CORNELL UNIVERSITY
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Announcement of The College of Engineering

Comprising

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

1922-23

Ithaca, New York
Published by the University
February 15, 1922

CALENDAR

1922-23

First Term

1922		
Sept. 12,	*Tuesday*,	Entrance examinations begin.
Sept. 20,	*Wednesday*,	Registration and assignment of new students.
Sept. 21,	*Thursday*,	
Sept. 22,	*Friday*,	Registration and assignment of old students.
Sept. 23,	*Saturday*,	Assignments concluded.
Sept. 25,	*Monday*,	Instruction begins at 8 a. m.
Oct. 13,	*Friday*,	Last day for payment of tuition fee for the first term.
Nov. 30,	*Thursday*,	Thanksgiving Day: *a holiday*.
Dec. 21,	*Thursday*,	Instruction ends at 1 p. m.

Christmas Recess until Thursday, Jan. 4, 1923, at 1 p. m.

1923		
Jan. 4,	*Thursday*,	Instruction resumed at 1 p. m.
Jan. 11,	*Thursday*,	FOUNDER'S DAY: *Convocation*.
Jan. 27,	*Saturday*,	Instruction ends.
Jan. 29,	*Monday*,	Term examinations begin.
Feb. 7,	*Wednesday*,	Term ends.
Feb. 8,	*Thursday*,	*A holiday*.

Second Term

Feb. 9,	*Friday*,	Registration of all students.
Feb. 10,	*Saturday*,	
Feb. 12,	*Monday*,	Instruction begins at 8 a. m.
March 2,	*Friday*,	Last day for payment of tuition fee for the second term.
April 4,	*Wednesday*,	Instruction ends at 1 p. m.

Spring Recess until Wednesday, April 11, at 1 p. m.

April 11,	*Wednesday*,	Instruction resumed at 1 p. m.
June 5,	*Tuesday*,	Term examinations begin.
June 13,	*Wednesday*,	End of term examinations.
June 20,	*Wednesday*,	COMMENCEMENT.

CORNELL UNIVERSITY'S MAIN QUADRANGLE
The Principal Buildings of the College of Engineering are here shown at the farther end of the Quadrangle.

CORNELL UNIVERSITY

Cornell University was incorporated under the laws of the State of New York on April 27, 1865, and was opened on October 7, 1868.

By the Morrill Land Grant Act (July 2, 1862) Congress granted to each of the several states public lands the proceeds from the sale of which should be used to establish at least one institution of higher learning in each State. By the act of April, 27, 1865, the Legislature of New York State granted its share of these lands and a charter to Cornell University.

To this combination of federal and state beneficence, Ezra Cornell added the resources of his own private fortune, and through his effort the University was established.

With the exception of the New York State Colleges of Agriculture and of Veterinary Medicine, which were founded and are supported almost entirely by the New York State Legislature with the aid of the federal government, the University is supported in the main by the income from the original endowment and from the funds donated subsequently by various benefactors.

The University is at Ithaca, New York, a city of seventeen thousand inhabitants, located at the south end of Cayuga Lake. The University Campus, lying high on the slope of the hills east of the town, commands a view of the western hills and of the valley and lake which is of exceptional beauty.

The University, with an instructing staff numbering about eight hundred, and a student enrollment of more than five thousand, is composed of the Graduate School (degrees A.M., M. C. E.., M. M. E., M. E. E., Ph.D., etc.) and the following colleges:

The College of Arts and Sciences (degree A. B., B. Chem.),
The College of Law (degree LL. B.),
The Medical College (degree M. D.),
The New York State Veterinary College (degree D. V. M.),
The New York State College of Agriculture (degree B. S.),
The College of Architecture (degree B. Arch. and B. S. in Arch.),
The College of Engineering, comprising the School of Civil Engineering, (degree C. E.); the Sibley School of Mechanical Engineering (degree M. E.); and the School of Electrical Engineering (degree E. E.).

The students of the College of Engineering, constituting more than one-fifth of the total number in the University, are thus associated with the Faculties and students of other colleges, and may receive intellectual stimuli in many fields other than engineering, thus being broadened and given a clearer understanding of the relation of engineering to other human activities and interests.

THE COLLEGE OF ENGINEERING

Instruction in engineering was instituted at Cornell University at its founding, and the College of Mathematics and Engineering and the College of Mechanic Arts were opened when instruction began, in 1868. The former of these consisted of two schools, namely, the School of Mathematics and the School of Engineering. In 1871 Mathematics was separated from Civil Engineering, and Architecture was added to it, thus forming the College of Civil Engineering and Architecture. In 1873 Architecture was separated from Civil Engineering, and the latter existed as a department 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 Land Grant Act on which the University was founded. In 1871 Mr. Hiram Sibley, ot Rochester, erected a special building known as Sibley College to house the College of Mechanic Arts, gave liberally to its equipment, and endowed the Sibley Professorship of Mechanic Arts to the amount of fifty thousand dollars. During the years 1870 to 1887, Mr. Sibley gave more than $180,000 for the erection and equipment of buildings, workshops, and laboratories. In 1885, in recognition of the growth and importance of mechanical engineering the college was renamed The Sibley College of Mechanical Engineering and Mechanic Arts. The benefactions of Mr. Hiram Sibley have been continued by his son, Mr. Hiram W. Sibley, who has given approximately $170,000 for additional buildings and equipments.

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 has been developed within that college.

In 1919 the Board of Trustees, recognizing that the fundamentals of all engineering are common, voted to consolidate all engineering instruction at Cornell in one institution to be called The College of Engineering, and this action of the Board has now been carried into effect. The combined college consists of 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 been developed from the Department of Electrical Engineering, formerly a part of Sibley College. The educational changes and advancements made possible by the consolidation are described in the subject matter following. There are obvious gains in administration, and it is believed that the new college will serve the nation more efficiently than ever and that, through this combination, engineering education at Cornell University has been greatly advanced and brought into harmony with the progress of industry.

FACULTY

The College of Engineering

ADMINISTRATION

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

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 Hydraulics.
FRANCIS JOSEPH SEERY, S. B., Professor of Civil Engineering.
SAMUEL LATIMER BOOTHROYD, M. S., Professor of Astronomy.
MILES ALBION POND, Ph.B., Assistant Professor of Civil Engineering.
ERNEST WILLIAM RETTGER, Ph.D., Assistant Professor of Mechanics of Engineering.
CHARLES LEOPOLD WALKER, C. E., Assistant Professor of Sanitary Engineering and Secretary of the College Faculty.
PAUL HALLADAY UNDERWOOD, C. E., Assistant Professor of Surveying.
EARLE NELSON BURROWS, M. C. E., Assistant Professor of Bridge Engineering.
WALTER L. CONWELL, C. E., Assistant Professor of Highway Engineering.
LEONARD ALEXANDER LAWRENCE, Assistant Professor of Surveying.
LEONARD CHURCH URQUHART, C. E., Assistant Professor of Bridge Engineering.
HERBERT HENRY SCOFIELD, M. E., Assistant Professor of Testing Materials.
JOHN L. WEBER, C. E., Assistant Professor of Hydraulics.
CARL CRANDALL, C. E., Assistant Professor of Railroad Engineering.
JOHN EDWIN PERRY, B. S. in C. E., Assistant Professor of Railroad Engineering.
ERIC V. HOWELL, M. C. E., Instructor in Civil Engineering.
CHARLES EDWARD O'ROURKE, C. E., Instructor in Bridge Engineering.
CLAUDE M. PENDLETON, C. E., Instructor in Bridge Engineering.
EDWIN FRANK CHOBOT, C. E., Instructor in Surveying.
THAD LUMPKIN COLLUM, C. E., Instructor in Bridge Engineering.
HOWARD ERWIN WHITNEY, C. E., Instructor in Civil Engineering.
GERALD CROFOOT WILLIAMS, C. E., Instructor in Surveying.

SIBLEY SCHOOL OF MECHANICAL ENGINEERING

HERMAN DIEDERICHS, M.E., Director of the School and Professor of Experimental Engineering.
ALBERT WILLIAM SMITH, B.M.E., M.M.E., Professor of Mechanical Engineering, Emeritus.
GEORGE ROBERT MCDERMOTT, Professor of Structural Design.
WILLIAM NICHOLS BARNARD, M.E., Professor of Power Engineering.
EDGAR HARPER WOOD, M.M.E., Profesor 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., 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., Assistant Professor of Experimental Engineering.
MYRON A. LEE, M.M.E., Assistant Professor of Machine Design.
FREDERICK GEORGE SWITZER, M.M.E., Assistant Professor of Hydraulics.
FRED STILLMAN ROGERS, M.E., Assistant Professor of Machine Design.
CLARENCE ELLSWORTH TOWNSEND, M.E., Assistant Professor of Machine Design.
ADAM CLARKE DAVIS, JR., M.E., Assistant Professor of Experimental Engineering.
ROY EDWARDS CLARK, M.E., Assistant Professor of Power Engineering.
WALTER RODNEY CORNELL, B.S., C.E., Assistant Professor of Mechanics of Engineering.
ENOCH FRANCIS GARNER, M.E., Assistant Professor of Machine Design.
WARREN HOWARD HOOK, M.E., Assistant Professor of Power Engineering.
HOMER JAMES HOTCHKISS, A.M., M.M.E., Instructor in Mechanics of Engineering.
WILLIAM EMERSON MORDOFF, M.E., Instructor in Experimental Engineering.
CHARLES BEVERLY BENSON, C.E., Instructor in Mechanics of Engineering.
STEPHEN FARRELL CLEARY, Instructor in Machine Design.
LESLIE A. FENNER, M.E., Instructor in Machine Design.
JAMES BONIFACE LAVIN, B.S., Instructor in Machine Design.
JOHN H. COLLINS, B.E., Instructor in Machine Design.
ROLFE SHELLENBERGER, B.S., Instructor in Machine Design.
JOHN ROBERT BANGS, JR., Instructor in Industrial Engineering.
ALBERT R. NOLIN, M.E., Instructor in Machine Design.
DEMETRIUS W. GRISWOLD, Instructor in Machine Design.
WILLIAM B. GREGORY, Instructor in Experimental Engineering.
STANLEY MOTT-SMITH, M.E., Instructor in Experimental Engineering.
HAROLD CHARLES PERKINS, M.E., Instructor in Mechanics of Engineering.
AXEL MARTIN LARSON, B.S.E., Instructor in Machine Design.
WILLIAM COOK ANDRAE, M.E., Instructor in Experimental Engineering.

EUGENE STANLEY AULT, M.E., Instructor in Machine Design.
RALPH R. BUSH, M.E., Instructor in Machine Design.
ELLIOT BOUGHTON SMITH, Instructor in Machine Design.
EDWARD STERLING DAUGHERTY, B.S., Instructor in Machine Design.
PAUL BURNS EATON, M.E., Instructor in Machine Design.
FREDERICK CHARLES EVANS, M.E., Instructor in Power Engineering.
KNEELAND ABRAM MERENESS, M.E., Instructor in Machine Design.
NAIRNE FORSYTH WARD, M.E., Instructor in Machine Design.
JAMES HARRY SCOFIELD, B.S., Instructor in Machine Design.
HERBERT ALBERT JULIUS WEISS, M.E., Instructor in Machine Design.
RUSSELL CLOUGH KINSMAN, B.S. in E.E., Instructor in Machine Design.
PETER CHERDANTZEFF, M.E., Instructor in Heat-Power Engineering.
RAYMOND TERRY STARR, Instructor in Experimental Engineering.
WALTER WILLIAM WERRING, Instructor in Experimental Engineering.
ARTHUR STEWART GRISWOLD, Instructor in Experimental Engineering.
GEORGE HAIGH ACKER, Instructor in Experimental Engineering.
CHARLES KARLETON MILLER, Instructor in Experimental Engineering.
WILLIAM LESTER LEWIS, Instructor in Heat-Power Engineering.
CLAUDE MYRON BIGELOW, Instructor in Heat-Power Engineering.
ERNEST LATHROP THEARLE, Instructor in Mechanics of Engineering.
KARL DAWSON WOOD, Instructor in Mechanics of Engineering.
BERNHARD EDWARD FERNOW, A.B., M.E., Instructor in Experimental Engineering.

Assistants

DANA BUSH GREEN, Foreman in the Machine Shop.
CHARLES E. PATTERSON, Foreman in the Foundry.
WALTER LISTON HEAD, Foreman in the Blacksmith Shop.
LEROY HOOPER, Foreman in the Pattern Shop.
HOWARD STANLEY BUSH, Assistant in the Pattern Shop.
STEWART ARTHUR WILCOX, Assistant in the Pattern Shop.
ERNEST STANLEY YAWGER, Assistant in the Pattern Shop.
GEORGE SANDERSON, Assistant in the Foundry.
BURDETTE N. HOWE, Assistant in the Machine Shop.
RUDOLPH SCHALLOWITZ, Assistant in the Machine Shop.
HARRY HERRICK, Assistant in the Blacksmith Shop.

SCHOOL OF ELECTRICAL ENGINEERING

———— ————, Director of the School and Professor of Electrical Engineering.
VLADIMIR KARAPETOFF, M.M.E., C.E., Professor of Electrical Engineering.
JOHN GEORGE PERTSCH, JR., M.E. (in E.E.), Assistant Professor of Electrical Engineering.
WILLIAM CYRUS BALLARD, JR. M.E. (in E.E.), Assistant Professor of Electrical Engineering.
ROBERT FRANKLIN CHAMBERLAIN, M.E. (in E.E.), Assistant Professor of Electrical Engineering.
GEORGE FRANCIS BASON, B.E., M.E. (in E.E.), Instructor in Electrical Engineering.

BURDETTE KIBBE NORTHROP, M.E. (in E.E.), Instructor in Electrical Engineering.
CLARENCE HERSCHEL DAGNALL, S.B., Instructor in Electrical Engineering.
ALBRECHT NAETER, B.S. in E.E., Instructor in Electrical Engineering.
ROY EDWARD HEFFNER, A.B., B.S., Instructor in Electrical Engineering.
FRED SCHMIDT HOEFER, B. S., Instructor in Electrical Engineering.
WILLIAM LITTELL EVERITT, Instructor in Electrical Engineering.
THEODORE SUMNER FARLEY, Instructor in Electrical Engineering.
LELAND HALSEY HILL, Instructor in Electrical Engineering.
HUBERT HAWLEY RACE, Instructor in Electrical Engineering.
JOSEPH GALLUCHAT TARBOUX, B.S. in E.E., Instructor in Electrical Engineering.
CYRIL J. WERTZ, B.S. in E.E., Instructor in Electrical Engineering.
JAMES STEWART ARBUCKLE, B.S. in E.E., Instructor in Electrical Engineering.
WESLEY BENNETT BROWN, M.E. (in E.E.), Instructor in Electrical Engineering.
FRANK BUTLER DOYLE, B.S. in E.E., Instructor in Electrical Engineering.
ROBERT CHARLES GORHAM, B.A., Instructor in Electrical Engineering.
FREDERICK DEWEY JACKSON, B.S. in E.E., Instructor in Electrical Engineering.
ANDREW SIMPSON, A.B., Instructor in Electrical Engineering.
JOHN HALL SKEEN, B.S. in E.E., Instructor in Electrical Engineering.

OTHER OFFICERS

———— ————, Recorder.
LULU M. MARKELL, Secretary to the Dean.
LOUISE WHITTAKER, 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.
LENA GERTUDE MARSH, Librarian of the Sibley School of Mechanical Engineering.
———— ————, 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.
GEORGE ALFRED CULLIGAN, Mechanician in the School of Electrical Engineering.
PAUL CULLIGAN, Assistant Mechanician in the School of Electrical Engineering.

THE PURPOSE OF INSTRUCTION

The various Schools of the College of Engineering were organized, primarily, to teach the fundamental principles, theoretical and practical, that underlie the various branches of engineering. In addition to this, there is included such work 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. Since the time devoted to this is, however, only a minor part of the entire time of the course, it follows that specialization cannot be carried very far. In fact, the Faculty of Engineering generally holds 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 none too long for this purpose. Hence, the pressure to introduce narrow 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 commercial engineering practice, to the end that he may thus become familiar with problems encountered in modern engineering and with commercial 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.

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 preferable that the student before entering the College should have a thorough general education, and if possible, the training of a liberal college course. Those who have not had this broader education should, if possible, devote one or two years to subjects taught in the College of Arts and Sciences. 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 described on pages 26 and 27. The entrance requirements for this course demand less mathematical preparation than is specified for the four-year engineering course, but the student must meet the entrance requirements specified by the College of Arts and Sciences.

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.

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 year 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 year 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 another year. At the beginning of the third year the courses for mechanical and electrical engineering students differentiate, and thereafter these students commence to specialize in their particular branches.

For the Courses of Instruction covering the work of the first year, common to all engineering students, see pp. 30-32 of this Announcement. The work of the last three years is outlined on pp. 34-54 for civil engineers, pp. 54-75 for mechanical engineers and on pp. 76-82 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, location, and construction of roads, railroads, canals, and water works; the construction of foundations under water and on land, and of superstructures and tunnels; the survey, improvement, and protection of coasts, and the regulation of rivers, harbors, and lakes; the astronomical determination of geographical co-ordinates 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 laws 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 railroad engineers and surveyors, sanitary engineers, water-works engineers, highway engineers, city engineers

and managers, bridge designers and contractors, structural 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 eventually shows the proper qualifications he may rise 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 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, especially designed for its purpose. In addition to the laboratories and museums, the building contains the working library of the School, aggregating about four thousand volumes, reading rooms, class rooms, and drafting rooms. The astro-

nomical 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 Fall Creek Gorge, near Lincoln Hall.

The Sibley School of Mechanical Engineering receives 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 three stories 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 three drying ovens; scales, slates, and plate-glass 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, and time of set, and constancy of volume by normal and accelerated tests; also standard sieves for determining fineness, and apparatus for determining voids in sand and stone.

The Testing Laboratory for materials of construction and for full-sized members, joints, and structures. 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; 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 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 fireproof building used entirely for testing asphalts, tars, etc. This portion of the laboratory is equipped with a gas drying oven, electric oven, Engler viscosimeter, molds and float for float 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 ¼ to 12 feet a second.

Outdoors there are two parallel concrete flumes with water supplied from Beebe Lake independently of the large canal. These are 2 feet wide, 2½ 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 standpipe 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.

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 37½° 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 Astromonical Observatory has been replaced by a new observatory 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 a 12-inch equatorial telescope, in addition to a comparator room and two constant temperature rooms for geodetic laboratory work.

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 12-inch equatorial telescope which will soon be completely equipped, a 4-inch portable equatorial telescope, as well as sextants, surveyor's transits, clocks, collimators, micrometers, spherometer, level-trier, 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.

For the investigation of measures of length and coefficients of expansion a 4-meter comparator is available, being housed in a specially constructed room in the basement of the observatory. A 4-foot comparator is used for the study of leveling rods. It is planned to remove the 100-meter field comparator from the site of the former observatory and to construct one of 50-meters at the new building, for the study of tapes under field conditions. Plumbing tubes of the Repsold type transfer the underground marks to the micrometer microscopes. Invar tapes standardized at the Bureau of Standards are used for comparison. A 100-foot tape comparator is located on the fourth floor of Lincoln Hall.

The standards of length include: 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 Genévoise; precision thermometers by Tonnelot and Boudin, standardized at the International Bureau in Paris; a small comparator for calibrating thermometers; and the usual auxiliary apparatus.

Mechanician's Room. This room is used in connection with the laboratories for the construction of special apparatus and instruments 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 of the School of Civil Engineering contain the following collections: (1) The Muret collection of models in descriptive geometry and stone cutting. (2) The DeLagrave 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 movable 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, altmeters, hypsometers, odometers, meteorological instruments, etc., with a large number of auxiliary and special instruments such as planimeters, pantographs, elliptographs, calculating devices, and computing machines.

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 300,000-lb. machine, a Riehlé 100,000-lb. machine, a 200,000-lb. Emery hydraulic machine, together with several other machines varying in capacity from 10,000 to 100,000 pounds. For transverse tests there is a Riehlé machine of 200,000 pounds capacity and a Fairbanks machine of 10,000 pounds capacity. There are two Thurston autographic torsion machines, one Olsen torsion machine of 200,000 inch-pounds capacity, and two Upton-Lewis fatigue testing machines. The equipment includes extensometers a cathetometer, gas furnace, 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 Troy, a Wickes Bros. automatic engine, and a three-cylinder, compound, Laidlaw-Dunn-Gordon steam pump capable of delivering 300 gallons of water a minute against a pressure of 300 lbs. a square inch. There are three surface condensers which may be connected with these engines as desired. There is a 35-kw. horizontal Curtis turbine and a 15-kw. De Laval turbine which drives electric generators and may be run condensing or non-condensing.

A two-stage steam-driven Ingersoll-Rand compressor and three air-brake pumps of different types, together with meters, nozzles, and other instruments, are 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, and one 100-HP Babcock and Wilcox water-tube boiler of the standard type both of which are fitted with internal superheaters. There is also one 80-HP Heine water-tube boiler and one 25-HP Roberts safety boiler connected with a Foster independent superheater. 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 includes an 8-HP Westinghouse gas engine, an 8-HP Olds gasoline engine, an 8-HP Fairbanks gasoline engine, a 6-HP "Ingeco" oil engine, a 6-HP Hornsby-Akroyd oil engine, a 15-HP Hornsby Akroyd oil engine, a 16-HP Acme gas engine run on producer gas from a 15-HP suction gas-producer, and a 30-HP three-cylinder Westinghouse gas engine with gas producer and a 45-HP McIntosh & Seymour Diesel engine direct connected to a D. C. generator. Hot air engines are represented by a Rider and an Ericsson engine. This engine equipment is chosen to give as great a variety as possible in the fuels used, types of governing, etc.

The supply of testing instruments includes several outside spring indicators, optical indicators, a manograph and a Midgley indicator. For temperature measurements there are available high-reading thermometers and pyrometers of the expansion and electrical types.

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 measuring 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, 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 moulding machines of different types selected to illustrate the production of castings of various kinds at lowest labor cost.

The Forge Shop has the usual equipment of standard forges and small tools, as well as a modern drop-forge plant. Forging by the drop-hammer method, and power press work are demonstrated and discussed.

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.

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 truck with motors 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 Wireless Laboratory. This laboratory has a 5-kilowatt, 500-cycle sending set, also a 2-kilowatt, 60-cycle set, both being equipped with rotary and also with quenched spark gaps. The receiving equipment includes crystal, audion, and other detectors. The aerial is about 500 feet long and, by means of some of the new supersensitive apparatus, a receiving range of 5000 miles is obtained.

The power for the various laboratories is obtained from the University Hydro-electric Plant, which contains large three-phase alternators, direct-driven by both impulse and reaction water-wheels. This plant is complete in every respect and is used for inspection.

LIBRARIES

Besides the General Library of about 675,000 volumes, Cornell University maintains **department libraries,** for the School of Civil Engineering in Lincoln Hall, and for the Schools of Mechanical and Electrical Engineering in Sibley Dome. These libraries are under the supervision of the school authorities and in them may be found the standard reference and text books as well as 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 engineering library of the late Emil Kuichling, A.B., C.E., of Rochester, New York. The collection was presented to the College of Civil Engineering of Cornell University in 1919 by Mrs. Sarah L. Kuichling, and was accompanied by a gift of one thousand dollars, the income from which is to be used to extend the collection and to maintain it as a separate library.

FELLOWSHIPS, SCHOLARSHIPS, PRIZES, AND LOAN FUNDS

More particular information under this head is given in certain publications of the University. *The Announcement of the Graduate School* contains such

information about the fellowships and graduate scholarships; the *General Circular of Information* tells all about the University Undergraduate Scholarships; particulars about the scholarships awarded by the State of New York may be found in the *General Circular* or obtained from the State Commissioner of Education of Albany; any information about the loan funds which is not to be found in the *General Circular* may be obtained upon application to the Secretary of the University; and the University issues a special pamphlet entitled *Prize Competitions*.

FELLOWSHIPS AND GRADUATE SCHOLARSHIPS

(Open to Graduate Students in the School of Civil Engineering)

The McGraw Fellowship, of an annual value of $400 and exempting the holder from payment of the tuition fee, is offered to graduates of the School of Civil Engineering and similar schools of equivalent rank.

A Graduate Scholarship of an annual value of $200 is offered under similar conditions. Holders of the graduate scholarship are also exempt from the tuition fee.

The Elon Huntington Hooker Fellowship in Hydraulics, of the annual value of $510, is offered for research in experimental hydraulics in Europe or America. This scholarship was founded in 1919 by E.H. Hooker, a graduate of the School of Civil Engineering of the Class of 1894; it is open to graduates of the School of Civil Engineering and similar schools of equivalent rank. (Not available in 1922-23.)

(Open to graduate students in the School of Mechanical Engineering)

The Sibley Fellowship; annual value $400, and exempting the holder from the payment of the tuition fee.

The Edgar J. Meyer Memorial Fellowship; annual value $400, and exempting the holder from the payment of the tuition fee.

(Open to graduate students in the School of Electrical Engineering)

The Charles Bull Earle Memorial Fellowship; annual value $400, and exempting the holder from the payment of the tuition fee.

More complete information concerning fellowships and graduate scholarships may be secured upon application to the Dean of the Graduate School. See also the *Announcement of the Graduate School.*

UNDERGRADUATE SCHOLARSHIPS

The State Tuition Scholarships in Cornell University; awarded by New York State; open to residents of the State only, under regulations administered by the State Commissioner of Education.

The State University Scholarships; awarded by New York State; each of an annual value of $100; open to residents of the State only, under regulations administered by the State Commissioner of Education.

The University Undergraduate Scholarships, eighteen in number, each continuing for two years and of an annual value of $200; awarded by the University each year to members of the incoming freshman class. The award is made on the basis of a special competitive examination held in Ithaca in September between the period of entrance examinations and the opening of the University. Every candidate for such a scholarship must have satisfied the entrance requirements of one of the colleges of the University. Holders of New York State Scholarships are eligible to the University Undergraduate Scholarships. The University Undergraduate Scholarships are awarded on the basis of competitive examination in three of the following eight subjects; English, Greek, Latin, French, German, Spanish, Elementary Mathematics, and Advanced Mathematics. Certain combinations of these subjects are specified; see the *General Circular of Information*.

SPECIAL UNDERGRADUATE SCHOLARSHIPS

(Open to undergraduates in the Schools of Mechanical or Electrical Engineering)

The Frank William Padgham Scholarship. 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, Plain 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. The sum of approximately $4000 was bequeathed to Cornell University by Mrs. Mary Northup Wilson 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 con-

sisting 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, founded in 1920 by Mrs. Sara B. Audenreid in memory of John Leisenring Wentz, a member of the class of 1898, consists of the income from a fund of $5500. It is awarded at the end of each academic year to a member of the incoming senior class who is in need of financial assistance and who during his junior year maintained a high scholastic standing. 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 purposes of record.

The William Delmore Thompson Scholarship. (Open only to undergraduates in Mechanical Engineering.) This scholarship, 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 in Mechanical Engineering. It is awarded at the beginning of the junior year, and if the student's work proves satisfactory is continued through the senior year.

PRIZES

The Fuertes Medals, established by the late Professor E. A. Fuertes, are 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 nominated to the University Faculty by the School of Civil Engineering annually.

The Fuertes Memorial Prizes in Public Speaking were founded by 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 is open to seniors and juniors in the Colleges of Engineering and Architecture. (2) The competition will be held on the evening of the third

Friday in April. (3) The candidates are required to read a summary of their arguments (not more than four hundred words in length) before a committee representing the Colleges of Engineering and Architecture. These summaries shall be read on the Monday of the week in which the final competition falls. Competitors, not to exceed eight in number, will then be selected for the final competition, the choice being based on the character of the summaries submitted. (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 will 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 prizes will be awarded by a committee consisting of five members, two selected by the College of Engineering, one selected by the College of Architecture, one selected by the Department of Public Speaking, and one selected by the President of the University from citizens of Ithaca promiment in mercantile or banking business or in public affairs. (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, consist of 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.

The Sibley Prizes in Mechanic Arts; awarded to undergraduates in Mechanical or Electrical Engineering. Under the 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 school named. The prizes are $30, $25, $20, $15, and $10.

LOAN FUNDS

The F. W. Guiteau Student Loan Fund. Through the generosity of the late Frederick W. Guiteau and his sister, the late Nancy G. Howe, both of Irvington-on-Hudson, New York, a fund, known as the F. W. Guiteau Student Loan Fund, has been established in Cornell University, the income from which, amounting

to about $14,000 annually, is to be used "in advancing and assisting needful, worthy young men in pursuing their studies in said University." There is also a small separate fund available for women students. The benefits of these funds are open to young men and young women who have been in attendance at Cornell University for at least one year, but 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 primarily to cover tuition fees.

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 from 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 Student Fund of The Cornell Club of Rochester provides for a loan of an annual value of $200.

The William C. Seidell Book Fund of $1000 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.

ADMISSION

Application.—Any prospective undergraduate student intending to register in the University at Ithaca for the first term of the academic year must apply for registration not later than August 1 of that year, and the application must be accompanied by a deposit of twenty-five dollars. An application received after August 1 may be accepted if, in the judgment of the Faculty concerned there is adequate provision for the student's instruction. If a student completes his registration for the first term the deposit will be credited to his account. If a prospective student whose application and deposit have been accepted fails to complete his entrance requirements he is entitled to a refund of the deposit in excess of accrued charges. If an applicant fails for any other reason to enter the University at the beginning of the term there may, in the discretion of the Comptroller and the Registrar, be refunded to him any balance above charges accrued. Such a refund will generally be made where the vacancy caused by the student's withdrawal is filled.

Preparation.—As the instruction in the College of Engineering is almost entirely of a scientific or engineering character, and as, at best, the student in the four-year course has only very limited opportunities for instruction along broader lines, it is desirable that the training for entrance to that course should be as liberal as possible with stress on subjects like Language and History, and with Physics and Chemistry deferred until after entering the University.

Although three years of any one, or two years of any two of the foreign languages listed on p. 25, will be accepted by this college as satisfying the language requirement for admission, prospective students are strongly advised to study German and French, not only for their cultural value but for their engineering literature.

It is of advantage to those entering the engineering courses to have had some instruction in free-hand sketching.

Students who have had some engineering experience 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 touch with some kind of engineering work.

As already mentioned, it is desirable for the student to obtain if possible, the training of a liberal college course before entering the College, and those 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.

Classification.—The College of Engineering admits only regular students, that is, applicants who have fifteen units of entrance credit, and who will pursue the regular four-year curriculum after admission. (For details of a six-year course in Arts and Engineering, see. p. 26)

Students who have attended other colleges may be admitted to advanced standing, provided they are in good standing in the college from which they come and provided also that they meet the full entrance requirements of the College of Engineering. (See p. 26)

Graduate students from this college or from other colleges may enter the Graduate School and pursue work in the College of Engineering. Such a student may enter as a candidate for a degree (M.S., M.C.E., M.M.E., M.E.E. or Ph.D.) or not, according to the character of his previous training. (See the *Announcement of the Graduate School.*)

Entrance Credits that may be Offered for Admission.—Candidates for admission should consult the *General Circular of Information*, which will be sent post-free on application to the Secretary of Cornell University, Ithaca, New York. All applications for admission to the freshmen class should be addressed to the Registrar.

The subjects that may be offered for admission to the College of Engineering are named in the following list; the figure in parenthesis following each subject indicates its value expressed in units and shows the maximum and minimum amount of credit allowed in the subject. A unit represents five prepared recitations a week for one year of study.

1a.	English 1	(1½)	4d.	Fourth Year German	(1)
1b.	English 2	(1½)	5a.	First Year French	(1)
1c.	English (elective)	(1)	5b.	Second Year French	(1)
2a.	First Year Greek	(1)	5c.	Third Year French	(1)
2b.	Second Year Greek	(1)	5d.	Fourth Year French	(1)
2c.	Third Year Greek	(1)	6a.	First Year Spanish	(1)
3a.	First Year Latin	(1)	6b.	Second Year Spanish	(1)
3b.	Second Year Latin	(1)	6c.	Third Year Spanish	(1)
3c.	Third Year Latin	(1)	6d.	Fourth Year Spanish	(1)
3d.	Fourth Year Latin	(1)	7a.	First Year Italian	(1)
4a.	First Year German	(1)	7b.	Second Year Italian	(1)
4b.	Second Year German	(1)	7c.	Third Year Italian	(1)
4c.	Third Year German	(1)	8a.	Ancient History	(½–1)

8b.	Modern History	(½–1)	11.	Chemistry	(1)
8c.	Am. History, Civics	(½–1)	12.	Physical Geography	(½–1)
8d.	English History	(½–1)	13.	Biology*	(1)
9a.	Elementary Algebra	(1)	14.	Botany*	(½–1)
9b.	Intermed. Algebra	(½)	14a.	Zoology*	(½–1)
9c.	Advanced Algebra	(½)	15.	Bookkeeping	(½–1)
9d.	Plane Geometry	(1)	16.	Agriculture	(½–1)
9e.	Solid Geometry	(½)	17.	Drawing**	(½–1)
9f.	Plane Trigonometry	(½)	18.	Manual Training**	(½–1)
9g.	Spher. Trigonometry	(½)	19.	Any high school subject or subjects not already used	(½–1)
10.	Physics	(1)			

Methods of Obtaining Entrance Credit.—All correspondence concerning admission to the College of Engineering should be addressed to the Registrar of Cornell University, Ithaca, N. Y., who will forward the proper application blanks upon request. All credentials relating to admission of new students must be in the hands of the Registrar before September first. (See p. 24.)

Credit for entrance subjects may be secured in the following ways:

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.

ENTRANCE CREDITS REQUIRED FOR ADMISSION

(1) **The Regular Four-Year Course.**—For admission to the regular course, the applicant must offer fifteen specific units from the foregoing list of entrance subjects, as follows: English (3), History (1), Elementary Algebra (1), Intermediate Algebra (½), Advanced Algebra (½), Plane Geometry (1), Solid Geometry (½), Plane Trigonometry (½), either Greek, Latin, French, German, Spanish, or Italian (3 units in one language or 2 units in each of two languages†), and elective (4 or 3††). Applicants offering fifteen units will, however, be admitted, if the credits do not differ from the specific list by more than (a) one unit of History, or (b) one unit of a foreign language, or (c) one-half unit of Advanced Algebra or Trigonometry, provided that the mathematics lacking is not offered in the school from which the applicant enters; and that an applicant lacking either of these mathematical subjects submits evidence to show that he stood in the upper third of his class (scholastically) for the year preceding his admission to Cornell; or, if he has not attained this standing, that he gives evidence of mental ability by a corresponding rating in an intelligence test given or, approved, by this college.

(2) **The Six-Year Course.**—For admission to the six-year course, leading

*If an applicant has counted Biology (1) he may not also offer Botany (½) or Zoology (½).
**Three hundred actual hours are required for one unit.
†It is recommended that the language requirement be satisfied by French or German.
††It is strongly recommended that at least three of these elective units be offered in language and history.

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 secure 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 had by applying to the Director of the school concerned and to the Dean of the College of Arts and Sciences.

There is also a six-year course leading to the degree of Civil Engineer at the end of five years and to the degree of Bachelor of Architecture at the end of six years. This course, arranged through the co-operation of the Faculties of Civil Engineering and of Architecture, provides a progressively arranged series of studies planned to give suitable training in Building Design and Construction. It follows the civil engineering course closely for the first four years, substituting, however, some fundamental architectural subjects for civil engineering work so that the full requirements for the C. E. degree cannot be met until the end of the fifth year. For details, see *Announcement of the College of Architecture.*

DETAILED REQUIREMENTS FOR ADMISSION UNDER VARIOUS CONDITIONS

(1) **Admission as a Regular Student in Regular Undergraduate Courses.**—The applicant must be at least sixteen years of age. The time required for graduation depends upon the combination of units offered for entrance. Students lacking at entrance not more than one of the three subjects in Advanced Mathematics (Advanced Algebra, Solid Geometry, Plane Trigonometry), but offering otherwise 15 units, may so arrange the course as to graduate in four years plus attendance in one Summer Session. More detailed information on courses requiring more than four years will be furnished upon application to the Secretary of the College of Engineering.

(2) **Admission from Other Colleges.**—A student who, having already attended some college or university, desires to enter one of these courses, should file with the Registrar of Cornell University, on an official blank to be obtained from him, a formal application for admission, along with an official certificate from the college or university already attended, of his honorable dismissal; his entrance examinations in detail; his terms of attendance and the amount of work that he has completed; and a detailed statement of the courses pursued. He should send also a catalog of the institution, writing on it his name and marking the entrance requirements that he has satisfied and each subject that he has completed.

(3) **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.

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.), and Doctor of Philosophy (Ph.D.) are granted upon fulfilment of the conditions prescribed by the Faculty of the Graduate School. See the *Announcement of the Graduate School*.

MILITARY SCIENCE AND TACTICS, AND 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 department is a unit of the Reserve Officers' Training Corps of the United States Army. The students are organized in an infantry regiment of twelve regular companies, a battalion of field artillery of three batteries, one headquarters company, one machine gun company, and a band.

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 the 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.

REQUIREMENTS FOR GRADUATION

The C. E., M. E., or E. E. degree 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) 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 the 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.

PAYMENTS TO THE UNIVERSITY

[For detailed information regarding payments to the University and the expense of living in Ithaca, see the *General Circular of Information*.]

Tuition and Other Fees

Students entering the College of Engineering are subject to a matriculation fee of $10 and to the following payments:

	1st Term	*2d Term*
University Tuition ($250 yearly)	$135.00	$115.00
Engineering Fee*		
Freshmen	12.50	12.50
Sophomores, juniors, and seniors in M.E. and E.E.	12.50	12.50
Sophomores, juniors, and seniors in C.E.	4.00	4.00
Infirmary Fee ($10 yearly)	5.00	5.00

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 student who fails to pay his indebtedness to the University within twenty days after the last registration day of the term is thereby dropped from the University.

Any tuition fee or other fee may be changed by the Trustees to take effect at any time without previous notice.

A Locker fee of $2 a term is required, at the beginning of each term, of every male undergraduate student. 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.

Laboratory Fees.—Students in the College of Engineering who take laboratory courses in other colleges of the University must pay to the Treasurer a fee or

*Students in the five-year course pay this for but eight terms.

deposit for materials used in the work. Students not registered in the College of Engineering but taking work in the shops must 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 the 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.)

Assessments

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 continue his university work after being absent, without excuse from his dean, from any class or exercise occuring during the two days immediately preceding or the two days immediately following the Thanksgiving Recess, the Christmas Recess, or the Easter Recess, shall pay a fee of $5 for each day on which an absence occurred. [Students in the Graduate School are excepted.]

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 reason beyond his control.

COURSES OF STUDY IN THE COLLEGE OF ENGINEERING

1. Regular four-year courses are offered in the Schools of the College, leading to the degrees of C.E., M.E., and E.E.

2. The first year of all the courses is common, so that no student needs to make his choice of Civil Engineering, Mechanical Engineering, or Electrical Engineering until near the end of the first year of residence. For the curriculum of the first year, see below.

3. The last three years of each course are spent by the student under the direct supervision of one of the three Schools. For detailed information of the various curricula for the last three years, see the particular School announcement contained in the following pages.

4. In the last year or last two years 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. For detailed information on these options or electives see the School announcements in the following pages.

Curriculum, Freshman Year

All engineering students, except those entering with advanced standing, are required to take the following courses for the first year:

Course	*Hours 1st Term*	*Hours 2nd Term*
Analytical Geometry and Calculus 4, 5	3	5
Physics 2, 7	5	3
Chemistry 120, 125	4	4
Drawing 121, 122	2	2
Elementary Surveying 110	0 or 3	3 or 0
Forge Shop 101	1 or 0	0 or 1
Wood Working 102	2 or 0	0 or 2
Introductory Lectures 130	1	0
Military Drill 1	1	1
Total number of hours	19	18

In addition all freshman students are required to attend a course of lectures on Hygiene given once a week throughout the year.

For the arrangement of the curricula for the last three years of the courses in Civil Engineering, Mechanical Engineering, and Electrical Engineering, see the School announcements in the following pages.

Courses of Instruction, Freshman Year

The following subjects are common to engineering freshmen in the four-year course leading to the degree of Civil Engineer, Mechanical Engineer, or Electrical Engineer.

MATHEMATICS (*Given in College of Arts and Sciences*)

Course 4, 5 or 6 may not, without special permission, be taken simultaneously with any of the other courses in Mathematics.

4, 5, 6. **Analytical Geometry and Calculus.** Prerequisite courses, Solid Geometry, Advanced Algebra, and Trigonometry.

4. First term; credit three hours. Repeated in the second term; credit three hours.

5. A continuation of the work of 4. Daily except Saturday, second term; credit five hours.

6. A continuation of the work of 5. Sophomore year, first term; credit three hours.

PHYSICS (*Given in the College of Arts and Sciences*)

Examinations for those who were unavoidably absent from either term examination in courses 2 to 7, and for those who have conditions to make up, will be held on Wednesday, September 20, 1922, at 9 a. m. in Rockefeller A. Similar examinations in connection with courses 8 to 14 will be held in Rockefeller A at 2 p. m. on the same day. Students expecting to take any of these examinations should notify the department not later than September 13, 1922.

2. **Introductory Experimental Physics.** Repeated in second term. Credit five hours. Three lectures, one class-room period and one two-hour laboratory period each week. Lectures T Th S, 9, 11, Rockefeller A. Professors MERRITT and GIBBS. Class-room and laboratory work; hours to be arranged. Assistant Professor HOWE, Messrs. FISHER, MAY, NORTHROP, and NOYES. Required of candidates for B.Chem., C.E., M.E., E.E. *Rockefeller Hall.*

7. **General Physics.** Primarily for students in engineering. Class-room work. Credit three hours. Prerequisite, Physics 2. Assistant Professor COLLINS, Messrs. JOLLIFFE, SCOTT, and TYNDALL. Hours to be arranged. *Rockefeller Hall.*

CHEMISTRY (*Given in the College of Arts and Sciences*)

Entrance credit in Chemistry does not carry with it University credit in Course 120 or 125. If a student entering the University from a preparatory school desires credit in Course 120 he must pass an examination set by the Department of Chemistry. This examination is held both in New York City and in Ithaca on the same day in September as the entrance examination. University credit in Course 120 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 examinations in Course 120 will be held at 2 p. m. on the day before instruction begins in the fall. Students expecting to take a final examination in Course 120 should notify the department not later than Sept. 15, 1922.

120. **Introductory Inoganic Chemistry.** For engineers. Lectures and recitations. First term. Credit four hours. Professor BROWNE, Mr. MCKINNEY, and assistants. *Morse Hall.*

125. **Introductory Inoganic Chemistry.** For engineers. Recitations and laboratory. Second term. Credit four hours. Professor BROWNE, Mr. MCKINNEY, and assistants. *Morse Hall.*

DRAWING, LETTERING, SURVEYING, SHOPWORK, INTRODUCTORY LECTURES

Given in the College of Engineering

121. **Drawing and Lettering.** General course for all freshmen in engineering. This course will include such subdivisions as use of instruments, simple projections, free-hand sketching, lettering, geometric problems, conventional signs, tracing, blue-printing, etc. Assistant Professor TOWNSEND and others. *The Engineering Buildings.*

122. **Drawing.** The work of Course 121 continued.

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. Textbook: 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. Assistant Professors UNDERWOOD and LAWRENCE, and Messrs. BROWN, CHOBOT, PENDLETON, and WILLIAMS. *Lincoln Hall.*

101. **Shopwork.** Freshmen. One hour either term as assigned. Forging, welding, tool dressing, tempering, etc., together with demonstrations in the production of drop forgings and in riveting. Messrs. HEAD and HERRICK. *The Sibley Shops.*

102. **Shopwork.** 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, WILCOX, and YAWGER. *The Sibley Shops.*

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

General Outline of 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 other 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 a 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 in 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

1. The Regular Four-Year Course

FRESHMAN YEAR

The curriculum of the freshmen year for students in the School of Civil Engineering is identical with that for students in the Sibley School of Mechanical Engineering and in the School of Electrical Engineering. For a statement specifying the entrance requirements and the courses included in the freshman year, see pp. 24-33 of this Announcement.

LINCOLN HALL
The Main Building of the School of Civil Engineering.

SOPHOMORE YEAR

Course	*Hours 1st Term*	*Hours 2d Term*
Mathematics 6	3	0
Practical Geology 31	0 or 3	3 or 0
Descriptive Geometry 201	2	0
Descriptive Geometry 202	0	2
Drawing 203	1	0
Drawing 204	0	2
Surveying 211	2	0
Surveying 212	0	3
Mechanics of Engineering 220	5	0
Mechanics of Engineering 221	0	5
Materials of Construction 225	3 or 0	0 or 3
Materials Laboratory 226	2 or 0	0 or 2
Technical Reports 294	0 or 3	3 or 0
Total number of hours	18 or 19	18 or17

Summer Survey 213 (Five weeks in June and July) 6

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

JUNIOR YEAR (*For the class graduating in 1924 only*)

Course	*Hours 1st Term*	*Hours 2d Term*
Public Speaking 1	3 or 0	0 or 3
Elementary Economics 51	0 or 5	5 or 0
Survey Computations 214	1	0
Engineering Problems 223	0	2
Hydraulics 240	4	0
Municipal Sanitation 252	0	4
Railroad Surveying and Drawing 260	4	1
Engineering Construction 264	0	3
Structural Design and Bridge Stresses 270	4	0
Structural Design 271	0	3
Technical Reports 294	0 or 3	3 or 0
Total number of hours	19 or 18	18 or 19

In the planning of his work, each student in the School of Civil Engineering is subject to the following limitation: "No student shall anticipate the work of the curriculum of the School of Civil Engineering by more than one year."

SENIOR YEAR (*For the class graduating in 1923 only*)

Course	*Hours 1st Term*	*Hours 2d Term*
Public Speaking 1a	3 or 0	0 or 3
Heat Engines and Auxiliaries, P 11	0 or 3	3 or 0
**Essentials of Electrical Engineering, E 12	4	0
Water Supply 230	0 or 3	3 or 0
Municipal Sanitation 252 or Concrete Construction 280	3	0
Highway Engineering 265	3 or 0	0 or 3
Specifications and Contracts 290	2 or 0	0 or 2
Engineering Design 291	0 or 3	3 or 0
*Electives	3	9
Total number of hours	18 or 19	18 or 17

2. A Six-Year Course Leading to the Degrees of A.B. and C.E.

See page 26.

COURSES OF INSTRUCTION IN THE SCHOOL OF CIVIL ENGINEERING

For Sophomores, Juniors, and Seniors

(*For a description of the freshman courses in Mathematics, Physics, and Chemistry and a description of the Engineering Courses given to freshmen, see pp. 31-33 of this Announcement*).

MATHEMATICS (*Given in the College of Arts and Sciences*)

(*Course 4, 5, or 6 may not, without special permission, be taken simultaneously with any of the other courses in mathematics.*)

4, 5, 6. **Analytical Geometry and Calculus.** Prerequisite courses, Solid Geometry, Advanced Algebra, and Trigonometry.

4. First term, credit three hours. Repeated in the second term, credit three hours.

5. A continuation of the work of 4. Second term. Credit five hours.

6. A continuation of the work of 5. Sophomores. First term. Credit three hours.

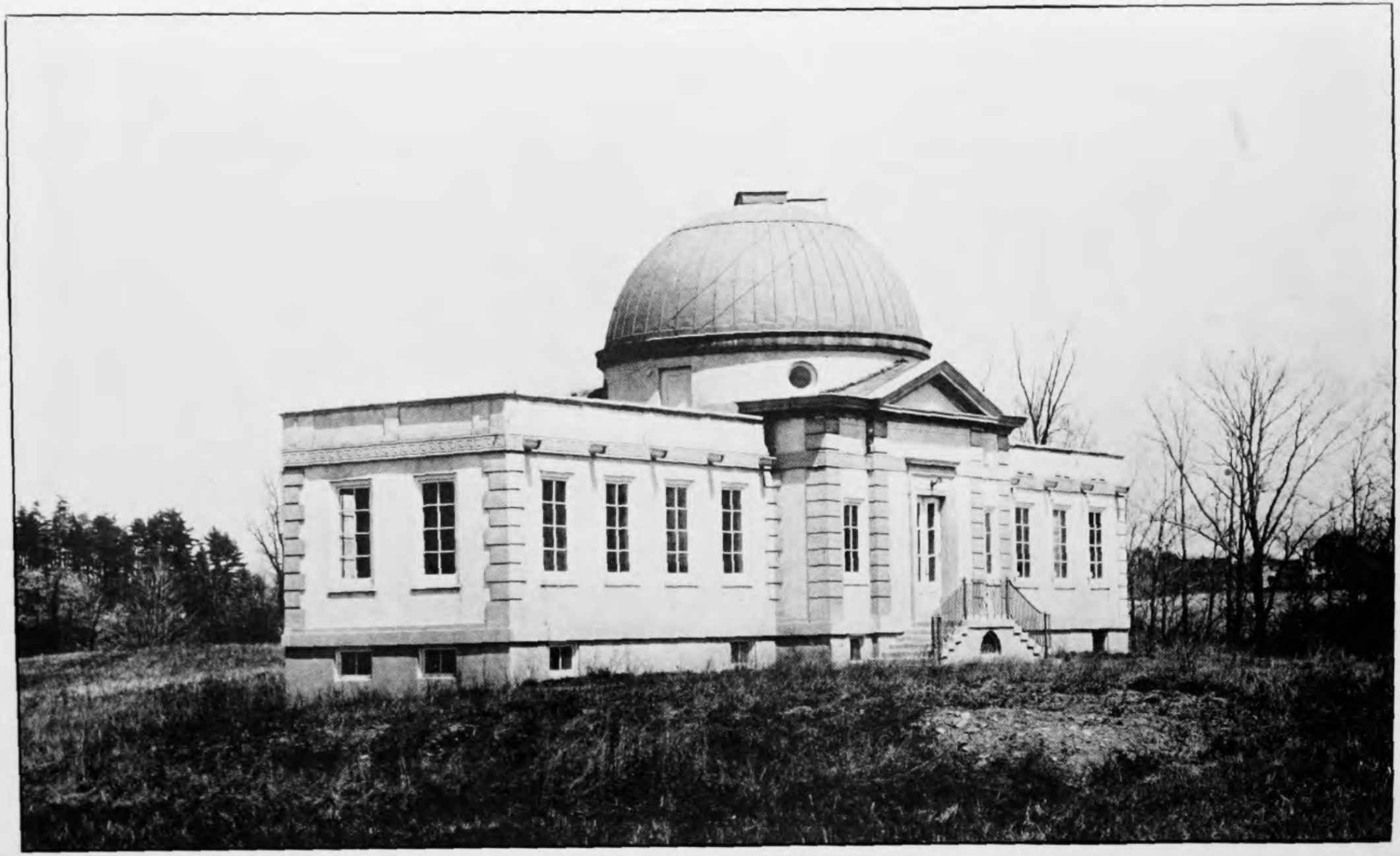
GEOLOGY (*Given in the College of Arts and Sciences*)

31. **Practical 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. Professor RIES.

**Any qualified student in Civil Engineering desiring to take a more extended course than E 12 may substitute E 411, 412 and E 431, 432. (See description of courses in Electrical Engineering on pp. 79-82 of this Announcement.)

*(a) Of the elective hours in the Senior year at least six must be taken in Civil Engineering.

(b) The elective courses taken outside the school of Civil Engineering must be selected from t hose not open to freshmen, unless approved by the class adviser.



THE FUERTES ASTRONOMICAL OBSERVATORY

ECONOMICS (*Given in the College of Arts and Sciences*)

51. **Elementary Economics.** First or second 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 to sections will be made on registration days at *Goldwin Smith* 260. Professor DAVENPORT.

PUBLIC SPEAKING (*Given in the College of Arts and Sciences*)

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 (*Given in the Sibley School of Mechanical Engineering*)

341. **Heat Engines and Auxiliaries.** Required of all seniors in Civil Engineering. For a description of this course see p. 69 of this Announcement.

342. **Small Power Plants.** Elective. For description of this course see p. 69 of this Announcement.

ELECTRICAL ENGINEERING

(*Given in the School of Electrical Engineering*)

E 12. **Essentials of Electrical Engineering for Civil Engineers.** Required of all seniors in Civil Engineering. For a description of this course, see p. 79 of this Announcement. See also footnote on p. 36.

ASTRONOMY

181. **General Astronomy.** Three hours a week throughout the year. Prerequisite, Physics 3 or a satisfactory equivalent.

Section A, M W, 12, *Lincoln* 31, and Th, 7:30 to 9:30 p. m. *Fuertes Observatory*.

Section B, M F, 12, *Lincoln* 31, and W, 7:30 to 9:30 p. m. *Fuertes Observatory*.

A study of the facts and principles of the science of astronomy, accompanied by laboratory exercises in which the student is guided to a knowledge of the scientific method and its use in discovering some of the laws of nature, from observations of the orderly phenomena of the heavens. Professor BOOTHROYD.

182. **History of Astronomy.** Second term. Credit three hours. Prerequisites, six acceptable hours in history and must be preceded or accompanied by Astronomy 181. A study of the historical development of the oldest of the sciences from the dawn of history to the present. Since the development of the science of astronomy is an especially good illustration of the scientific method much emphasis is laid upon this idea. M W F, 8. *Goldwin Smith*. Professor BOOTHROYD.

183. **Geodetic Astronomy.** Second term. Credit three hours Prerequisite courses, Calculus and Astronomy 181 or C.E., 213. 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.

184. **Modern Astronomy.** First term. Credit three hours. Prerequisite courses, Astronomy 181 and 183 and Advanced Physics (spectroscopy). 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.

185. **Practical Astronomy.** Second 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

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

202. **Descriptive Geometry.** 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 will be introduced throughout the course. Two two-hour exercises each week. Assistant Professor POND.

203. **Drawing and Lettering.** Sophomores in Civil Engineering. First term. Credit one hour. Prerequisite course 121. A study of the Roman, Gothic, and other styles of letters, and practice in forming the letters and combining them into appropriate titles; drawing, in dimension and in detail. Professor PARSON.

204. **Drawing.** Sophomores in Civil Engineering. Second term. Credit two hours. Line shading, which includes the shading of flat and curved surfaces by lines variously spaced and by lines of different thickness; making detail drawings from sketches, models, and from other drawings on different scales; topographic signs, including practice in the different kinds of standard topographic signs for mapping; tinting and shading, with instruction in, and practice with water colors, in the rendering of flat and curved surfaces, and in the use of crayon. Each student is required to make a number of plates and to become reasonably proficient in handling the brush and in using crayon. Professor PARSON.

205. **Advanced Drawing.** Elective. Juniors and seniors. Either 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, mouldings, 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.

206. **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 p. 33.

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. Assistant Professors UNDERWOOD and LAWRENCE, and Messrs. PENDLETON and————.

211A. **Advanced Surveying.** For students in Forestry and Landscape Art. 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*. Assistant Professors UNDERWOOD and LAWRENCE, and Mr. CHOBOT.

212. **Advanced Surveying.** Sophomores. Second term. Credit three hours. Prerequisite course 211. Topographic, hydrographic, and geodetic surveying and field astronomy; transit and stadia; plane table; sextant; soundings; stream measurements; triangulation; base lines; precise leveling; field determinations of azimuth, time, and latitude. Recitations, and field and office work. Textbook: Breed and Hosmer's *Higher Surveying*. Assistant Professors UNDERWOOD and LAWRENCE, and Messrs. PENDLETON and————.

213. **Summer Survey; Topographic, Hydrographic, and Geodetic Survey; Camp.** Sophomores. Five weeks in June and July. Credit six hours. Date of beginning to be announced in second term. Prerequisite course 212. Open also to students in Forestry and Landscape Art 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. Astronomic observations for azimuth, latitude, 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. Assistant Professors UNDERWOOD and LAWRENCE, and others.

214. **Survey Computations.** Juniors. Prerequisite course 213. First term. Credit one hour. Reduction of the observations made at the Camp during the previous summer in Course 213, embracing base-line measurement, 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. Assistant Professors UNDERWOOD and LAWRENCE.

214A. **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. Assistant Professor UNDERWOOD and Mr. HOWELL.

215. **Problems in the Adjustment of Observations.** Elective. Upperclassmen. Prerequisite course 213. Second term. Credit one hour. 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*. Assistant Professor UNDERWOOD.

216. **Least Squares; Adjustment of Observations.** Elective. Prerequisite, Calculus and Physics. First term. Credit two hours. 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. Prerequisite course 213. First term. Credit two hours. 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. Prerequisite course 212. First term. Credit three hours. 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.

THE HYDRAULIC LABORATORY

MECHANICS OF ENGINEERING

220. **Mechanics of Engineering.** For sophomores in Civil Engineering. First term. Credit five hours. Repeated in one section, second term. Prerequisite course, Mathematics 5. 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. Textbooks: Church's *Mechanics of Engineering*, and *Notes and Examples in Mechanics* supplemented by other printed notes and problems. Four recitations and one computing period a week. The computing period will be in charge of an instructor and will be devoted to the solution of mechanics problems, the use of the slide rule, planimeter, etc. The solution of each problem is to be written up in good form and will be criticized by the instructor. If found unsatisfactory, either as to form or matter, it will be returned for revision. Emphasis will be placed particularly upon correct numerical work and consistent use of proper units. Each student is required to provide himself with a slide rule of approved type. Professor GEORGE, Assistant Professor RETTGER, and Mr. HOWELL.

221. **Mechanics of Engineering.** Second term. Credit five 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 Mechanics in Engineering Design. Textbooks: Church's *Mechanics of Engineering*, and *Notes and Examples in Mechanics*, supplemented by other printed notes and problems. Four recitations and one computing period a week. Professor GEORGE, Assistant Professors RETTGER and WEBER, and Mr. HOWELL.

222. **Advanced Mechanics.** Seniors and graduates. Either 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. Professor GEORGE and Assistant Professor RETTGER.

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 course involving additional practice in using the principles and methods of applied mechanics. A series of problems, such as occur in ordinary engineering practice, and covering a wide range of topics, is given out for solution. Computations and reports. Five hours a week. Professor GEORGE and Assistant Professor RETTGER.

MATERIALS OF CONSTRUCTION

225. **Materials of Construction.** Sophomores. Either term (one-half of the class each term). Credit three hours. Should preferably be preceded by, or taken with Course 221, and must precede or be taken with Course 222. The mate-

rials 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. The work is planned to co-ordinate with the course in Materials Laboratory and to supplement that work where necessary. Three recitations a week. Textbook: Mill's *Materials of Construction.* Assistant Professor SCOFIELD.

226. **Materials Laboratory.** Sophomores. Either term (about one-half of the class each term). Credit two hours. Should preferably be preceded by or taken with Course 221, and must be preceded by or taken with Course 225. Experimental determination of the properties of materials by mechanical tests. Study of testing machines (their theory, construction, and manipulation); calibration of testing machines and apparatus; commercial tests of iron and steel; tensile, compressive, torsional, shearing, and flexure tests of metals and various woods with stress-strain observations; tests of cement for fineness, specific gravity, normal consistency, time of setting, soundness, and tensile and compressive strength for neat and mortar mixtures; tests of concrete aggregate, and of road material and paving brick. The course is planned to co-ordinate with course 225 and to supplement directly the study of the properties of materials by the actual handling of the materials and by observations of their behavior under stress. Laboratory work two and one-half hours a week. Assistant Professor SCOFIELD and Mr. WHITNEY.

227. **Testing Materials.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite courses 222 and 225, or their equivalents. Special investigations of an advanced nature of the properties of structural units and the materials of construction; tests upon full-sized sections in iron and steel upon wooden columns, beams, and trusses; standard tests of paving brick and macadamizing materials; standard tests of cement and concrete aggregates; special investigations of the properties of concrete, plain and reinforced, and upon full-sized beams and columns; tests upon the bonding strength of steel and concrete; tests upon riveted steel joints; tests upon wire cables, etc. Textbook: Mill's *Materials of Construction;* the publications of the American Society of Civil Engineers and of the American Society for Testing Materials are used as reference works. The aim of the course is to provide not only a knowledge of materials by observation of their behavior under stress, but also a knowledge of the technique of testing materials; a training in precise methods of observation and interpretation of results; and an appreciation of the relation of theoretical investigation to engineering practice. Advanced students are encouraged to make use of the laboratory facilities for special research. Seven and one-half hours a week as arranged. Assistant Professor SCOFIELD.

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.** 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 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. Course 231 may be substituted for Engineering Design, Course 291. Professor SEERY.

232. **Water-Power Engineering.** 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. Course 232 may be substituted for Engineering Design, Course 291. Professor SEERY.

233. **Pumps and Pumping.** Seniors and graduates. Second term. Credit three hours. Prerequisite course 240, and should be preceded by, or taken con-

currently 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.** Seniors and graduates. Elective. 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.

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. Professor SCHODER and Assistant Professor WEBER.

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 and Assistant Professor WEBER.

242. **Hydraulic Measurements.** Elective for seniors and graduates. First term. Credit three hours. Prerequisite courses 240 and 241. Three periods a week in laboratory or computing room. In addition to more thorough experi-

mental 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 241. Three periods a week. The determination of efficiency, capacity, and characteristics of hydraulic machinery by tests. Professor SCHODER and Assistant Professor WEBER.

244. **Experimental Hydraulic Investigation.** Elective for seniors and graduates. Either term. Credit three hours (or more in special cases). Prerequisite courses 240 and 241, or their equivalents. The subject and scope of the investigation should be selected by conference at the beginning of the term if not previously arranged. It is often permissible and desirable 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.

MUNICIPAL AND SANITARY ENGINEERING

250. **Sanitary Biology.** 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 anaylses 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. Assistant Professor WALKER.

251. **Sanitary Biology.** 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. Textbook, notes, and various references. One laboratory period a week. Assistant 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. Textbooks: Ogden's *Sewer Design*, Ogden's *Sewer Construction*, and *Notes on Sewage Disposal*. Four sections. Professor OGDEN and Assistant Professor WALKER.

253. **Purification and Control of Water Supplies.** 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). Professor OGDEN.

254. **Sewerage Works.** 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. **Sanitary Laboratory.** Seniors. Second term. Credit three hours. Prerequisite courses 250, 252, and Chemistry 6. This course offers a practical demonstration of some of the topics considered in Courses 252, 253, and 254. Studies of the qualities of water in streams, sewers, and in the city sewage settling tank are made by means of the usual tests for suspended solids, for dissolved oxygen, and for oxygen consumed; examination of samples of sand for percentage of voids, for turbidity, for frictional resistance to water flow, and for efficiency as filters; comparative tests of precipitants on various naturally and artificially polluted waters and of losses of head in columns of sand; measurements of velocities and grades in the city sewers and a study of their interrelation with sizes of pipes and depths of flow. Nine hours a week. Professor OGDEN.

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. Professor OGDEN and Assistant Professor WALKER.

RAILROAD AND HIGHWAY ENGINEERING

260. **Railroad Surveying and Drawing.** Juniors. Throughout the year. Credit four hours first term and one hour second term. Sections of twenty to twenty-five men each. Prerequisite course 213.

Railroad Surveying. First term. The work consists of field problems, location work, and recitations.

(1) *Field Problems.*—In the field problems 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 could otherwise. Each party's work involves the laying out and checking of simple and transition curves, the use of the aneroid barometer, study and inspection of the details of switches, turnouts, and other yard work, and occasional recitations and office problems. The greater portion of the time is spent on simple and transition curve problems. Two periods, of two and one half hours each, a week for the first ten weeks.

(2) *Location work.*—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 period so that each student receives practice in the various kinds of field work and in the office work of computing and plotting involved in a survey of this character. One six-hour period a week for ten weeks.

(3) *Recitations.*—Three recitations a week are given for the remaining five weeks of the term. The first two weeks are spent on earthwork computations; the remaining three weeks are devoted to a review of the theory and applications of simple and transition curves, switches and turnouts, barometric leveling, vertical curves, etc. Textbooks: Crandall and Barnes's *Railroad Surveying* and Crandall's *Earthwork Tables.*

Railroad Drawing. Second term. Each student makes a map and profile of the line surveyed by his section during the first term. He is required to compute part of the earthwork, to make a mass diagram of the line, and to use the same in determining the best distribution of the material. Each student also makes an estimate of cost for the entire line. One three-hour period a week throughout the term. Professor BARNES, Assistant Professors CONWELL, PERRY, and CRANDALL.

261. **Railroad Maintenance of Way.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 260. The subjects treated are: Track materials (with especial 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 Mr. PERRY.

262. **Railroad Operation and Management.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 260. The course is based on Morris' *Railroad Administration* and Latimer's *Railway Signaling*, both of which are used as textbooks. 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.

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; 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.** Juniors. Second term. Credit three hours. Prerequisite courses 240 and first term of 271. A course in the fundamentals of construction with special reference to field methods, plant layouts, and costs. The course includes estimates and analyses of costs with reference to planning, preparatory and construction periods; earth and rock excavations; tunneling; foundations; masonry; haulage; timbering; 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 economic selection of structures, etc. Lectures, recitations, and problems, three hours a week. Professor BARNES, Assistant Professors CONWELL, PERRY, and CRANDALL.

265. **Highway Engineering.** Seniors and graduates. Either term. Credit three hours. Prerequisite course, 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. Assistant Professors CONWELL and PERRY.

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. Assistant Professors CONWELL and PERRY.

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 interpretations 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. Assistant 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. Assistant Professor Conwell.

BRIDGE 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 in chapters I and II of Merriman and Jacoby's *Roofs and Bridges, Part II.* The computations and drawings include complete detail de-

signs 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. Reference book: 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; panel loads and locomotive axle loads; 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. Text book: Merriman and Jacoby's *Roofs and Bridges, Parts I and II*. Three recitations a week. Assistant Professors URQUHART and BURROWS, and Messrs. O'ROURKE and COLLUM.

271. **Structural Design.** Juniors. Second term. Credit three hours. Prerequisite course 270. An elementary course in Steel Design. Complete design, detail drawings, bill of material and estimate of weight of a steel roof truss and of a through and deck railroad plate girder bridge. Textbook: Merriman and Jacoby's *Roofs and Bridges, Part III*. Three computation and drawing periods a week. Assistant Professors URQUHART and BURROWS, and Messrs. O'ROURKE and COLLUM.

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, swing bridges, 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 deflections of trusses and the reactions of statically indeterminate structures, and the use of influence lines to find their loading and stresses. These studies are accompanied by historical notes on arches, drawbridges, and cantilever bridges. Textbook: Merriman and Jacoby's *Roofs and Bridges, Part IV*. Recitations three hours a week. Assistant Professors URQUHART and BURROWS.

273. **Steel Buildings.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite courses 220, 221, and 271. This course may be substituted for Engineering Design, Course 291. 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. Reports 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. This course may be substituted for

Engineering Design. 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, pin plates, 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: Merriman and Jacoby's *Roofs and Bridges, 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. This course may be substituted for Engineering Design. Inspection of existing structures for the determination of sizes and condition 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.** 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. Laboratory work includes the making and testing of columns, beams, and bond specimens. Two recitations and one laboratory or computing period a week. Assistant Professor URQUHART, Mr. O'ROURKE, and Mr. COLLUM.

280-A **Concrete Construction.** For students in the College of Architecture. Second term. Credit three hours. Recitations, lectures, and computing periods. Elementary theory of reinforced concrete, as applied to columns, beams, and slabs. The latter portion of the work will consist of the partial design and detailing of a reinforced concrete building. Assistant Professor URQUHART and Mr. O'ROURKE.

281. **Masonry and Foundations.** 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; cylinder 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. Assistant Professor URQUHART and Mr. O'ROURKE.

282. **Concrete Design.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 280. This course may be substituted for Engineering Design, Course 291. Applications of the theory of reinforced concrete to the design of the various types of retaining walls; selective problems in the

design of reinforced concrete structures such as buildings, sewers, etc. Reports and drawings. Seven and one-half hours a week. Assistant Professor URQUHART and Mr. O'ROURKE.

283. **Reinforced Concrete Arch.** Seniors and graduates. Elective. First term. Credit three hours. This course may be substituted for Engineering Design, Course 291f. Prerequisite course 280. The design of an arch of reinforced concrete and its abutments; investigations 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. Assistant Professor URQUHART and Mr. COLLUM.

284. **Concrete Highway Bridge Design.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 280. This course may be substituted for Engineering Design, Course 291. Application of the theory of reinforced concrete to the design of short-span bridges and their piers and abutments, of the type used on state highways, in viaduct construction, and in grade elimination. Reports and drawings. Seven and one-half hours a week. Assistant Professor URQUHART and Mr COLLUM.

SPECIFICATIONS, DESIGNS, ETC.

290. **Specifications and Contracts.** Seniors. Either term. Credit two 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, contractor's risks, 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 in Engineering* is used as a text, and Wait's *Law of Operations in Engineering Construction* as a reference book. Lectures and recitations, two hours a week. Professor BARNES, and assistant Professors CRANDALL and PERRY.

291. **Engineering Design.** Seniors. Credit three hours. The student is required to make completed designs in one of the following subdivisions, subject to approval. Hours to be arranged.

(c) **Hydraulic Engineering.** Second term. Prerequisite courses 240 and 229. 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 stuent 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 assigned in 1909-10 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 drawings 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 detail drawings 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 and Highway Engineering.** Second term. The problems are those encountered in the location and construction of railroads and highways, and include the following subjects: Economic location of railroads and highways; selection, design and detailed estimates of cost of different types of highway surfaces for various traffic conditions; 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 CONWELL, 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, supension, 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. Assistant Professors URQUHART and BURROWS.

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.** Elective. Seniors and graduates only. First term. Credit two hours. An elementary course on the principles which govern the organization and management of laborers on construction; systems of payment; measurement of efficiency and cost keeping, with illustrative examples. Professor BARNES.

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 *Handbook of English for Engineers*. Professor Ogden and others.

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.

THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

General Outline of Instruction

The instruction in Mathematics, Chemistry, Physics, 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) Mechanics of Engineering; (4) Power Engineering; (5) Experimental Engineering; (6) Industrial Engineering.

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

1. 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.

In the freshman year wood-working is taught, 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 sweepwork.

The student further receives manual instruction in the forging and heat treatment of both iron and steel, supplemented with illustrations of drop-hammer work and methods used in manufacturing large quantities.

In the sophomore year the student receives instruction in the foundry in moulding, core making, mixing of metals, operation of cupalo, the uses of moulding machines, etc., with consideration given to the methods and appliances for sweepwork, 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

The courses in drawing, design, and shopwork are organized to secure close correlation. Many of the exercises in the drawing room, pattern shop, foundry, and machine shop involve work on the same machine parts. In this way the student has presented to him all the necessary steps from the inception to the production of finished machine parts.

Instruction in this department begins with lettering, the use of drawing instruments, the elements of mechanical drawing according to the best practice in commercial drafting rooms, and descriptive geometry. After that the student is taught empirical design and the principles of mechanism. The drawing-room work in the latter course is closely related to the class-room instruction on cams, gearings, and linkages, with application to the kinematic design of machines. After the student has received instruction in mechanism and applied mechanics, he takes up the mathematical side of machine design, the instruction being given by lectures, recitations, and drawing-room work. The student "lays out" mechanisms of the drawing board; analyzes the force, velocity, and energy transformations involved; proportions the members, giving due consideration to strength, rigidity and shop operations; and makes working drawings of the complete designs of machines.

The department offers a senior option in ship design and construction, which includes both lectures and drafting-room work bearing on the theoretical and practical design of ships and also a discussion of the important features in the resistance, propulsion, and powering of vessels.

3. MECHANICS OF ENGINEERING

In this department instruction is given in theoretical and applied mechanics, beginning with a course for sophomores in the fundamental principles of statics and kinetics, with application to mechanisms, followed by a comprehensive study of the mechanics of materials with their application to engineering design. 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. 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.

4. 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, theoretical and actual cycles, and steam engines. This is followed by a study of steam turbines, internal combustion engines, 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, refrigeration, and air compressors.

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, heating and ventilating, and motor car construction.

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 p. 16), not only to familarize 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 investiga-

THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

tions 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 co-operate 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.

6. 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 to-day 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 college 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; special courses of lectures and drawing room work in plant organization and arrangement; and a carefully selected group of economic studies treating of Accounting, Business Law, Industrial History, and kindred subjects.

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 and electrical engineering. 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

1. The Regular Four-Year Course

NOTE.—*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.*

FRESHMAN YEAR

The work of the freshman year is common to all engineering students. For the entrance requirements, see pp.24-27; for an outline of the curriculum, see p. 31; for an outline of the course of instruction, see pp. 31-33.

SOPHOMORE YEAR

Course	*Hours 1st Term*	*Hours 2nd Term*
Mathematics 6	3	0
Mechanics 330, 331	3	4
Physics (Recitation) 11	0	3
Physics (Laboratory) 14	2	2
Empirical Design 311	2	0
Descriptive Geometry 312	2	0
Kinematics 313	0	2
Kinematic Drawing 314	0	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
English 2	2	2
Total number of hours	18 or 17	18 or19

In addition to these courses, sophomores are required to take Military Drill and Hygiene. See pp. 28-29.

JUNIOR YEAR

For Students Electing Option A or B in the Senior Year

Course	*Hours 1st Term*	*Hours 2nd Term*
Mechanics 332	3	0
Heat-Power Engineering 340a, b	3	3
Mechanical Laboratory 365, 366	3	3
Machine Design, Theory, 316a, b	2	2
Machine Design, Drawing, 317a, b	2	2
Hydraulics 335	0	3
Machine Shop 305a, b	2	2
Industrial Economics, I 24	2	2
Industrial Organization 380	2 or 0	0 or 2
Elective	0 or 2	2 or 0
Total number of hours	19	19

For Students Electing Option C in the Senior Year

Course	*Hours 1st Term*	*Hours 2nd Term*
Mechanics 332	3	0
Heat-Power Engineering 340a, b,	3	3
Mechanical Laboratory 365, 366	3	3
Machine Design 316a, b,	2	2
" " 317a, b,	2	0
Hydraulics 335	0	3
Machine Shop 305a, b,	2	2
Industrial Economics, I 24	2	2
Industrial Organization 380	2	0
Elements of Naval Architecture 320	0	4
Total number of hours	19	19

SENIOR YEAR (*For the class graduating in June 1923*)

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

Option A: Power-Plant Engineering

The object of 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 design, construction, and equipment of the plant. After studying the details of 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, prin-

ciples of economic selection of machinery with respect of the load curve and local conditions, selection and arrangement of main units and their auxiliaries, planning the piping and the coal and ash conveying machinery, plant location, and the layout of the power plant as a whole.

The work is taught by lectures supplemented by a drafting course in which the student draws the load curves and the curves showing the performance and the cost of power under variable loads, selects the equipment, locates the machinery, plans the buildings and yards, and carries the work to the point usually required in a preliminary design.

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

SENIOR POWER-PLANT ENGINEERING OPTION

Course	*Hours 1st Term*	*Hours 2nd Term*
Heat-Power Engineering, P 20	4	4
Mechanical Laboratory, X 20, 21	3	3
Electrical Engineering, E 36	2 or 0	0 or 2
Electrical Engineering, E 37	0 or 2	2 or 0
Steam Power Plant, P 23	3	3
Drawing and Design, P 24	2	2
Steam Turbines, P 25	2	0
Industrial Economics, I 24	2	2
Non-Resident Lectures 391	0	1
Electives*	1	2
Total number of hours	19	19

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. The time alloted to Economics will be devoted to such courses as Accounting, Business Law, Government Control of Industry, and Financial History. Students who wish to elect this option must receive credit for Elementary Economics 52 or its equivalent, be-

*Not more than four hours credit in Advanced Military Science (in addition to the four hours of Drill regularly required of first and second-year men) will be accepted toward meeting the requirements for the M. E. degree.

fore the senior year, since this is a prerequisite for some of the courses required in the option. Students expecting to elect this option are also advised to read for preparation as much industrial history and kindred subjects as possible.

SENIOR INDUSTRIAL ENGINEERING OPTION

Course	*Hours 1st Term*	*Hours 2nd Term*
Heat-Power Engineering, P 20	4	4
Mechanical Laboratory, X 20, 21	3	3
Electrical Engineering, E 36	2 or 0	0 or 2
Electrical Engineering, E 37	0 or 2	2 or 0
Industrial Administration, I 20	2	2
Drawing and Design, I 22	3	3
Safety Engineering and Fire Protection, I 23	0	2
Non-resident Lectures 391	0	1
*Electives	3	0
Total number of hours	17	17

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 the 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 has 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.

*See footnote, page 60.

SENIOR NAVAL ARCHITECTURE AND MARINE ENGINEERING

(Effective in the Fall of 1922)

Course	*Hours 1st Term*	*Hours 2nd Term*
Mechanical Laboratory, X 20,21	3	3
Naval Architecture 321a, b, (lectures)	4	4
" " 322a, b, (office work)	3	3
Marine Engineering 323 a, b	3	3
Electrical Engineering, E 36 or E 37	2	2
Ind. Economics, I 24	2	2
Elective	2	2
Total number of hours	19	19

SENIOR NAVAL ARCHITECTURE AND MARINE ENGINEERING

(Effective in the Fall of 1923 and thereafter)

Course	*Hours 1st Term*	*Hours 2nd Term*
Mechanical Laboratory, X 20, 21	3	3
Naval Architecture 321a,b (lectures)	4	4
" " 322a,b (office work)	2	2
Marine Engineering 323a, b	3	3
Electrical Engineering	5	5
Elective	2	2
Total number of hours	19	19

2. A Six-Year Course Leading to the Degrees of A. B. and M.E.

See pp. 26-27.

ELECTIVES

Students having the necessary preparation and having the approval of their class adviser may take any subject in any department of the University. For detailed information regarding these elective subjects, see the Announcements of the departments in which they are given.

TECHNICAL ELECTIVES GIVEN IN THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING FOR SENIORS ONLY

Course	*Hours 1st Term*	*Hours 2nd Term*
Thesis, X 32	0-8	8-0
Steam Boiler Design, P 30	2	0
Steam Turbines, P 25	0	2
Steam Power Plants, P 23	3	3
Internal Combustion Engines, P 29	2	0
Pumping and Pneumatic Machinery, P 31	0	2
Refrigeration, P 32	0	2
Motor Car Construction, X 33	0	2
Heating and Ventilating, X 34	2	0
Engineering Research, X 30	1-3	1-3

Industrial Administration, I 20	2	2
Hydraulic Power Plants, M 21	2	0
Hydraulic Power Plant Design, M 22	0	2-4
Sibley Journal Credit, 390	0-2	0-2
Costs, Wages, and Management, I 21	2	0
Industrial Relations, I 25	0	2
Advanced Industrial Engineering, I 40	2	2
Advanced Heat-Power Engineering, P 40	2	2
Graphical Computation and Representation, 392	0	2

COURSES OF INSTRUCTION IN THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

For Sophomores, Juniors, and Seniors

(For a description of the freshman courses in Mathematics, Physics, and Chemistry, and a description of the engineering courses given to freshmen, see pp. 31-33 of this Announcement.)

MATHEMATICS (*Given in the College of Arts and Sciences.*)

Examinations for the removal of conditions in Mathematics 1-8 are held in September just before registration. Similar examinations are held in April for the removal of conditions incurred at the end of the first term. For further information apply to the department.

4. See p. 31.
5. See p. 31.
6. **Integral Calculus.** Sophomores. First term. Credit three hours.

PHYSICS (*Given in the College of Arts and Sciences.*)

Examinations for those who were unavoidably absent from either term examination in Courses 2 to 7, and for those who have conditions to make up, will be held on Wednesday, September 20, 1922, at 9 a. m. in Rockefeller A. Similar examinations in connection with Courses 8 to 14 will be held in Rockefeller A at 2 p. m. on the same day. Students expecting to take any of these examinations should notify the department not later than September 13, 1922.

2. See p. 32.
7. See p. 32.

11. **General Physics.** Theory and problems covering selected topics in heat, light, and electricity. Required of candidates for the degree of M.E. or E.E. Second term. Credit three hours. Prerequisites, Physics 7 and Mathematics 6. Three classroom periods as arranged. Rockefeller as arranged. Assistant Professor BIDWELL and Messrs. RICHMOND, BECKER, MACKEOWN, MOTT-SMITH, NOYES, and REYNOLDS.

14. **Physical Measurements.** Required of candidates for the degree of B. Chem., M.E., or E.E. Either term or throughout the year. Credit two or four hours a term. One or two three-hour laboratory periods a week. Prerequi-

site, the calculus and Physics 7. Physics 11 must be taken in parallel with the second half of Physics 14. 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 Messrs. HYATT, BECKER, COTTRELL, JOLLIFFE, MACKEOWN, MOTT-SMITH, REYNOLDS, RICHMOND, WILBER, and NOYES. Eight sections as assigned. *Rockefeller 250.*

CHEMISTRY! (*Given in the College of Arts and Sciences.*)

Entrance credit in Chemistry does not carry with it University credit in Course 120 or 125. If a student entering the University from a preparatory school desires credit in Course 120, he must pass an examination set by the Department of Chemistry. This examination is held both in New York City and in Ithaca on the same day in September as the entrance examination. University credit in Course 1 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 Course 120 will be held at 2 p. m. on the day before instruction begins in the fall. Students expecting to take a final examination in Course 120 should notify the department not later than September 15, 1922.

(*For the introductory course in Chemistry see p. 32.*)

775. **Engineering Chemistry.** Repeated in second term. Two lectures a week. Credit two hours. Prerequisite course Chemistry 1. 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 manufacture of electric furnace products, the refining of petroleum, the manufacture of coal tar products, etc. Professor RHODES.

ENGLISH (*Given in the College of Arts and Sciences.*)

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.

ELECTRICAL ENGINEERING (*Given in the School of Electrical Engineering.*)

Courses 411, 412, 431, 432, E36, and E 37 are required of all candidates for the M. E. degree. For a description of those courses, see pp. 76-82 of this Announcement.

MACHINE CONSTRUCTION

(*For courses in Wood Working and Forging, see Courses 101 and 102 under courses offered to freshmen, p. 33.*)

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

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300. **Foundry Work.** Either term. Credit two hours. Five hours 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.

305 a, b. **Machine Work.** Juniors. Throughout the year. Credit two hours a term. Six hours of work a week. Prerequisite courses 101, 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. GREEN, HOWE and SCHALLOWITZ.

MACHINE DESIGN

A. Courses in Machine Design

(*For the course in Elementary Drawing and Lettering, see Courses 121 and 122 under courses offered to freshmen, p. 32.*)

310. Drawing. For students registered 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. Assistant Professor TOWNSEND and instructors.

311. Empirical Design. Sophomores. First term. Credit two hours. Prerequisite courses 121 and 122. Two recitations a week for the first quarter of the term and two three-hour drawing periods a week for the first three quarters of the term. 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 assembly of such elements. Assistant Professor ROGERS and instructors.

312. Descriptive Geometry. Sophomores. First term. Credit two hours. Prerequisite courses 121 and 122. Two recitations a week for the last three quarters of the term, including assigned home problems, and two three-hour drawing periods a week for the last quarter of the term on advanced problems. Assistant Professor ROGERS and instructors.

313. Kinematics. Sophomores. Second term. Credit two hours. Must be taken with Course 314. Prerequisite courses, Physics 2 and 7; 330, 311, and 312. Two recitations a week throughout the term on the theory of mechanisms, instant centers, cams, gears, linkages, velocity and acceleration diagrams, etc. Assistant Professor ROGERS and instructors.

314. Kinematic Drawing. Sophomores. Second term. Credit two hours. Must be taken with course 313. Prerequisite courses, Physics 2 and 7; 330, 311, and 312. 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. Assistant Professor ROGERS and instructors.

316 a, b. General Machine Design Theory. Juniors. Throughout the year. Credit two hours each term. Prerequisite courses 311,312,313,314,330, and 331. Two recitations a week throughout the year on the theoretical and practical

application 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, Assistant Professor GARNER, and instructors.

317 a, b. **Machine Design.** Juniors. Throughout the year for Mechanical Engineers; first term only for those in Electrical Engineering and for those electing Naval Architecture and Marine Engineering. Must be taken in conjunction with 316a and b. Prerequisite courses, 311, 312, 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, Assistant Professor GARNER, and instructors.

B. Courses in Naval Architecture and Marine Engineering.

320. **Elements of Naval Architecture.** Juniors. Second term. Credit four hours. Prerequisite courses 316a and 317a. Two lectures and two periods of drawing and computations. The subject is dealt with as a whole and separated into its natural subdivisions. Derivation and conception of the "Elements of Form," methods of laying down and fairing of the lines; discussion of the general arrangement plans, cargo spaces, 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. Professor MCDERMOTT.

321a. **Ship Design and Construction.** Seniors. First term. Credit four hours. Lectures. Statical and dynamical stability, rolling in a seaway, the steering and maneuvering powers 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.

321b. **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.

322a. **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 the Course 321a, supplemented by personal discussion of the problems arising in the design of the individual vessels in hand. Professor McDERMOTT.

322b. **Strength, Resistance, etc.** Seniors. Second term. Credit three hours. Office work. Three three-hour periods a week. Drawing and investigations covering the work as discussed in the lectures of Course 321b. Professor McDERMOTT.

323a. **Marine Engineering; Applications.** Seniors. First term. Credit three hours. Prerequisite courses, 340 a and b. Two 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 pump, 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. LARSEN.

323b. **Essentials of Marine Power Engineering.** Second term. Credit three hours. Two 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 LARSEN.

MECHANICS OF ENGINEERING

330. **Theoretical Mechanics.** Sophomores. First term. Credit three hours. Two recitations and one computation period a week. Prerequisite courses, Mathematics 4 and 5. Must be taken with or preceded by Mathematics 6. 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; rigid body; parallel forces; center of gravity. Statics of single pieces, cords, pulleys, structures and mechanism. Professor WOOD, Assistant Professors SWITZER and CORNELL, and instructors.

331. **Strength of Materials.** Sophomores. Second term. Credit four hours. Three recitations and one computation period a week. Prerequisite courses, 330 and Mathematics 6. 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. Professor WOOD, Assistant Professor CORNELL, and instructors.

332. **Applied Mechanics.** Juniors. First term. Credit three hours. Two recitations and one computation period a week. Prerequisite courses 330 and 331. Motion of a rigid body: Translation; rotation; moment of inertia of solids; plane motion. Work and energy: Friction; brakes and dynamometers; power, efficiency and regulation of machines; impact and impact loads. Combined loads and resultant stresses; curved bars. Professor WOOD, Assistant Professors SWITZER and CORNELL, and instructors.

333. **Ordnance Problems.** Open only to men taking Advanced Ordnance R.O.T.C. One lecture a week throughout the year. Credit one hour each term. Prerequisite courses 330 and 331. Professor GARRETT.

335. **Hydraulics.** Juniors. Second term. Credit three hours. Prerequisite courses 330, 331, and 332. Lecture and two recitations. Hydrostatics: pressures in containing vessels, centers of pressure. Hydrokinetics: flow through orifices and over weirs; general equation of energy; losses of head; flow in pipes and open channels and dynamic action of streams. Lectures on the essential features of the design and equipment of water power plants. Assistant Professor SWITZER and assistants.

337. **Hydraulic Power Plants.** Elective. First term. Credit two hours. Prerequisite course 335. Two lectures a week. Elements of hydrology; design and selection of equipment; theory, construction, installation, and operating characteristics of modern hydraulic turbines; power production costs; water power legislation. Assistant Professor SWITZER.

338. **Hydraulic Power-Plant Design.** Elective. Second term. Credit two to four hours; two hours credit for eighty hours of actual work. Prerequisite course 337. It is intended that in this course the student shall apply the knowledge gained in Course 337 to the design of a part or the whole of an hydraulic power plant. One or two students may work on a given problem which shall be chosen with a view to meeting the needs of the students. Hours to be arranged. Assistant Professor SWITZER.

HEAT-POWER ENGINEERING

340 a,b. **Elementary Heat-Power Engineering.** Required of all juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 11 and 14; 311, 312, 313, 330 and 331. Two recitations and one lecture a week throughout the year. Thermodynamics of gases and vapors; ideal heat engines; cycles and general theory of heat engines; application to steam engines, turbines, internal combustion motors, and air compressors; practical modifications in real engines; engine efficiencies and performances; the indicator card as a measure of work and basis for design; economic features (reduction of losses by jacketing, super-heating, compounding, etc.); application of unaflow and locomobile principles; types of steam engines, internal combustion engines and 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, Mr. EVANS, and instructors.

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 2 and 7 (or the equivalent), Chemistry 120 and 125, 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 and air compressors; internal combustion engines; theory of vaporization; study of boilers, types of boilers, advantages and disadvantages of various types; action of vapors in cylinders; steam engines and turbines (application, steam consumption, and efficiencies); advantages of condensing; types of condensers; condenser auxiliaries; contractors plants; cost of power.

This course is recommended for all students who wish to obtain a general elementary knowledge of Heat-Power Engineering without great technical detail. Professor ELLENWOOD and Mr. EVANS.

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 carburation; discussion of recent improvements in small engines, turbines, and boilers; reading of assigned technical articles in library books or magazines. Professor ELLENWOOD.

343 a, 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 11 and 14; 311, 312, 330 and 331. The first term is an abridged treatment of substantially the same ground as 340. The second term is an abridgement of Course P 20. The longer courses, 340 and P 20, may be substituted for 343 a, b. Assistant Professor HOOK.

P 20. **Heat-Power Engineering.** Required of all seniors in Mechanical Engineering. Throughout the year. Credit four hours a term. Prerequisite course, P 10. Two lectures and two recitations a week. An extension of Course P 10. 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, natural and forced; 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. CHERDANTZEFF.

P 21. **Heat-Power Engineering.** Required of seniors in Electrica lEngineering in 1922-23. Not given thereafter. An abridged course covering about the same ground as P 20. Second term. Credit three hours. Assistant Professor HOOK.

P 23. **Steam-Power Plants.** Required of seniors in Option A. Lectures throughout the year. Credit three hours a term. Prerequisite courses, D 10, D 16, and P 10 and must be accompanied by Courses P 20 and P 24. 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.

P 24. **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 P 23. Two drawing periods a week. The practical solution of problems discussed in P 23. Load curves; curves of performance and of cost of power; layouts of prime movers, boiler and furnace settings, condensing apparatus, auxiliary equipment, piping, draft apparatus, and the power plant as a whole. Professor BARNARD and Assistant Protessor CLARK.

P 25. **Steam Turbines.** Required of seniors in option A. Elective for others. First term. Credit two hours. Prerequisite course, P 10. 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. Professor BARNARD.

P 29. **Internal Combustion Engines.** Seniors. Second term. Credit two hours. Prerequisite courses, D 10, D 16, and P 10. 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.

P 30. **Steam Boilers and Boiler Plants.** Seniors. Second term. Credit two hours. Prerequisite courses, D 10, D 16, and P 10. 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.

P 31. **Pumping and Pneumatic Machinery.** Elective. First term. Credit two hours. Prerequisite courses, D 10, D 16, and P 10. A course dealing with principles of pumping, air compression, and pneumatic machinery. Professor ELLENWOOD.

P 32. **Refrigeration.** Elective. First term. Credit two hours. Prerequisite courses, D 10, D 16, and P 10. Refrigeration and refrigerating machinery. Professor ERNSBERGER.

P 40. **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 of Engineering Materials.** Required of sophomores. First or second term. Credit three hours. Prerequisite courses, Chemistry 120 and 125. Three lectures a week. Metallurgy of iron and steel, etc. Professor DIEDERICHS.

365. **Mechanical Laboratory—Introductory Experimental Engineering.** Juniors. First term. Credit three hours. Prerequisite courses, Mechanics 330 and 331, Chemistry 120, 125, Physics 2, 7, 11, 14. 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. Assistant Professor DAVIS and instructors.

366. **Mechanical Laboratory—Properties of Engineering Materials.** Juniors. Second term. Credit three hours. 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. Assistant Professor DAVIS and instructors.

367. **Mechanical Laboratory.** For students in Chemistry. Second term only. Credit four hours. Prerequisite courses, 330 and Physics 10 and 14. One laboratory period and one report a week. Principal tests on materials of construction; use, adjustment and calibration of common engineering instruments; testing of oils and lubrication; engine and boiler trials; stud of rerfrigeration, etc. Assistant Professor GAGE and instructors.

X 20. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering. First term. Credit three hours. Prerequisite courses, 365 and 340 a, 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. Assistant Professor GAGE and instructors.

X 21. **Mechanical Laboratory—General 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 X 20. Assistant Professor GAGE and instructors.

X 22. **Mechanical Laboratory.** Required of seniors in Electrical Engineering. First term. Credit two hours. Prerequisite courses, 365 and 343 a,b. Selected experiments from Course X 20. Assistant Professor GAGE and instructors.

B. Engineering Research

X 30. **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, and UPTON, Assistant Professors GAGE and DAVIS, and Mr. MORDOFF.

X 32. **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 8 x 10½ inches in size must be deposited at the Dean'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, and UPTON, and Assistant Professors GAGE and DAVIS.

X 33. **Motor Car Construction.** Elective. Second term. Credit two hours. Prerequisite courses 340, 316 and 317. Two lectures a week, illustrated by lantern slides showing the structure and development of the motor car. Professor UPTON.

X 34. **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.

INDUSTRIAL ENGINEERING

380. **Industrial Organization.** Required of all juniors in Mechanical and Electrical Engineering. First term. Credit two hours. 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.

381. **Industrial Organization.** Open to engineering students for whom 380 is not a required subject and to juniors and seniors in other Colleges. Two lectures a week. First term. Credit two hours. A consideration of modern industrial tendencies and the principles that underlie modern methods of manufacture. Not only is the history of industry considered but present methods of administration and production are studied, including such features as time-keeping, cost finding, planning and scheduling work, reports, time and motion study, labor administration and industrial legislation. Assistant Professor LEE.

I 20. **Industrial Administration.** Required of all seniors in Option B. Elective for seniors pursuing other options. 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. Professor KIMBALL and Assistant Professor LEE.

I 21. **Cost, Wages, and Management.** Elective for juniors and seniors in Mechanical Engineering, except those who are electing, or expect to elect the senior industrial group. Open also to upperclassmen in other colleges. First Term. Credit two hours. Two lectures a week. A discussion of the fundamental principles underlying the management of industrial works with a more detailed analysis of the elements of cost finding, wage systems, time and motion study, planning of work, etc. Professor WELLS.

I 22. **Industrial Engineering Problems.** Required of all seniors in Option B. One lecture and six hours drawing, computing or time study a week throughout the year. Credit three hours a term. Prerequisite courses 316 and 317. Must be accompanied by I 20.

First term. Design of factory buildings including the detailed design of a reinforced concrete building; the development of organization charts and ad-

ministrative and other industrial forms. Cost keeping methods are considered and each student is required to develop a complete system for the Machine Rate method of distribution of overhead in an assumed shop.

Second Term. Design and layout of a plant, and selection and location of machinery necessary to manufacture some small assembly such as an automobile transmission. The solution of problems in costing, planning, routing etc. in connection with this plant. Each student also makes several time studies of operations in the shops. Assistant Professor LEE and Mr. BANGS.

I 23. **Safety Engineering and Fire Protection.** Required of, and open only to seniors in Option B. Two lectures a week during the second term. Credit two hours. Prerequisite course, 380. A discussion of organization for safety, the workmen's compensation laws, the standard requirements for industrial safety, modern factory construction and arrangement from the standpoint of fire protection, sprinkler systems and other fire protective appliances. Professor WELLS.

I 24. **Industrial Economics.** Throughout the year. Credit two hours a term. Required of candidates for the M.E. or E.E. degree. An elementary study of the economics of the present industrial system with especial emphasis on production. Lectures and assigned readings. (Note: For engineering students, this course will be accepted in place of Economics 51 as a prerequisite for admission to courses given in the Department of Economics, College of Arts and Sciences.) Professor GARRETT.

I 25. **Industrial Relations.** Elective. Two lectures a week during the second term. Credit two hours. Prerequisite course 380 or 381. 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. Assistant Professor LEE.

I 40. **Advanced Industrial Engineering.** Open to graduates and seniors who have completed the equivalent of I 20 and I 22. Professors KIMBALL, WELLS, ALBERT, and LEE.

COURSES NOT PERTAINING TO ANY DEPARTMENT

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 as active members to the end of the term in which credit is desired.

391. **Non-resident and Special Lectures.** These lectures are given either at some hour in the day specially set aside in the senior schedules, or before the evening meetings of the Student Branch of the A.S.M.E. Notices of the lectures will be posted on the bulletin board of the Sibley School of Mechanical Engineering.

Credit toward graduation, one hour, which may be obtained by attendance at 75% of the lectures offered during the student's senior year. For credit a notebook showing a resumé 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. The honor system applies to attendance at these lectures.

Students may obtain an additional hour of elective credit by attending the non-resident lectures during the junior year also, under the same conditions as outlined above. No excuse from regular work will, however, be given for conflicts with such non-resident lectures.

392. **Graphical Computation and Representation.** Senior elective. Second term. Credit two hours. Prerequisite courses 316, 317, 340. Graphical analysis and solution of equations; graphical representation of properties and statistics; derivations of empirical equations from experimental curves; approximate integration and differentiation; recording instruments and similar topics. Mr. EVANS.

THE SCHOOL OF ELECTRICAL ENGINEERING

General Outline of 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 well balanced course of study along broad lines, while 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 and 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 p.26.)

The instruction in Mathematics, Physics, Chemistry, and English is given in the College of Arts and Sciences. All other subjects in the regular curriculum areof an engineering nature and are given in the various departments of the Sibley School of Mechanical Engineering and in the School of Electrical Engineering. The sequence of subjects and the time devoted to each course are given on pp. 31-33 for Freshman Subjects, pp. 58-74 for M.E. Subjects, and pp. 76-82 for E.E. Subjects.

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 teests to check the theoretical work.

The principal part of the work for seniors in Electrical Engineering is given in a well 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 very flexible lends itself particularly to the development of resourcefulness and initative on the part of the 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.

FRANKLIN HALL

The Main Building of the School of Electrical Engineering.

The Senior Electrical Laboratory occupies the second floor of Rand Hall (See view facing title page).

COURSES LEADING TO THE DEGREE OF ELECTRICAL ENGINEER

1. 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.

NOTE.—*One hour of credit in the following schedules corresponds to about three hours of actual work a week for the 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.*

All engineering students, except those entering with advanced standing, are required to take the following courses for the first year:

FRESHMAN YEAR

Course	*Hours 1st Term*	*Hours 2d Term*
Analytical Geometry and Calculus 4, 5 ..... p.31	3	5
Physics 2, 7 ..... p 32	5	3
Chemistry 120, 125 ..... p.32	4	4
Drawing 121 and 122 ..... p.32	2	2
Elementary Surveying 110 ..... p.33	0 or 3	3 or 0
Forge Shop 101 ..... p.33	1 or 0	0 or 1
Wood Working 102 ..... p.33	2 or 0	0 or 2
Introductory Lectures 130 ..... p.33	1	0
Military Drill I ..... (See p. 28)	1	1
Total number of hours	19	18

In addition, all freshman students are required to attend a course of lectures on Hygiene given once a week throughout the year. See p.28.

SOPHOMORE YEAR

Course	*Hours 1st Term*	*Hours 2d Term*
Mathematics 6 ..... p.31	3	0
Mechanics 330, 331 ..... p.68	3	4
Physics (Recitation) 11 ..... p.63	0	3
Physics (Laboratory) 14 ..... p.63	2	2
Empirical Design 311 ..... p.65	2	0
Descriptive Geometry 312 ..... p.65	2	0
Kinematics 313 ..... p.65	0	2
Kinematic Drawing 314 ..... p.65	0	2
Engineering Chemistry 775 ..... p.64	2 or 0	0 or 2
Foundry 300 ..... p.65	2 or 0	0 or 2
Materials 360 ..... p.71	0 or 3	3 or 0
English 2 ..... p.64	2	2
Total number of hours	18 or 17	18 or 19

In addition to these courses sophomores are required to take Military Drill and Hygiene. See p. 28.

JUNIOR YEAR

Course	Hours 1st Term	Hours 2d Term
Electrical Engineering, 411, 412 ... p. 79	3	3
Electrical Laboratory 431, 432 ... p. 80	2	2
Mechanics 332 ... p. 68	3	0
Hydraulics, 335 ... p. 68	0	3
Heat-Power Engineering, 343, 344 ... p. 69	3	3
Mechanical Laboratory 365, 366 ... p. 71	3	3
Machine Design—Recitations 316 a, b ... p. 65	2	2
Drawing 317a ... p. 66	2	0
Machine Work 306 ... p. 65	0	2
Total number of hours ...	18	18

SENIOR YEAR (*Effective Sept. 1923*)

For the Senior curriculum to be given in 1922-23, see below.

Advanced Electrical Engineering—Lect, 421, 422 ... p. 80	2	2
Rec. and Comp. 423,424 ... p. 80	3	2
Electrical Laboratory, 433, 434 ... p. 81	3	4
Electrical Option, A or B* ...	3	4
A. Electrical Power Stations and Design, 441, 442 ... p. 80		
B. Electrical Communication Eng'g. 451, 452 ... p. 81		
Mechanical Laboratory, 371 ... p. 72	2	0
Industrial Organization, 380 ... p. 73	2	0
Economics, I 24 ... p. 74	2	2
Electives ... (See p. 79)** ...	2	5
Total number of hours ...	19	19

SENIOR YEAR (*For 1922-23 only*)

Course	Hours 1st Term	Hours 2d Term
Electrical Theory—Lec. E20 ... p. 80	2	2
Electrical Theory Rec. and Comp. E21 ... p. 80	3	2
Electrical Laboratory, E 28 ... p. 81	3	4
Electrical Option, A or B* ...	3	4
A. Electrical Power Stations and Design, 441, 442 ... p. 80		
B. Electrical Communication Eng'g. 451, 452 ... p. 81		
Heat-Power Engineering, P 21 ... p. 70	3	0
Mechanical Laboratory, X 22 ... p. 72	2	0
Economics ... p. 74	2	2
Electives ... (See p. 79)** ...	2	4
Total number of hours ...	20	18

2. A Six-Year Course Leading to the Degrees of .B. and E.E.

See page 26.

*One of the above options must be completed for the E. E. degree, the courses in the other option may be taken towards elective credit, if desired.

**Not more than four hours credit in Advanced Military Science (in addition to the four hours of Drill regularly required of first and second year men) will be accepted toward meeting the requirements for the E.E. degree.

ELECTIVES

Students having the necessary preparation and having the approval of their class adviser may take any subject in any department in the University. For detailed information regarding these elective subjects see the Announcements of the departments in which they are given.

TECHNICAL ELECTIVES TO BE GIVEN IN THE SCHOOL OF ELECTRICAL ENGINEERING, 1922-23

FOR SENIORS AND GRADUATES STUDENTS ONLY

Course	*Hours 1st Term*	*Hours 2d Term*
Electrical Design, E 22	0	4
Electrical Power Stations, E 23	3	0
Elements of Electric Railway Practice, E 25	0	2
Electrical Communication Engineering E 26,27	3	4
Engineering Mathematics, E 30	0	2
Special Electrical Engineering Problems, E 33	1-3	1-3
Current Electrical Topics, E 34	2	0

COURSES OF INSTRUCTION IN THE SCHOOL OF ELECTRICAL ENGINEERING

FOR JUNIORS AND SENIORS

For a description of courses given to freshmen see pp. 31-33, for a description of the courses given to sophomores, and of M. E. courses for juniors and seniors in Electrical Engineering, see the course in the School of Mechanical Engineering, pp. 54-75.

The following Courses are given in the School of Electrical Engineering:

E 12. **Essentials of Electrical Engineering.** Required of seniors in Civil Engineering and Chemistry. First term only. Credit four hours. Two recitations and one laboratory experiment with report each week. The purpose of the course is fourfold: (1)To review and emphasize the fundamental physical principles applied in electrical engineering; (2)to familarize 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; (4)to enable the student to read intelligently electrical engineering literature. Assistant Professor BALLARD and instructors.

411,412. **Electrical Engineering for E.E. Juniors.** Required of juniors in Electrical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 11 and 14, M.E. 330,331, and must be accompanied by E.E.431, 432. Two lectures and one recitation with computing period a week during both terms. A general course in direct and alternating current circuits and machinery. Assistant Professor PERTSCH and instructors.

415,416. **Electrical Engineering for M.E. Seniors.** Required of seniors in Mechanical Engineering, beginning with the class of 1924. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 11 and 14, M.E. 330

and 331, and must be accompanied by E.E. 435,436. Similar in scope to E.E. 411,412. Professor————and instructors. (This course will not be given in 1922-23.)

431,432 **Electrical Laboratory for E.E. Juniors.** Required of juniors in Electrica Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 11 and 14, M.E.330,331, and must be accompanied by E.E. 411,412. One laboratory period and report each week during both terms. Experimental work on the subjects taken up in E.E. 411, 412. Assistant Professor CHAMBERLAIN and instructors

435,436. **Electrical Laboratory for M.E. Seniors.** Required of seniors in Mechanical Engineering, beginning with the class of 1924. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 11 and 14, M.E. 330 and 331, and must be accompanied by E.E. 415, 416. Similar in scope to E.E. 431, 432. Professor————and instructors. (This course will not be given in 1922-23.)

E 20. **Advanced Electrical Engineering.** Required of seniors in Electrical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, E 14 and E 15. Two lectures a week. The work of the first term covers chiefly the laws of the electric and the magnetic circuits; representation of alternating currents by vectors and by complex quantities; the nature and effects of inductance, capacity, and iron loss; theory of transmission lines and transformers. The second term is devoted to the theory of transmission lines, transformers, generators, motors, and synchronous converter. The lectures are as far as possible correlated with the work in Course E 21. Professor KARAPETOFF. (After 1922-23, this course will be known as 421,422.)

E 21. **Advanced Electrical Engineering.** Required of seniors in Electrica Engineering. Throughout the year. Credit three hours first term, two hours second term. Prerequisite courses, E 14 and E 15; must be accompanied by E 20. Two recitations and one computing period a week first term, two recitations the second term. Problems on the work covered by Course E 20. Professor KARAPETOFF and instructor. (After 1922-23, this course will be known as 423, 424.)

E 22. **Electrical Design.** Required of seniors in Electrical Engineering, except those electing the electrical communication option; open to such students as an elective. Second term only. Credit four hours. Must be accompanied by E 20 and E 21. Two lectures or recitations and two computing periods a week. A study of the fundamental principles underlying the design of direct- and alternating-current machinery. Assistant Professor PERTSCH, and instructor.

(After 1922-23 this course will be known as 442.)

E 23. **Electrical Power Stations.** Required of seniors in Electrical Engineering, except those electing the electrical communication option; open to such students as an elective. First term only. Credit three hours. Prerequisite courses, E 14 and E 15. Two lectures and one computing period a week. Selection and arrangement of the proper electrical equipment for direct and alternat-

ing current power-plants. Some attention is also devoted to operating features, and to questions of public policy and finance. Assistant Professor PERTSCH, and instructor. (After 1922-23 this course will be known as 441.)

E 25. **Elements of Electric Railway Practice.** Elective for seniors. Second term only. Credit two hours. Prerequisite courses, E 14 and E 15. 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. Assistant Professor CHAMBERLAIN.

E 26, 27. **Electrical Communication Engineering.** Required of seniors taking the Electrical Communication Option. Throughout the year. E 26. First term. Credit three hours. Two recitations and one laboratory or computing period a week. E 27. Second term. Credit four hours; Two recitations, one laboratory period and one report each week. Prerequisite courses, E 14 and E 15. Detailed consideration of electrical communication systems including wave propagation and attenuation phenomena; multiplex telegraph transmission; submarine telegraphy; telephone exchange apparatus (including manual and automatic types); telephone repeaters; carrier-wave telephony; various radio systems utilizing damped and sustained waves; radio telephony. Special emphasis is placed upon the theory of the electron tube and its practical application to telephone and radio transmission. Assistant Professor BALLARD, and Mr. NORTHROP. (After 1922-23, this course will be known as 451,452.)

E 28. **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 E 20 and E 21. 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. Assistant Professor CHAMBERLAIN, Mr. BASON, and instructors.

(After 1922-23, this course will be known as 433,434.)

E 30. **Engineering Mathematics.** Elective. Open to seniors and graduate students only. Second term. 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.

E 33. **Special Electrical Engineering Problems.** Open to seniors. First or second term or both. Credit one or more hours. A course to meet the needs of men 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. Professor——and other instructors as required.

E 34. **Current Topics in Electrical Engineering.** Elective. Open only to seniors and graduate students. First term. Credit two hours. 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. Assistant Professor PERTSCH.

E 36. **Electrical Engineering for M.E. Seniors.** Required of seniors in Mechanical Engineering. May not be taken simultaneously with E 37. Credit two hours. Repeated in the second term. Prerequisite courses, X 11, E 14 and E 15. One lecture and one computing period a week. The course is arranged for the needs of mechanical engineers, particular attention being paid to the operating features of electrical machinery, and to selection of proper electrical apparatus for power and industrial purposes. Professor KARAPETOFF and instructor. This course will not be given after 1922-23. (See E.E. 415, 416.)

E 37. **Electrical Laboratory for M.E. Seniors.** Required of seniors in Mechanical Engineering. May not be taken simultaneously with E 36. Credit two hours. Repeated in the second term. Prerequisite courses, X 11, E 14 and E 15. One recitation and one laboratory period a week. A continuation of the electrical laboratory work of course E 15. Assistant Professor CHAMBERLAIN, Mr. BASON, and instructors.

This course will not be given after 1922-23. (See E.E. 435,436.)

Seminary in Electrical Engineering. Required of all graduate students. Seniors may attend by special permission but no credit will be given. Conducted by Professors —— and KARAPETOFF.

Note: For other theoretical, electrical, and illumination courses, see under Mathematics and Physics in the *Announcement of the College of Arts and Sciences*.

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