as an elective by other seniors and graduates. Lectures throughout the year. Credit two hours each term. Prerequisite courses 330, 331, and either 334 or 335. 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 useable 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. A course in Geology 503 is given primarily for students taking this course. Professor SWITZER.

337a, b. Hydraulic Power Plant Problems. Required of seniors in Option E. Computation periods throughout the year. Credit two hours in first term, three hours in second term. Must be accompanied by course 336a, b. Problems are assigned involving the principles taken up in course 336a, b. 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.

338. Special Hydraulic Power Plant Problem. Elective for seniors and graduates. Either term. Credit two to five hours as arranged. Prerequisite course 336a, b, but may be taken at the same time as 336b. Selected topics from course

337 and other special problems to meet the individual needs of each student. Students who have completed course 337a, b or equivalent may elect this course for more advanced work. Professor SWITZER.

503. **Engineering Geology Problems.** First term. Credit one hour. Required of seniors in water power engineering. One lecture discussing geologic problems encountered in the water power field. Mr. LANGFORD.

HEAT-POWER ENGINEERING

340a, b. **Heat-Power Engineering.** Required of all juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 28, 29, 34 and 311, 313, 330 and 331. Two recitations and one lecture 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, binary locomobile, and other types of steam engines; types of air compressors. 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. Professor ELLENWOOD, Assistant Professor EVANS, and Mr. BRETT.

341. **Heat Engines and Auxiliaries.** Required of seniors in Civil Engineering. Either term. Credit three hours. Not open to students in Mechanical or Electrical Engineering. Prerequisite courses, Physics 6 (or the equivalent), Chemistry 101 and 105, C.E. 220 and 221. One lecture and two recitations a week. Elementary consideration of behavior of gases and vapors as applied to heat engines; study of air compressors, internal combustion motors, steam boilers, engines, turbines, and condensers; contractors' plants; cost of power; and similar topics. This course is recommended for all students who wish to obtain a general elementary knowledge of Heat-Power Engineering without great technical detail. For a two-term substitute course covering substantially the same ground, see 343a, b. Professor ELLENWOOD, Assistant Professor EVANS, and Mr. BRETT.

342. **Small Power Plants.** Elective. For seniors in Civil Engineering; not open to others. Second term. Credit two hours. Three recitations a week. Prerequisite course 341 or its equivalent. Discussion of the selection, operation, and maintenance of small steam engines, turbines, and internal combustion motors, particular attention being paid to ignition and carburetion; discussion of recent improvements in small engines, turbines, and boilers; reading of assigned technical articles in library books or magazines. Professor ELLENWOOD and Assistant Professor EVANS.

343a, b. **Heat-Power Engineering, for Electrical Engineers.** Required of juniors in Electrical 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, Physics 28, 29, 34 and 311, 330 and 331. The first term is an abridged treatment of substantially the same ground as Course 340. The second term is an abridgement of Course 345. The longer courses 340 and 345, may be substituted for 343a, b. Assistant Professor HOOK and Mr. WARD.

345a, b. **Heat-Power Engineering.** Required of all seniors in Mechanical Engineering. Throughout the year. Credit four hours a term. Prerequisite course 340a, b. Two lectures and two recitations a week. An extension of Course 340a, b. Steam engine valve gears and governors; evolution of engine types; steam turbine theory, development of present forms, economy, suitability for particular service; fuels and fuel resources; combustion, theoretical and in the actual furnace; boiler types, rating and performance, superheaters and economizers; stack losses; draft; heat transfer; feed water heaters, condensers, cooling towers and subsidiary apparatus; flow of vapors and gases; gas producers; internal combustion engines; refrigerating systems and apparatus. Consideration of the economical combination of elements in plants. Professor ERNSBERGER, Assistant Professor HOOK, and Mr. BRETT.

346a, b. Steam-Power Plants. Required of seniors in Option A. Lectures throughout the year. Credit four hours a term. Prerequisite courses 316, 317, and 340a, b, and must be accompanied by Course 345a, b. Steam prime movers, boilers, condensers, and auxiliary equipment; elements of design; selection; installation and operation; load curves; station factors; variable load economy; cost of equipment and power; principles of economic selection of machinery with respect to the load curves and local conditions; selection and arrangement of main units and auxiliaries; piping; coal and ash storage and conveying machinery; plant location; plant layout; comparison of steam and other types of plants; and similar considerations. Professor BARNARD and Assistant Professor CLARK.

347a, b. Designing and Drawing. Required of seniors in Option A, and not open to others. Throughout the year. Credit two hours a term. Must be accompanied by 346a, b. Two drawing periods a week. The practical solution of problems discussed in 346; Valve gears, governor characteristics, balancing, flywheel analysis, and similar problems; layouts of prime movers, boiler and furnace settings, and condenser apparatus; auxiliary equipment; piping and draft apparatus; power-plant project, based on the consideration of the load curve, station factors, economic performance and costs. Professor BARNARD and Assistant Professor CLARK.

350. Steam Turbines. Elective for seniors. Second term. Credit two hours. Prerequisite course 340a, b, or 343a, b. Two lectures a week. Classification of turbines and description of leading features of the various types; mechanical and thermal considerations underlying the action of steam in turbines; calculations involved in turbine design; discussion of building, erecting, and testing; adaptability to special conditions of service; economic results of the use of turbines in engineering practice. Assistant Professor CLARK.

351. Internal Combustion Engines. Elective. Seniors. First term. Credit two hours. Prerequisite courses, 316a, b, 317a, b, and 340a, b, or 343a, b. Two lectures a week. Fuels; general theory and salient points in the design and operation of internal combustion engines; description of existing commercial types, study of relative advantages, and consideration of questions of economy. Assistant Professor CLARK.

352. Steam Boilers and Boiler Plants. Elective. Seniors. Second term. Credit two hours. Prerequisite courses 316a, b, 317a, b, and 340a, b, or 343a, b. Lectures on fuels, combustion, types of boilers, general proportions, materials, design of boiler details, settings, stokers, accessories, and the equipment and arrangement of boiler plants. Assistant Professor HOOK.

353. Pumping and Pneumatic Machinery. Elective. Second term. Credit two hours. Prerequisite courses 340 or 343. Principles involved in the pumping of liquids and the compression of air and other gases; study of the various types of commercial machines commonly used. Professor ELLENWOOD.

354. Refrigeration. Elective. First term. Credit two hours. Prerequisite courses 316a, b, 317a, b, and 340a, b, or 343a, b. Refrigeration and refrigerating machinery. Professor ERNSBERGER.

355. Power Plant Auxiliaries. Elective. Second term. Credit two hours. Prerequisite courses 316a, b, 317a, b, and 340a, b, or 343a, b. Auxiliaries and instruments for steam power plants. Professor ERNSBERGER.

359. Advanced Heat-Power Engineering. Elective for those who have completed the equivalent of the design subjects in Senior Option A. Work and credit as arranged with Professors BARNARD, ELLENWOOD, and ERNSBERGER.

EXPERIMENTAL ENGINEERING

The work in this department is given in two divisions: (A) Courses that are required of all students for graduation, and (B) research courses that are elective.

A. MECHANICAL LABORATORY

360. **Manufacture and Properties of Engineering Materials.** Required of sophomores. First or second term. Credit three hours. Prerequisite courses Chemistry 101 and 105. Three lectures a week. Metallurgy of iron and steel, etc. Professor DIEDERICHS.

365. **Mechanical Laboratory—Properties of Engineering Materials.** Juniors. First term. Credit four hours for M.E. and three hours for E.E. students. Prerequisite courses 360, 330 and 331. One laboratory period a week. Mechanical strength of materials; tension, torsion, transverse, and compression tests; the variation of the mechanical strength with differences in composition or heat treatment; demonstration of different methods of tempering, annealing, forging, etc. The student is required to write and submit one report each week upon the experiment of the previous week. Professor DAVIS and instructors.

366. **Mechanical Laboratory—Introductory Experimental Engineering.** Juniors. Second term. Credit four hours for M.E. and three hours for E.E. students. Prerequisite courses, Mechanics 330 and 331, Chemistry 101 and 105, Physics 6, 28, 29, 34. One laboratory period a week as assigned; one written report a week. Calibration of indicator springs, steam gauges, thermometers, and dynamometers; flue gas analysis and calculations; viscosity and friction tests of lubricants on various testing machines; tests of heating values of coals; steam quality tests, with various forms of calorimeters; tests of ignition and carburation of gasoline engines, etc. Reports are required and must include all the data and results of the various tests, together with conclusions. The preparation of the report is considered an important part of the course. Professor DAVIS and instructors.

367. **Mechanical Laboratory.** For students in Chemistry. Second term only. Credit four hours. Prerequisite, Physics 6, 28, 29, 34. One laboratory period and one report a week. Principal tests on materials of construction; use, adjustment and calibration of common engineering instruments; testing of oil and lubrication; engine and boiler trials; study of refrigeration, etc. Professor GAGE and instructors.

370. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering. First term. Credit four hours. Prerequisite courses 366 and 340a, b. One laboratory period a week. Efficiency tests of gas and gasoline engines, steam injectors, steam turbine, blowing fan, hydraulic turbine, and centrifugal pump. Reports are required to be full and complete; and to include data and results of each test under consideration, and all information necessary to understand completely the machine tested and the methods used. Professor GAGE and instructors.

371. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering. Second term. Credit three hours. One laboratory period a week alternating with one computing period. A written report is required on each experiment. Detailed study of methods of testing and methods of computation in the following subjects: testing of engines and boilers, air compressors, ice machines; measurement of flow of water, etc. Reports required as in 370. Professor GAGE and instructors.

372. **Mechanical Laboratory.** Required of seniors in Electrical Engineering. First term. Credit two hours. Prerequisite courses, 366 and 343a, b. Selected experiments from Course 370. Professor GAGE and instructors.

B. ENGINEERING RESEARCH

375. **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 laboratories under the immediate direction of the members of this department, but which may be carried on in any department of the College under the general supervision of this department. Professors DIEDERICHS, SAWDON, UPTON, GAGE, and DAVIS, and Mr. EGBERT.

376. Thesis. Senior elective. Either or both terms. Maximum total credit eight hours. If a thesis is elected, permission to carry on the work connected with it must be obtained before October 31. The work on which the thesis is based must be original investigation. All theses are under the general supervision of the Department of Experimental Engineering. The thesis may be a theoretical investigation, a design, experimental work, or other research, and may be conducted under the guidance of members of any department of the College, but subject to the general supervision of this department. All students who are considering the preparation of a thesis should consult the head of this department during the junior year if possible. A bound copy of the thesis, in the original typewriting (not a carbon copy) on paper 8x10 $\frac{1}{4}$ inches in size must be deposited at the Director's office before May 15, with the approval of the professor in charge of the investigation. This copy becomes the property of the University, and is filed in the General Library, where it becomes accessible for reference. Professors **DIEDERICHS, SAWDON, UPTON, GAGE, and DAVIS.**

378. Heating and Ventilating. Elective. First term. Credit two hours. Prerequisite courses 340, 316, 317. Lectures and recitations covering the methods of design and of construction of various forms of ventilating and heating apparatus. Professor **SAWDON.**

379. Applied Metallography. Elective. First term. Credit two hours. Prerequisite courses 360 and 365. 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.**

INDUSTRIAL ENGINEERING

380. Industrial Organization. Required of all juniors in Mechanical and in Electrical Engineering. Either term. Credit two hours. Open only to upperclassmen. A course of lectures on modern industrial tendencies and the principles that underlie modern methods of production. The treatment includes not only the reasons for our changed methods of production but also discussion of the principal features of such industrial factors as factory legislation, factory welfare work, and modern methods of administration. Professor **KIMBALL,** Assistant Professor **BANGS** and Mr. **KNEEN.**

382a, b. Industrial Engineering. Required of all seniors in Option B. Two lectures a week throughout the year. Credit two hours a term. Prerequisite course 380. A discussion of modern time-keeping and cost-finding systems, methods of planning work and of insuring production, administrative reports, time and motion study, purchasing, etc.; plant location and arrangement; heating, lighting, and powering of plants, safety engineering, fire protection, and workmen's compensation laws. Must be accompanied by 383a, b. Professor **LEE,** Assistant Professor **BANGS,** and Mr. **KNEEN.**

383a, b. Industrial Engineering Problems. Required of all seniors in Option B. Six hours of drawing, computing or time study a week throughout the year. Credit two hours a term. Must be accompanied by 382a, b. Prerequisite courses 316 and 317. Design and layout of a plant, including the selection and location of the machinery necessary to manufacture some small assembly such as an automobile transmission. A rather detailed solution of problems in costing, planning, routing, scheduling, etc., in connection with this plant, including the development of organization charts and administrative and other forms. The work also includes a detailed study of the use of the Machine Rate method of distributing overhead expense and a thorough practice in the making and using of time studies and rate tables. Professor **LEE,** Assistant Professor **BANGS,** and Mr. **KNEEN.**

384. Industrial Engineering. Cost finding. Required of all seniors in Option B. Repeated in the second term. Credit three hours. Two recitations and one

computation period a week. A study of the fundamentals of accounting as found applicable to the work of the industrial engineer and the interpretation of results for use in manufacturing industries including the relations of cost finding systems to the general books. Assistant Professor BANGS and Mr. KNEEN.

385. **Corporation and Investment Finance.** Required of all seniors in Option B. Repeated in the second term. Credit three hours. A study of the financial problems of the business corporation from the points of view of the management and of the investor. Given by the Department of Economics of the College of Arts and Sciences. Mr. O'LEARY.

386. **Industrial Relations.** Required of seniors in the Industrial Option, elective for others. Two lectures a week during the first term. Credit two hours. Prerequisite course 380. 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 LEE, Assistant Professor BANGS, and Mr. KNEEN.

387. **Advanced Industrial Engineering.** Open to graduates and seniors who have completed the equivalent of 382 and 383. Professors KIMBALL, WELLS, and LEE.

ELECTIVE COURSES OUTSIDE THE CURRICULUM

390. **Sibley Journal Credit.** Undergraduate members of the Sibley Journal 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 Sibley Journal*, 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.

391. **Non-resident Lectures.** Required for graduation of all seniors in Mechanical 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.

392. **Graphical Computation and Representation.** Elective. Second term. Credit two hours. Prerequisite courses 316a, 317a, 340a. Slide rules; construction of net work charts and alignment charts for the solution of equations; representation of statistics; and derivation of empirical equations from experimental curve. Assistant Professor EVANS.

393. **A.S.M.E., Student Branch.** Members of the junior and senior classes in Mechanical Engineering may obtain one hour elective credit in one, or both years, by joining the Student Branch of the American Society of Mechanical Engineers, and by attending all of the Branch Meetings during the year. Application for membership should be made at the Director's office in October of each year, or to Professor S. S. Garrett, Honorary Chairman of the Student Branch.

394. **Sibley Readings in English Literature.** These readings are given by Professor M. W. Sampson, Head of the Department of English, one hour a week from Thanksgiving to the Easter Recess. They are open only to students in the College of Engineering. Credit one hour, second term. Students taking this work should register for Course 394, beginning of second term.

SCHOOL OF ELECTRICAL ENGINEERING

OUTLINE OF THE INSTRUCTION

The regular four-year course in Electrical Engineering is planned to give the thorough grounding in electrical engineering required by engineers connected with the design, construction, and operation of the electrical part of engineering properties. The curriculum forms a balanced course of study along broad lines, and a moderate amount of special work is provided for by elective courses. 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 nor 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 E.E., is offered. (See page 81.)

The instruction in Mathematics, Physics, Chemistry, Economics, and English is given in the College of Arts and Sciences. All other subjects in the regular curriculum are of an engineering nature and are given in the various departments of the Sibley School of Mechanical Engineering and the School of Electrical Engineering.

The instruction in the School of Electrical Engineering is distributed among the following departments: (1) Fundamental Elements, (2) Advanced Theory and Research, (3) Electrical Laboratories, (4) Electrical Design, (5) Electrical Communication, and (6) Electrical Transportation.

Instruction in Electrical Engineering begins in the junior year, and is based on the required courses in Physics and Mathematics. Emphasis is placed on the fundamental principles, and the subject is developed by elaborating these principles rather than by the use of mathematical equations. Both direct and alternating current circuits and machinery are taken up. The theory is given in experimental lectures and in recitations, and is applied to short problems in the computing room. In the laboratory, the student handles machinery, selects his own instruments and control apparatus, and makes the necessary tests to check the theoretical work.

The principal part of the work for seniors in Electrical Engineering is given in a balanced course in which advanced theory, problem work, design and laboratory practice are combined to give the student a broad training. The electrical laboratory, being flexible, lends itself particularly to the development of resourcefulness and initiative on the part of students. A moderate amount of special work is provided for by elective courses in electrical power stations, electrical design, electrical communication, electric traction, illumination, etc., in which the classes are small and more time is devoted to these subjects than is possible in the more general courses.

Instruction in Electrical Engineering is also provided for students in Chemistry, Civil Engineering, and Mechanical Engineering, and is adapted in each case to meet the respective requirements in those branches.

COURSES LEADING TO THE DEGREE OF ELECTRICAL ENGINEER

I. THE REGULAR FOUR-YEAR COURSE

The first two years of this course are the same as the first two years of the course for the degree of Mechanical Engineer. Specialization in Electrical Engineering begins in the third year. In the fourth year each student has a certain amount of latitude in selecting the particular branch of Electrical Engineering in which he may be most interested.

One hour of credit in the following schedules corresponds to about three hours of actual work a week for the term of fifteen weeks. Thus, from two and one-half to three hours a week of actual work in shop, laboratory, computing room, or drawing room count as one hour of credit, and each recitation hour assumes about two hours of outside preparation.

THE FRESHMAN YEAR

There is a single schedule of studies prescribed for all students alike, except as stated in Drawing, in the freshman year of the College of Engineering, whether they expect to graduate in civil, mechanical, or electrical engineering. That schedule is set forth in full under the head THE FRESHMAN YEAR, beginning on page 38.

THE SOPHOMORE YEAR

Mechanics 334, 336	6	5
Physics, Recitations, 28, 29	2	2
Physics, Laboratory, 34	2	2
Empirical Design 311	3	0
Kinematics, Recitations, 313	0	3
Kinematic Drawing 314	0	2
English 2	2	2
Engineering Chemistry 775	2 or 0	0 or 2
Foundry 300	2 or 0	0 or 2
Materials 360	0 or 3	3 or 0

Total number of hours each term 19 or 18 19 or 20

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 Circular of Information), and must also attend lectures in Hygiene and Preventive Medicine given once a week throughout the year.

THE JUNIOR YEAR

Electrical Engineering 411, 412	4	4
Electrical Laboratory 431, 432	2	2
Hydraulics 335	0	3
Heat-Power Engineering 343, 344	3	3
Mechanical Laboratory 365, 366	3	3
Machine Design, Recitations, 316a, b	2	2
Machine Design, Drawing, 317a	2	0
Machine Work 306	0	2
Industrial Organization 380	2	0

Total number of hours each term 18 19

THE SENIOR YEAR

Electrical Theory, Lectures, 421, 422	2	2
Electrical Theory, Recitations and Computing, 423, 424 . .	3	3
Electrical Laboratory 433, 434	3	4
Electric Power-Plant Design 441	3	0
Medium and High Frequency Phenomena 451	3	0
Mechanical Laboratory 372	2	0
Economics 3	0	3
Electives*	2	6
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Total number of hours each term	18	18

*At least four hours of the senior year electives must be in approved technical courses. The remaining hours may be taken in any department of the University provided the student has the necessary preparation and the approval of his class adviser.

ELECTIVE COURSES OF STUDY

A student may elect any course of study offered by any department of the University, provided he have the necessary preparation for that course and the approval of his class adviser.

Not more than four hours credit in Advanced Military Science, in addition to the required military training of the freshman and sophomore years, will be accepted toward meeting the requirements for the E.E. degree.

Following is a list of the technical electives to be given in the School of Electrical Engineering; they are for seniors and graduate students only:

Electrical Design 442	0	4
Electrical Communication Engineering 452	0	4
Industrial Applications and Control 461	0	2
Elements of Electric Railway Practice 462	2	0
Electrical Transmission and Distribution 463 (for M.E.) . .	0	3
Electrical Transmission and Distribution 465 (for E.E.) . .	0	3
Current Electrical Topics 471, 472	2	2
Engineering Mathematics 481, 482	2	2
Special Electrical Engineering Problems 483, 484	1-3	1-3
Special and Non-resident Lectures, 491 throughout the year	0	1

2. A SIX-YEAR COURSE LEADING TO THE DEGREES
OF A.B. AND 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 LIST OF THE COURSES OF INSTRUCTION

FOR FRESHMEN

A description of the courses of instruction for freshmen is given under the head THE FRESHMAN YEAR, beginning on page 38.

FOR SOPHOMORES

Sophomores in the four-year course in Electrical Engineering have the same studies as sophomores in the four-year course in Mechanical Engineering. A description of their courses will therefore be found in the List of the Courses of Instruction of the Sibley School of Mechanical Engineering, which begins on page 68.

FOR JUNIORS AND SENIORS

The courses in the following list are given in the School of Electrical Engineering. Information about other theoretical, electrical, and illumination courses will be found under Mathematics and Physics in the Announcement of the College of Arts and Sciences.

411, 412. Elements of Electrical Engineering. Required of juniors in Electrical Engineering. Throughout the year. Credit four hours a term. Prerequisite courses, Physics 28, 29, and 34; Mechanics 330, 331; and must be accompanied by Electrical Laboratory 431, 432. Three lectures and a recitation-computing period a week during the first term; two lectures, a recitation, and a computing period a week during the second term. The first term is devoted chiefly to a study of the fundamental physical relations in electric and magnetic circuits and their application to direct-current generators, motors, and distributing systems. The second term is devoted to a study of alternating-current circuits and machinery and their practical applications. Professor PERTSCH and instructors.

415, 416. Principles of Electrical Engineering. Required of juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 28, 29 and 34; Mechanics 330, 331. 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 physical 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. Professor PERTSCH and instructors.

417. Essentials of Electrical Engineering. Required of seniors in Civil Engineering and Chemistry. One term only; given both terms. Credit four 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.

421, 422. Advanced Electrical Theory. Required of seniors in Electrical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses 411, 412, and 431, 432. Two lectures a week. The work of the first term covers chiefly the laws of the electric and the dielectric circuits; representation of alternating currents by vectors and by complex quantities; the nature and effects of inductance and capacity; theory of transmission lines and transformers. The second term is devoted to the laws of the magnetic circuit, and the theory of transformers, generators, motors, and synchronous converter. The lectures are as far as possible correlated with the work in Course 423 and 424. Professor KARAPETOFF.

423, 424. Advanced Electrical Theory. Required of seniors in Electrical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses 411, 412, 431, and 432; must be accompanied by 421, 422. Two recitations and one computing period a week. Problems on the work covered by Course 421, 422. Professor KARAPETOFF and Messrs. RACE and MALTI.

431, 432. Electrical Laboratory for E.E. Juniors. Required of juniors in Electrical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 28, 29 and 34; Mechanics 330, 331 and must be accom-

panied by 411, 412. One laboratory period and report each week during both terms. Experimental work on the subjects taken up in 411, 412. Professor CHAMBERLAIN.

433, 434. **Advanced Electrical Laboratory.** Required of seniors in Electrical Engineering. Throughout the year. Credit three hours first term, four hours second term. Must be accompanied by 421, 422, 423, and 424. Laboratory experiment, one recitation, 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. The last eight weeks of the second term may be devoted to an elaborate piece of experimental work which is carried out as a research problem. Professor CHAMBERLAIN, Assistant Professor BASON, and instructors.

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 28, 29 and 34, Mechanics 330 and 331, and E.E. 415, 416. Similar in scope to 431, 432. Professor CHAMBERLAIN and instructors.

441. **Electrical Power-Plant Design.** Required of seniors in Electrical Engineering. First term only. Credit three hours. Prerequisite courses 411, 412 and 431, 432. Two lectures 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. Professor LINCOLN and Mr. TARBOUX.

442. **Electrical Design.** Elective for seniors in Electrical Engineering, Second term only. Credit four hours. Must be accompanied by 422 and 424. Three recitations and one computing period a week. A study of the fundamental principles underlying the design of direct- and alternating-current machinery. Professor LINCOLN and Mr. TARBOUX.

451. **Medium and High-Frequency Phenomena.** Required of seniors in Electrical Engineering. First term. Credit three hours. Two lectures and one laboratory or computing period a week. Prerequisites, courses 411, 412, 431, and 432 and concurrent with 421 and 423. 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 and Messrs. MCLEAN and NORTHROP.

452. **Electrical Communication Engineering.** Elective. Open to seniors in Electrical Engineering. Second term. Credit four hours. Two lectures, one laboratory period and one report a week. Prerequisites, courses 411, 412, 431, 432, 421, 423, and 451. Consideration of problems, apparatus, and measurements, particularly applicable to electrical communication engineering. Professor BALLARD and Messrs. MCLEAN and NORTHROP.

461. **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.

462. **Elements of Electric Railway Practice.** Elective for seniors. First term only. Credit two hours. Prerequisite courses 411, 412 and 431, 432. One recitation and one computing period a week. Apparatus and construction involved in a modern railway system, including cars and car equipment, overhead and track construction, and other topics of similar character. Some attention is devoted to the relation of electric railways to the public and to finance. Professor CHAMBERLAIN.

463. **Electrical Transmission and Distribution.** Required of M.E. seniors taking the Hydraulic Option. Second term only. Credit three hours. This course is designed to give an understanding of the fundamentals of electrical transmission and distribution. Prerequisites, 411, 412, 431 and 432 or equivalent. Mr. TARBOUX.

465. **Electrical Transmission and Distribution.** Elective for E.E. seniors. Second term only. Credit three hours. This course is designed to give an understanding of the fundamentals of elective transmission and distribution. Prerequisites, 411, 412, 431, 432, 421, 423. Must be accompanied by 422 and 424. Professor LINCOLN and Mr. TARBOUX.

471, 472. **Current Topics in Electrical Engineering.** Elective. Open to seniors and graduate students in Electrical Engineering. First or second term, or both. Credit two hours a term. Two one-hour seminar periods a week devoted to the presentation and discussion of noteworthy articles in current electrical literature. The purpose of the course is two-fold: (1) To familiarize the student with the latest development in the various branches of electrical engineering; and (2) to afford some practice in abstracting, presenting, and critically discussing engineering topics of timely interest. Professor PERTSCH.

481, 482. **Engineering Mathematics.** Elective. Open to seniors and graduate students only. 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. Professor KARAPETOFF and Mr. MALTI.

483, 484. **Special Electrical Engineering Problems.** Open to seniors. 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.

491. **Non-resident and Special Lectures.** Elective. 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.

Seminary in Electrical Engineering. For graduate students. Seniors may attend by special permission but no credit will be given. Conducted by Professor KARAPETOFF.