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ANNOUNCEMENT OF THE COLLEGE OF CIVIL ENGINEERING 1912-13

MARCH 1, 1912
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ITHACA, N. Y.

This announcement is intended to give detailed information to prospective students in the College of Civil Engineering of Cornell University.

For general information concerning the University and its various colleges, the requirements for admission, etc., the General Circular of Information should be consulted. This and the other Official Publications of Cornell University are listed on the last page of the cover of this pamphlet. Any one of the informational publications there mentioned will be sent gratis and post-free on application to The Registrar of Cornell University, Ithaca N. Y

CALENDAR

1912-13

Sept. 13,	Friday,	Entrance examinations begin.
Sept. 23,	Monday,	Academic year begins. Registration of new students. Scholarship examinations begin.
Sept. 24,	Tuesday,	Registration of new students.
Sept. 25,	Wednesday,	Registration of old students.
Sept. 26,	Thursday,	Instruction begins. President's annual address to the students.
Sept. 28,	Saturday,	Registration, Graduate School.
Oct. 15,	Tuesday,	Last day for payment of tuition.
Nov.	Thursday–Friday,	Thanksgiving recess.
Dec. 23,	Monday,	Instruction ends } Christmas Recess.
Jan. 6,	Monday,	Instruction resumed } Christmas Recess.
Jan. 11,	Saturday,	Founder's Day.
Jan. 27,	Monday,	Term examinations begin.
Feb. 8,	Saturday,	Registration, undergraduates.
Feb. 10,	Monday,	Registration, Graduate School.
Feb. 10,	Monday,	Instruction begins.
Feb. 29,	Friday,	Last day for payment of tuition.
April 2,	Wednesday,	Instruction ends. } Spring Recess.
April 8,	Tuesday,	Instruction resumed } Spring Recess.
May 31,	Saturday,	Navy Day,
June 2,	Monday,	Term examinations begin.
June 10,	Thursday,	Commencement.

1913-14

Sept. 12,	Friday,	Entrance examinations begin.
Sept. 22,	Monday,	Academic year begins. Registration of new students. Scholarship examinations begin.
Sept. 23,	Tuesday,	Registration of new students.
Sept. 24,	Wednesday,	Registration of old students.
Sept. 25,	Thursday,	Instruction begins. President's annual address to students.

COLLEGE OF CIVIL ENGINEERING

FACULTY

Jacob Gould Schurman, A.M., D.Sc., LL.D., President.

Eugene Elwin Haskell, C.E., Director of the College of Civil Engineering and Professor of Experimental Hydraulics.

Charles Lee Crandall, C.E., M.C.E., Professor of Railroad Engineering.

Irving Porter Church, C.E., M.C.E., Professor of Applied Mechanics and Hydraulics, in charge of the College Library.

Henry Sylvester Jacoby, B.E., Professor of Bridge Engineering.

Henry Neely Ogden, C.E., Professor of Sanitary Engineering.

John Thomas Parson, Assistant Professor of Drawing, in charge of the Photographic and Drawing Collections.

Ernest William Schoder, B.S., Ph.D., Assistant Professor of Experimental Hydraulics, in charge of the Hydraulic Laboratory.

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

Ora Miner Leland, B.S., C.E., Assistant Professor of Geodesy and Astronomy.

Miles Albion Pond, Ph.B., Assistant Professor of Civil Engineering, in charge of Descriptive Geometry.

Francis Joseph Seery, S.B., Assistant Professor of Civil Engineering.

Donald Derickson, C.E., Assistant Professor of Structural Engineering.

Samuel Latimer Boothroyd, B.S., M.S., Assistant Professor of Topographic and Geodetic Engineering.

Ernest William Rettger, A.B., Ph.D., Assistant Professor of Applied Mechanics.

Sidney Gonzales George, C.E., Assistant Professor of Applied Mechanics and Secretary of the College Faculty.

Charles Leopold Walker, C.E., Assistant Professor of Sanitary Engineering.

Kenneth Bertrand Turner, C.E., M.C.E., Assistant Professor of Hydraulics.

Adelbert Philo Mills, B.S., (C.E.), M.S., (C.E.), Assistant Professor of Testing Materials.

Paul Halladay Underwood, C.E., Instructor in Topographic and Geodetic Engineering.

Leonard Alexander Lawrence, B.S., Instructor in Surveying.

John Clarence McCurdy, B.S., Instructor in Surveying.

Edward Hooker Taylor, B.S. in C.E., Instructor in Civil Engineering.

Earle Nelson Burrows, C.E., Instructor in Bridge Engineering.

Julius Frederick Brauner, C.E., Instructor in Civil Engineering.

Nathan Washington Dougherty, B.S. in C.E., Instructor in Civil Engineering.

Claude Martin Thiele, C.E., Instructor in Civil Engineering.

Walter Lichtenthaeler Conwell, C.E., Instructor in Surveying.

Albert George Fred Buehler, C.E., Instructor in Civil Engineering.

Leonard Church Urquhart, C.E., Instructor in Bridge Engineering.

Ernest C. White, C.E., Instructor in Civil Engineering.

Frank A. Hitchcock, B.S. in C.E., Instructor in Civil Engineering.

Thomas A. H. Teeter, B.S. in C.E., Instructor in Surveying.

Gertrude Marsh Sanford, College Librarian.

Eleanor E. Illston, Secretary to the Director.

Lena K. Haylett, College Stenographer.

Clinton D. Cass, College Mechanician.

GENERAL PLAN OF STUDIES

The courses of preparatory and professional studies have been planned with a view to laying a substantial foundation for the general and technical knowledge needed by practitioners in civil engineering so that our 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 and for advanced investigations are believed to be thorough and efficient. Laboratory work is required in chemistry, mineralogy, geology, mechanics, testing materials, and hydraulics. In addition to the special library and laboratories of the College, all the other libraries, collections, and laboratories of the University are open to the students of this College.

The work of the student comprises an extended course in mathematics, mechanics, and graphics, and in their applications to engineering. The object aimed at is to give as thorough a preparation as possible for the general purposes 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 coördinates 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 design, construction, application, and tests of hydraulic and electric motors and steam engines; the preparation of drawings, plans, and 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 ordinary principles of the laws of contracts and riparian rights.

The College of Civil Engineering is quartered in Lincoln Hall, a substantial brown stone structure, two hundred feet long and seventy feet wide, specially designed for its purpose. In addition to the laboratories and museums, the building contains the working library of the College, aggregating about four thousand volumes, reading rooms, class rooms, and draughting rooms. The astronomical and portions of the geodetic equipment are housed in the Fuertes Observatory containing all the instruments required for finding time, latitude, longitude, and azimuth. The instruments are duplicates, in the main, of similar ones in use by the Coast and Geodetic Survey. The large hydraulic laboratory with its buildings and equipment is located at the Fall Creek gorge, within a short distance of the College building.

LABORATORIES

The Civil Engineering Laboratories are located in three distinct buildings and comprise the following:

1. **A Laboratory of Mechanics** in the basement of Lincoln Hall, containing a collection of machines and appliances for the experimental illustration and application of the principles and subjects taught in the class room, and as preparation for special laboratories. It contains:

Numerous computing instruments, such as ordinary slide rules, Fuller spiral slide rules, Thacher calculating instruments, and Goodchild charts. Amsler mechanical integrators and planimeters, both for areas and moments of inertia. A cathetometer, in connection with a weighing scale, for observing elongations of steel and other wires. A smaller cathetometer for miscellaneous purposes. Various mechanical appliances, such as funicular polygons; wooden trusses for measurement of stresses in members; a "Willis apparatus" crane for efficiency tests; systems of levers; Jolly balances for determination of specific gravity; polygonal plates of sheet metal and wooden prismoids, for finding centers of gravity.

An inclined plane of glass and metal for efficiency tests, springs and weights for harmonic motion of suspended bodies. A Kater pendulum.

A 50,000 lb. and a 100,000 lb. Olsen testing machine for testing metals in tension and compression, a Henning extensometer and a dial extensometer for use with same. A Thurston autographic torsion testing machine for small test pieces. A Riehlé torsion testing machine, of 60,000 inch-lbs. capacity, for testing rods and shafts up to one and a half inches in diameter and length of six feet. Torsion clinometers, for use with the Riehlé machine and reading to single minutes of arc, for determining angles of torsion. A compression machine of capacity of 4,000 lbs., for testing wooden columns up to eight feet in length. Two machines for flexural tests of bars of metal and wood, with observation of deflections.

The Kew magnetometer and dip-circle, for observations on the magnetism of the earth.

2. **A Cement Laboratory.** This laboratory contains machines for tension tests, compression machines of from two to two hundred tons capacity, an impact machine, and a special machine for determining automatically the rate of setting and hardening of cement. For direct experiment with cement there is also provided a large number of tension and compression briquette moulds, a water tank with capacity for the storage of three thousand briquettes, a moist oven with a capacity of seven hundred briquettes, and three drying ovens; scales, slate and plate-glass mixing tables, thermometers, a Bunsen pump for determining permeability, 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.

3. **A 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 to 18 feet in length and for specimens in tension and compression up to 12 feet in length; a Riehlé 100,000 lb. testing machine, and an Olsen

50,000 lb. 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 flexular 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 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. The Martens mirror extensometer is also available. Knock-down forms are provided for the making of large concrete beams and columns.

4. **The Hydraulic Laboratory.** This laboratory, by reason of its unique location and unusual facilities, is adapted to investigations of great value to hydraulic science and the engineering profession. The water supply is obtained from Fall Creek with a watershed 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 per second may be passed.

A branch canal 6 feet wide leads from the lower end of the large 16-foot canal into the upper portion of the laboratory building which is built against the cliff of the gorge. This branch canal may also 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. Two sluice gates control the flow from the large canal, and a 30-inch valve controls the flow from the 48-inch pipe into the 6-foot canal. The 6-foot canal within the laboratory building 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 per 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.

The lower portion of the large 16-foot canal, 350 feet long between weirs, is used for measurements with floats and current meters. An electrically operated car spans this canal and is used for rating the current meters. Models of dams may be built in the canal and the flow over them investigated with precision.

There is an outdoor equipment for pipe flow experiments with pipes as large as 6 inches in diameter with a concrete tank for precise measurements of flow. The 8-inch pipe line supplying the University filtration plant is available for experimentation, giving a head of 225 feet.

A concrete Cippoletti weir with steel edges and with a crest length of 16 feet, and depth of notch of 6.5 feet is built in the gorge below Beebe Lake dam and serves to measure the creek flow to calibrate the dam and the 5-foot flood gate in the dam.

Part of the equipment of the University power plant may also be used for certain kinds of hydraulic experimentations. The available head here is 135 feet.

Although the laboratory needs still further additions to its very expensive 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 U. S. Deep Waterways Commission, the Michigan Lake Superior Power Company, the City of New York in connection with its water supply, and for the U. S. Geological Survey.

5. **A 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, a 37½° and two 20°C. incubators, a chemical balance, a U. S. 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.

6. **A Metric Laboratory** for the comparison of standards of lengths. The room is built with hollow double walls, and the daily range of temperature can be kept within 1° F. The four-meter comparator is of the Repsold type, but with the beam supporting the two micrometer microscopes resting on piers independent from those supporting the bed or main framework. The cradle supporting the two bars under comparison can be moved so as to bring first one and then the other under the microscopes, by a crank outside of the case which protects the apparatus from sudden temperature changes due to the presence of the observer. The standard of length is a steel meter bar of the International type which has been compared with the International Standard at the Coast and Geodetic Survey Office. There is also a Rogers speculum metal decimeter and 4-inch scale combined, accurately divided and compared, and a 4-meter bar for subsidiary standards.

Tonnelot and Boudin thermometers, standardized at the International Bureau in Paris, form the basis for temperatures. A 4-foot comparator is provided for the study of leveling rods. The 100-meter comparator for standardizing base line tapes is situated near the Observatory. Repsold cutoff tubes are used to transfer from the underground monuments to the tapes under field conditions. The standard is a 50-meter invar tape the length of which has been determined by the U. S. Bureau of Weights and Measures. The 100-foot chain tape comparator is located on the fourth floor of Lincoln Hall.

The laboratory also contains a Mendenhall half-second pendulum apparatus mounted upon a pier for the determination of the force of gravity. It is the standard type used by the Coast and Geodetic Survey.

7. **A Photographic Laboratory** for reproducing the appearance of tested specimens, for the purposes of the lecture room, as an aid in topographic surveys, and for the distribution of reprints of the collection of progress photographs of engineering structures owned by the College.

The equipment contains a revolving or panoramic transit camera constructed by the mechanician of the College from patterns generously supplied by the inventor, Mr. G. W. Parsons. This is especially valuable in topographic work since the entire sweep of 360° at a station can be included on a film 6-inches wide and about 70 inches long.

8. **The Fuertes Astronomical Laboratory and Observatory** is a brick building 20 feet wide by 80 feet long, with a wing 14 by 24 feet. It contains a computing room, a transit room with four piers, a clock room, and three domes.

It is equipped with a Howard mean time astronomical clock, Negus and Nardin sidereal chronometers, four chronographs, a Troughton and Simms transit, a Fauth transit, 2 Fauth zenith telescopes, a Troughton and Simms 12-inch altazimuth, a Fauth 10-inch altazimuth, a 4½-inch Clark equatorial, besides sextants, surveyor's transits, etc.

Students here become familiar with the observations, reductions, and computations required for the determination of time, latitude, azimuth, and longitude.

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 College 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 geognosy. 3. The Schroeder models in descriptive geometry and stereotomy with over 50 brass and silk transformable models made in this College after the Oliver 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. An extensive collection of instruments of precision, such as a Troughton and Simms astronomical transit; a universal instrument by the same makers, reading to single seconds; sextants, astronomical clocks, chronographs, a Negus and a Nardin chronometer, an equatorial having an objective, by Alvan Clark, four and one-half inches in diameter, two large zenith telescopes of improved construction for latitude work, by the eye and photographic methods; spherometers and other instruments, like pier collimators, etc., necessary to complete a most efficient equipment of a train-

ing observatory. 10. A geodesic collection, consisting of a four-meter comparator, built at the College; a set of improved pendulums for gravimetric investigations; a secondary base line apparatus made under the direction of the Coast Survey; two new base line bars designed and constructed in the laboratories of this College, and all the portable astronomical and field instruments needed for extensive triangulations, including sounding machines, tachometers, and heliotropes. 11. Among the usual field instruments, there is nearly every variety of engineers' transits, theodolites, levels, solar and other compasses, omnimeters and tachometers, with a large number of special instruments, such as planimeters, pantographs, elliptographs, arithmometers, computing machines, altazimuths, sextants, telemeters, and altmeters, hypsometers, and self-recording meteorological instruments of all descriptions.

REQUIREMENTS FOR ADMISSION

(Candidates for admission should consult the General Circular of Information, which will be sent post-free on application to the Registrar of Cornell University, Ithaca, N. Y. All applications for admission to the freshman class should be addressed to the Registrar.)

The subjects that may be offered for admission to the College of Civil Engineering are named in the following list and 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 recitations a week for one year in a study.

1a.	English A	(2)
1b.	English B	(1)
2a.	First Year Greek	(1)
2b.	Second Year Greek	(1)
2c.	Third Year Greek	(1)
3a.	First Year Latin	(1)
3b.	Second Year Latin	(1)
3c.	Third Year Latin	(1)
3d.	Fourth Year Latin	(1)
4a.	First Year German	(1)
4b.	Second Year German	(1)
4c.	Third Year German	(1)
5a.	First Year French	(1)
5b.	Second Year French	(1)
5c.	Third Year French	(1)
6a.	First Year Spanish	(1)
6b.	Second Year Spanish	(1)
6c.	Third Year Spanish	(1)
7a.	First Year Italian	(1)
7b.	Second Year Italian	(1)
7c.	Third Year Italian	(1)
8a.	Ancient History	(½–1)
8b.	Modern History	(½–1)
8c.	Am. History, Civics	(½–1)
8d.	English History	(½–1)
9a.	Elementary Algebra	(1)
9b.	Intermed. Algebra	(½)
9c.	Advanced Algebra	(½)
9d.	Plane Geometry	(1)
9e.	Solid Geometry	(½)
9f.	Plane Trigonometry	(½)
9g.	Spher. Trigonometry	(½)
10.	Physics	(1)
11.	Chemistry	(1)
12.	Physical Geography	(1)
13.	Biology *	(1)
14.	Botany *	(½–1)
15.	Zoology *	(½–1)
16.	Agriculture	(½–1)
17.	Drawing	(½–1)
18.	Manual Training	(1)

Four-Year Course

For admission under these requirements the applicant must offer fifteen units from the list of entrance subjects arranged as follows: English (3), history (1), elementary algebra (1), intermediate algebra (½), plane geometry (1), solid

*If an applicant has counted Biology (1) he may not also offer Botany (½) or Zoology (½).

geometry (½), advanced algebra (½), plane trigonometry (½), French (3) or German (3), †elective (4).

Five and Six-Year Courses

For admission to the College of Arts and Sciences under these requirements the applicant must offer fifteen units from the list of entrance subjects arranged as follows: English (3), history (1), elementary algebra (1), plane geometry (1), foreign languages (5), elective (4).

For the six-year course the elective (4) must include the following: Intermediate algebra (½), solid geometry (½), advanced algebra (½), plane trigonometry (½).

ADMISSION TO ADVANCED STANDING

A student who, having already attended some college or university, desires advanced standing in 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 to advance standing, 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; a detailed statement of the courses pursued for which he desires credit at Cornell. He should send also a catalogue of the institution, writing on it his name and marking the entrance requirements that he has satisfied and each subject that he has completed.

ADMISSION AS SPECIAL STUDENTS

College graduates over twenty-one years of age, who wish to pursue advanced work without being candidates for a degree, may be admitted without entrance examinations. See General Circular of Information.

PRIZES

For scholarships and prizes, see the General Circular of Information, and the Pamphlet on Prizes.

The Fuertes Medals, founded by Professor E. A. Fuertes and consisting of two gold medals, each of the value of one-half the amount of the income provided by the endowment fund will be awarded under the following conditions.

One of these medals will be awarded annually by the University Faculty to that student of the College of Civil Engineering, who may be 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 in the University for at least one and one-half years; and the other medal will be awarded annually by the Faculty to that graduate of the College of Civil Engineering who may write 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 15th. If a paper is presented in a printed form, it will not be received if it has been printed earlier than the next preceding April 15th.

†It is strongly recommended that at least three of these four elective units be offered in language and history.

Neither medal shall be awarded unless it appears to the Faculty of the College of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction. Candidates will be nominated to the University Faculty by the College of Civil Engineering annually.

The William C. Seidell Book Fund of $1,000, founded by Gerrit S. Miller. The income, to be used for the purchase of books for poor young men who are working their way through the College of Civil Engineering, is paid by the Treasurer of the University upon the recommendation of the Director of the College, preference being given to members of the freshman class.

COURSES OF INSTRUCTION

The registration of new students will take place from 9 a. m. to 4 p. m., Monday and Tuesday, September 23 and 24, 1912. Seniors, juniors, and sophomores in good standing, may register in the College between 9 a. m. and 4 p. m. on Tuesday and Wednesday, September 24 and 25, 1912.

A student must register for at least 12 hours each term.

The required courses in mathematics, physics, chemistry, geology, and political economy are given in the College of Arts and Sciences; for a description of these courses see Courses of Instruction for that College for 1912–13. The required work in electrical engineering and steam machinery is given in Sibley College; for a description of these courses see Announcement of that College for 1912–13.

A FOUR-YEAR COURSE LEADING TO THE DEGREE OF CIVIL ENGINEER

Freshman year	No. course	First term	Second term
Analytics	5	4	–
Differential Calculus	5	1	2
Integral Calculus	5	–	4
Physics	1	4	–
Physics	6	–	4
Chemistry	1	–	6
Descriptive Geometry and Drawing	1	5	2
Elementary Surveying	11	3	–

In addition to the above the required Drill must be taken.

Sophomore year	No. course	First term	Second term
Geology	31	3	3
Mechanics of Engineering	20	5	5
Engineering Laboratory	22	1	3
Drawing	4	4 or 1	0 or 3
Advanced Surveying	12	–	4
Materials of Construction	25	3	or 3
Chemistry	6	5	–
Geodetic and Topographical Surveys	13	–	6

(Six weeks at close of year).

In addition to the above the required Physical Training must be taken.

The work of the junior and senior years consists of the studies of some one of the six groups shown in the tabulation here appended, viz.: (a) general; (b) geodetic; (c) hydraulic; (d) sanitary; (e) railroad; (f) bridge.

On registering at the opening of the junior year each student of that class shall elect a group which he is to take for the remaining two years of his course.

The general group is strongly recommended in the case of all students who have no urgent reasons for electing one of the other (special) groups.

Junior Year

Course No.		Gen. (a) I–II		Geod. (b) I–II		Hyd. (c) I–II		San. (d) I–II		R. R. (e) I–II		Bridge. (f) I–II	
54	Political Economy	3	–	3	–					3	–	3	–
60	Railroads	4	4	4	4	4	2	4	2	4	4	4	4
71	Bridges	4	4	4	4	4	4	4	–	4	4	4	4
23	Hydraulics	6	–	6	–	6	–	6	–	6	–	6	–
52	Municipal Engineering	–	4	–	4	–	4	–	4	–	4	–	4
29	Engineering Problems	–	2	–	2	–	2	–	2	–	2	–	2
14	Survey Computations and Mapping	–	4	–	4	–	4	–	4	–	4	–	4
50	Sanitary Biology	–	–	–	–	–	–	3	3	–	–	–	–
76	Chemistry; Water Analysis							–	3				
E12	Electrical Engineering					3	–						
E23	Generation and Distribution of Electrical Energy					–	2						
		17	18	17	18	17	18	17	18	17	18	17	18

Senior Year (1913–14)

17	Geodesy and Geodetic Laboratory	–	–	3	–	–	–	–	–	–	–	–	–
18	Geodetic Astronomy	–	–	–	3								
19	Advanced Topographic Surveying			3	–								
26	Advanced Mechanics	3	–							3	–	3	–
30	Water Supply (must alternate with 77)	3 or 3		3 or 3		3 or 3		3 or 3		3 or 3		3 or 3	
31	Hydraulic Construction	3	–	3	–	3	–			–	3		
32	Water Power Engineering			–	3	–	3						
41	Hydraulic Measurements					3	–						
42	Experimental Hydraulic Motors and Pumps					–	3						
53	Purification and Control of Water Supplies							–	3				
53a	Sewage and Water Purification	–	3										
54	Sewerage Works							3	–				
55	Sanitary Laboratory							3	–				
61	Railroad Maintenance of Way									3	–		
62	Railroad Operation and Management									–	3		
71	Structural Design							–	4				
72	Reinforced Concrete Arch											2	–
73	Higher Structures											4	–
74	Masonry and Foundations	–	3			3	–					–	3
76	Steel Buildings											–	3
77	Concrete Construction (must alternate with 30)	3 or 3		3 or 3		3 or 3		3 or 3		3 or 3		3 or 3	
90	Specifications and Contracts	–	2	–	2	–	2	–	2	–	2	–	2
91	Engineering Design	–	3	–	3	–	3	–	3	–	3	–	3
92	Thesis	3	–	3	–	3	–	3	–	3	–	3	–
54	Political Economy					3	–	3	–				
—	Political Economy	3	–							3	–		
E12	Electrical Engineering	3	–	3	–			3	–	3	–	3	–
P11	Steam Machinery	–	3	–	3	–	3	–	3	–	3	–	3
		18	17	18	17	18	17	18	18	18	17	18	17

Senior Year (1912–13)

In the year 1912–13, seniors in all groups except the sanitary will be required to take courses 13a, 16a, 30, 77, 90, 91, 92, E12, and P11 of the following tabulation; and to fill in the remaining hours of each term (up to a total of 18 for the first term and 17 for the second) by taking such courses, appropriate to their respective groups, as they may elect subject to the approval of their class adviser; but seniors in the sanitary group shall take the courses already prescribed for that group in the foregoing schedule for senior year, 1913–14.

Course No.		Gen. (a) I–II		Geod. (b) I–II		Hyd. (c) I–II		San. (d) I–II		R. R. (e) I–II		Bridge. (f) I–II	
13a	Geodetic Surveying	5	–	5	–	5	–	–	–	5	–	5	–
16a	Cartography	–	3	–	3	–	3	–	–	3	–	–	3
17	Geodesy and Geodetic Laboratory			3	–	–	–	–	–	–	–	–	–
18	Geodetic Astronomy	–	–	–	3								
19	Advanced Topographic Surveying			3	–								
26	Advanced Mechanics	3	–							3	–	3	–
30	Water Supply (must alternate with 77)	3 or 3		3 or 3		3 or 3		3 or 3		3 or 3		3 or 3	
31	Hydraulic Construction	3	–	3	–	3	–			–	3		
32	Water Power Engineering			–	3	–	3						
41	Hydraulic Measurements					3	–						
42	Experimental Hydraulic Motors and Pumps					–	3						
53	Purification and Control of Water Supplies							–	3				
53a	Sewage and Water Purification	–	3										
54	Sewerage Works							3	–				
55	Sanitary Laboratory							3	–				
61	Railroad Maintenance of Way									3	–		
62	Railroad Operation and Management									–	3		
71	Structural Design							–	4				
72	Reinforced Concrete Arch											2	–
73	Higher Structures											3	–
74	Masonry and Foundations	–	3			3	–					–	3
76	Steel Buildings											–	3
77	Concrete Construction (must alternate with 30)	3 or 3		3 or 3		3 or 3		3 or 3		3 or 3		3 or 3	
90	Specifications and Contracts	–	2	–	2	–	2	–	2	–	2	–	2
91	Engineering Design	–	3	–	3	–	3	3	–	–	3	–	3
92	Thesis	–	3	–	3	–	3	–	3	–	3	–	3
54	Political Economy					3	–	3	–				
—	Political Economy	3	–							3	–		
E12	Electrical Engineering	3	–	3	–	3	–	3	–	3	–	3	–
P11	Steam Machinery	–	3	–	3	–	3	–	3	–	3	–	3

In the general group a senior may, with the approval of his class adviser, substitute three hours for advanced mechanics, first term, or for masonry and and foundations, second term, or for both.

Engineering design in the general group and in the geodetic group may be taken in any one of the other groups by approval of the head of the department concerned.

For the thesis, work in engineering design or in investigation may be substituted; but this substitution must be approved by the professor in charge of the group which the student has elected. For the general group the substitution must be approved by the class adviser and the department concerned.

A FIVE-YEAR COURSE LEADING TO THE DEGREE OF CIVIL ENGINEER

For those students who wish to cover a somewhat broader field than that of the four-year course in Civil Engineering, a five-year course has been arranged as given below. The first two years of this course are given by the College of Arts and Sciences and the student registers in that college for this period. At the beginning of the third year, transfer is made to the College of Civil Engineering, and the student enters upon his regular engineering work.

The five-year course is of particular advantage to those students who have, in their home schools, found it impossible to secure adequate preparation in the advanced entrance requirements in mathematics.

First Year—In College of Arts and Sciences

	No. course	First term	Second term
Solid Geometry, Trigonometry	1, 3	6	–
Advanced Algebra	2	–	5
Chemistry	1, 6	6	5
Other Arts Subjects. (See lists, etc., below)		5	6

In addition to the above, the required Drill must be taken.

Second Year—In College of Arts and Sciences

	No. course	First term	Second term
Analytic Geometry	5	4	–
Calculus	5	1	6
Physics	1, 6	4	4
Other Arts Subjects. (See lists, etc., below)		3	6
Descriptive Geometry and Drawing	1	5	2

In addition to the above, the required Physical Training must be taken.

List of Courses open to Freshmen without Special Permission of the Administrative Board in Charge of Freshmen and Sophomores

Greek, 1, 3, 5, 6; Latin, 1, 3, 4; Germanic Languages, 1, 2, 3, 4, 5, 6, 7, 8; Romance Languages, 1, 2, 3, 12, 30, 32, 40, 42; English, 1; Music, 1; History, 1, 21; Bibliography, 1, 1a; Mathematics, 1, 2a, 2b, 3, 4, 6, 7; Physics, 1, 5, 6, 10; Chemistry, 1, 6, 7; General Biology, 1; Botany, 1, 2; Entomology, etc., 2, 4, 5; Vertebrate Zoology and Neurology, 2, 5; Geology, 1, 2a, 2b, 2c.

For a student in the five-year course leading to the degree of Civil Engineer, this list is subject to the following restriction:

"He may not register or receive credit, during those years for any courses in mathematics, physics, or chemistry, or for any courses outside the College of Arts and Sciences, other than those there specified; nor may he register, during his freshman or sophomore year, for any course in the College of Arts and Sciences, which is specified for a later year of the outline which he is following."

Third Year—In the College of Civil Engineering

	No. course	First term	Second term
Geology	31	3	3
Physical Experiments	14	2	–
Mechanics of Engineering	20	5	5
Engineering Laboratory	22	1	3
Surveying	11, 12	3	4
Materials of Construction	25	3 or	3
Drawing	4	4 or 1	0 or 3
Summer Survey	13		6
(Six weeks at close of year.)			

Fourth Year—In College of Civil Engineering

(General Course)

Political Economy	54	3	–
Railroad Engineering	60	4	4
Bridges	71	4	4
Hydraulics	23	6	–
Municipal Engineering	52	–	4
Engineering Problems	29	–	2
Survey Computations and Mapping	14	–	4

Fifth Year—In College of Civil Engineering

(General Course)

Advanced Mechanics	26	3	–
Hydraulic Construction	31	3	–
Sewage and Water Purification	53a	–	3
Water Supply	30	3	–
Masonry and Foundations	74	–	3
Concrete Construction	77	3	–
Specifications and Contracts	90	–	2
Engineering Design	91	–	3
Thesis	92	–	3
Political Economy	–	3	–
Electrical Engineering (E)	12	3	–
Steam Machinery (P)	11	–	3

A Six-Year Course Leading to the Degree of Bachelor of Arts at the End of Four Years and of Civil Engineering at the End of Six Years

Seniors in good standing in the College of Arts and Sciences, who have been in actual residence at least six terms, exclusive of summer sessions, and have a credit of at least 90 hours, may be registered both in the College of Arts and Sciences and in the College of Civil Engineering.

In accordance with this provision the following suggestion is given for a six-year course leading to the degrees of A.B. and C.E.

The following subjects are to be included in the course of study of at least 90 hours in the College of Arts and Sciences during the first three years of residence.

	No. course	First term	Second term
Analytic Geometry	5	4	–
Calculus	3	1	6
Physics	1, 6	4	4
Physics	10	1	1
Chemistry	1	6	(or 6)
Chemistry	6	5	(or 5)
Geology	31	3	3
Descriptive Geometry and Drawing	1	5	2

The following subjects in Civil Engineering are to be taken during the fourth year, when registered in both colleges.

	No. course	First term	Second term
Political Economy	54	3	
Drawing	4	4 or 1	0 or 3
Elementary Surveying	11	3	–
Advanced Surveying	12	–	4
Mechanics of Engineering	20	5	5
Engineering Laboratory	22	1	3
Materials of Construction	25	3 or	3
Summer Survey	13		6
(Six weeks at close of year.)			

The work for the fifth and sixth years is to include the subjects of the junior and senior years of the general group of the four-year course leading to the degree of C.E., except that course 54 in Political Economy is replaced by an elective.

Students desiring to take this course are recommended to confer with the Deans of the Faculties concerned.

GRADUATE STUDY AND ADVANCED DEGREES

The facilities for study and research offered by the various laboratories of this College are available for graduate students; they will find also 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.) and of Doctor of Philosophy (Ph.D.) are granted upon fulfilment of the conditions prescribed by the Faculty of the Graduate School. See Announcement of the Graduate School.

COURSES OF INSTRUCTION

1. **Drawing and Descriptive Geometry.** Freshmen. Credit, five hours first term, and two hours second term.

Drawing and Lettering. Six hours a week during first term. The work is subdivided and is taken up in the following order. Geometrical problems, which includes the drawing of the problem in pencil and ink; also a study of simple forms of projection in plan, elevation, and section; thirty actual hours. Cross sections, which includes practice in using drawing instruments in making the conventional signs of sections through different materials; nine actual hours. Tracing details, which includes the use of tracing cloth in making tracings from blue prints of standard drawings, and from pencil drawings; also making blue prints from tracings; twenty-one actual hours. Freehand lettering, which includes instruction and practice in a one-stroke freehand letter for working drawings. It is intended that the student shall acquire proficiency in the use of a letter applicable for shop and other drawings where a finished letter is not required but where rapidity and clearness are essential; thirty actual hours.

Descriptive Geometry. A study of the representation of lines, planes, surfaces, and solids, and their interrelations. Warped surfaces. Tangencies. A textbook is used and recitations are held upon the problems there stated or ex-

plained. A drawing period serves to allow the student to make drawings of original problems which are illustrations and applications of the problems in the book. Recitations, two hours a week. Original problems, two and one-half actual hours a week. Two hours credit in second term. Intersections, shades and shadows, perspective. The intersections include various forms of the intersections of planes with surfaces and solids, or surfaces with solids and of solids with solids. The work in shades and shadows includes shade lines on solids and the shadows of solids on planes and other solids. Original problems are assigned for work in the drawing room. Recitations, one hour a week. Original problems, two and one-half actual hours a week. Assistant Professor POND and Instructors DOUGHERTY, THIELE, and HITCHCOCK. First term. Six sections in drawing, four sections in recitations, and eight sections in problems. Second term. Six sections in recitations, and six sections in problems.

4. **Drawing and Lettering.** Sophomores. Credit, four hours first term, for one-half of the class; and for the other half a credit of one hour first term and three hours second term. Preparation required: course 1. The work is subdivided and is taken up in the following order. Lettering, which includes a study of and practice in different styles of letters, as Roman, Gothic, and stump, together with their combination into appropriate titles; seventy-five actual hours. Isometric drawing, which includes the principles involved in isometric projection, with practice in drawing from models and from dimension drawings; twelve actual hours. Line shading, which includes the shading of flat and curved surfaces by lines variously spaced and by lines of different thickness; eighteen actual hours. Detail and dimension drawing, which includes the tracing of typical dimension drawings and in making detail drawings from sketches, models, and from other drawings on different scales; forty-eight actual hours. Topographic signs, which includes practice in the different kinds of standard topographic signs for mapping; twelve actual hours. Tinting and shading, which includes instruction in and practice with water colors, in the rendering of flat and curved surfaces, together with the use of crayon. Each student is required to make a number of plates and to become reasonably proficient with handling the brush and with the use of crayon; fifteen actual hours. Assistant Professor PARSON. Three sections for each half of the class.

TOPOGRAPHIC AND GEODETIC ENGINEERING

10. **Surveying** for students in Sibley College. Second term, credit two hours. Use of surveying instruments. Tape measurements. Leveling. Problems with transit and tape. Recitations, field work, computations, and plotting. Textbook: Breed and Hosmer's Elementary Surveying. Two periods a week. Instructors LAWRENCE and MCCURDY. Five sections.

11. **Elementary Surveying.** Freshmen. First term, 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. U.S. Public Lands. Recitations, field work, computations, and mapping. Textbook: Tracy's Surveying. Three periods a week. Assistant Professors LELAND and BOOTHROYD and Instructors LAWRENCE, MCCURDY, CONWELL, and TEETER. Eight sections.

12. **Advanced Surveying.** Sophomores. Second term, credit four hours. Preparation: course 11. City, topographic, hydrographic, mine, and geodetic surveying and field astronomy. Precise measurements. Transit and stadia; plane table; sextant. Soundings; stream measurement. Subterranean surveys. Earth volumes. Triangulation; base lines; precise leveling. Field determinations of azimuth, time, and latitude. Recitations and field work. Textbooks: Breed and Hosmer's Surveying and Campbell's Astronomy. Four periods a week. Assistant Professors LELAND and BOOTHROYD and Instructors LAWRENCE, McCURDY, and CONWELL. Eight sections.

13a. **Geodetic Surveying.** Seniors (for 1912–13 only). Credit, five hours. Preparation required: former course 15 or its equivalent. The course is divided into three parts, namely, astronomy, geodetic surveying, and the adjustment of observations by the method of least squares. The work in astronomy is devoted to the elements of practical astronomy with reference to the needs of engineers in the determination of azimuth and the auxiliary determinations of time and latitude. One afternoon a week is given to practice in computation including the reduction of the astronomic observations made at the junior camp of the preceding summer. In geodetic surveying, the methods of triangulation, base measurement, and precise leveling are studied, especially from the standpoint of economics. Methods of computation and reduction are considered. The application of the method of least squares to engineering problems is studied with special reference to the adjustment of triangulation and leveling. Campbell's Practical Astronomy and Crandall's Least Squares and Geodesy are used as textbooks. Four recitations and one three-hour computing period a week. Assistant Professors LELAND and BOOTHROYD and Instructor UNDERWOOD. Recitations and computations, six sections.

13. **Summer Survey; Topographic, Hydrographic, and Geodetic Survey; Camp.** Sophomores, six weeks during summer, credit six hours. Date of commencing to be announced during the second term. Preparation: course 12. Practical experience in surveying under field conditions. An extensive topographic survey with the transit and stadia and the plane table, also a hydrographic survey of a portion of some lake, is 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 party also does a number of field exercises in city surveying. Each student takes part in all branches of the work. Field and office work six days and evenings a week. Assistant Professors LELAND and BOOTHROYD, Instructors UNDERWOOD, LAWRENCE, McCURDY, TEETER, and CONWELL, and four assistants.

14. **Survey Computations and Mapping.** Juniors. Second term, credit four hours. Preparation required: courses 12 and 13. One-fourth of the time is devoted to the study of the subject of least squares, Crandall's Geodesy and Least Squares being used. An equal amount of time is devoted to the computations resulting from the field work of the previous summer surveys, course 13, embracing base-line measurement, triangulation, and trigonometric and precise leveling. The work results in a set of permanent records, with the geographic positions, azimuths, distances, and elevations of the various triangulation stations. The remainder of the course consists of the construction of a final topographic

map of a portion of the area covered in the preceding summer survey. Several of the field sheets are combined for this purpose, and reduced in scale from 1:4800 to 1:12000, using the triangulation system as a basis for the work. Assistant Professors LELAND and BOOTHROYD, and Instructors UNDERWOOD and LAWRENCE. Eight sections.

15. **Least Squares; Adjustment of Observations.** Elective. Preparation required: 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. Instructor UNDERWOOD.

16a. **Cartography.** Seniors. Second term, credit three hours. Preparation required: course 13a and former course 15. One-third of the time is devoted to the computations resulting from the field work of the previous summer surveys, course 15, embracing base-line measurement, triangulation, and trigonometric and precise leveling. The work results in a set of permanent records, with the geographic positions, azimuths, distances, and elevations of the various triangulation stations. The remainder of the course consists of the construction of a final topographic map of a portion of the area covered in the preceding summer survey. Several of the field sheets are combined for this purpose, and reduced in scale from 1:4800 to 1:12000, using the triangulation system as a basis for the work. Computing, three hours, and drawing, six hours a week. Assistant Professors LELAND and BOOTHROYD, and Instructors UNDERWOOD, and LAWRENCE. Eight sections.

16. **Advanced Topographic Surveying.** Elective. Seniors and graduates. Preparation: courses 12 and 13. Second term, credit three 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. Phototopographic surveying. Lectures and reading. Three hours a week. Assistant Professors LELAND and BOOTHROYD.

17. **Geodesy and Geodetic Laboratory.** Elective. Seniors and graduates. Preparation: course 12. Second 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; 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. Assistant Professor LELAND.

18. **Geodetic Astronomy.** Elective. Seniors and graduates. Preparation: course 12. Second term, credit three hours. A study of the more precise methods of determining time, latitude, longitude, and azimuth, together with practice at the observatory in making and reducing the observations, including the determination of instrumental constants. Lectures, recitations, and observations. Three periods a week as may be arranged. Assistant Professors LELAND and BOOTHROYD.

APPLIED MECHANICS AND HYDRAULICS

20. **Mechanics of Engineering.** For sophomores in civil engineering. Throughout the year, credit five hours for each term. Preparation required: Mathematics, course 5. A study of the principles, and applications to engineering, of the mechanics of solids; as relating to the mutual actions, motions, pressures, strength, stiffness, and resilience of the members of structures and machines. Original problems form a prominent feature. Statics of a material point and of rigid bodies. Centers of gravity. Chains and cords. Dynamics (kinetics) of a material point. Impact. Virtual velocities. Centrifugal and cetripetal forces. Pendulums. Moments of inertia of plane figures and of rigid bodies. Dynamics (kinetics) of rigid bodies. Work. Power. Energy. Fly-wheels. Friction. Graphical statics of mechanism. Dynamometers. General theorem of work and energy applied to machines. Stresses and strains. Tension. Shearing. Compression. Torsion. Flexure. Elastic curves. Safe loads. Columns. Textbooks: Church's Mechanics of Engineering, and Notes and Examples in Mechanics, supplemented by other printed notes and problems. Lectures and recitations, daily except S, throughout the year. Professor CHURCH, Assistant Professors GEORGE and RETTGER, and Instructors BRAUNER and TAYLOR. Seven sections.

22. **Engineering Laboratory.** Sophomores. First term, credit one hour, and second term, credit three hours. Must be preceded by, or taken with, course 20. Use of engineers' computing devices, viz: The common slide rule, the Fuller spiral slide rule, Thacher calculating instrument, and Goodchild chart. Use of the planimeter, adjustments and use of the cathetometer. Experiments involving the parallelogram of forces (funicular polygons). Determination of specific gravity with the Jolly balance. Centers of gravity of plates and prismoids (models). Efficiency of the inclined plane and of the compound crane. Systems of levers. Harmonic motion of masses, etc. Experiments in testing materials. Use of the 50,000 lb. and the 100,000 lb. Olsen machines, in tensile tests of bars of iron and steel. The Thurston and Riehlé torsion machines; determination of their constants; and tests of specimens for the determination of shearing stresses and of the modulus of elasticity for shearing. Flexure of wooden and steel bars; deflections, and modulus of elasticity. Elongation of steel wires with observations by cathetometer or dial extensometer. Breaking tests of wooden columns. Moments of inertia of beam sections by graphic and analytical methods; and also by the use of the mechanical integrator. Use of the Kew magnetometer. Determination of specific gravity, fineness, normal consistency, soundness (normal and accelerated tests), time of set, and strength (both in tension and compression) of cements, neat and with sand. Determinations of voids in sands and broken stone. Laboratory work, two and a half hours a week in the first term and five hours in the second. Home work, three hours in the second term. Professor CHURCH, Assistant Professor MILLS, and Instructors BRAUNER, DOUGHERTY, TAYLOR, and TEETER. Six sections.

23. **Hydraulics.** Juniors. First term, credit six hours. (With topics in hydrostatics and pneumatics.) Preparation required: course 20. Fluids at rest. Hydrostatic pressure. Manometers. Strength of pipes. Pressure of water against walls and dams. Earth pressure. Immersion and flotation. Compressed air motors. Air compressors. Gas engines. Barometric leveling.

Steady flow of liquids through pipes and orifices and over weirs. Fluid friction. Losses of head. Time of emptying vessels. Steady flow of water in open channels. Kutter's formula and diagrams based thereon. Steady flow of gases through pipes and orifices. Overshot, breast, and undershot water wheels. Theorems for flow in a revolving pipe. Impulse wheels (Pelton, Girard, etc.). Turbines and reaction wheels. Backwater. Theory of turbine testing. Other hydraulic motors and machinery. As part of the work of instruction, experimental demonstrations are given in the Hydraulic Laboratory to illustrate the principal phenomena of hydrostatics and hydraulics. Textbooks: Church's Mechanics of Engineering, and Hydraulic Motors. Lectures and recitations, daily except S. Professor CHURCH, and Assistant Professors SCHODER, RETTGER, and TURNER. Six sections.

25. **Materials of Construction.** Sophomores. Either term (one-half of the class each term), credit three hours. Must be preceded by, or taken with, course 20. Textbook: Johnson's Materials of Construction. The materials studied are: lime, cement, stone, brick, sand, timber, ores, cast iron, wrought iron, steel, and some of the minor metals and alloys. The chemical and physical properties, uses, methods of manufacture, methods of testing, and unit stresses of each material are considered, particular stress being laid on those points of importance to engineers. The work is planned to coordinate with the course in economic geology and supplements that work where necessary. One lecture and two recitations a week. Assistant Professor MILLS and Instructors TAYLOR and TEETER. Four sections each term.

26. **Advanced Mechanics.** Seniors and graduates. First term, credit three hours. Preparation required: course 20. 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. Applications. Recitations. Three hours a week. Professor CHURCH and Assistant Professor RETTGER. Two sections.

27. **Testing Materials.** Elective. Seniors and graduates. First term, credit three hours. Preparation required: courses 22 and 25 or their equivalents. Special investigations of an advanced nature of the properties of structural units and the materials of construction.

Tests may be made 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, 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. Johnson's Materials of Construction and 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. Professor CHURCH, Assistant Professor MILLS, and Instructors BUEHLER and TAYLOR.

29. **Engineering Problems.** Juniors. Second term, credit two hours. Preparation required: courses 20 and 23. The object of this course is to provide additional practice in using the principles and methods of Applied Mechanics, both of solids and fluids. 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; six hours a week. Professor CHURCH and Assistant Professors GEORGE, RETTGER, and TURNER. Five sections.

HYDRAULIC ENGINEERING

30. **Water Supply.** Seniors. Either term, credit three hours. Preparation required: course 23. Three hours recitation a week from assigned text and working of several extensive problems. Problems assigned must be worked before credit can be allowed. Texts used: Turneaure and Russell's Public Water Supplies, Hoyt and Grover's River Discharge, and pamphlets. About half of the term is devoted to the preliminary investigations for determining the available supply of water from a drainage basin, general hydrology, methods of stream gauging, use of Mass Diagrams in study of storage, ground water resources, etc. The second half of the term is devoted to the methods of development, structures, and working conditions, particular attention being given to the requirements for a satisfactory fire protection, and the economics of pumped supplies. Applications of the methods of the texts are made to particular localities, the topographic maps of adjacent cities and basins forming the bases of problems in design. Given each term. Students specializing in the hydraulic group should arrange to be enrolled for the first term. Assistant Professors SEERY and WALKER.

31. **Hydraulic Constructions.** Elective for seniors and graduates. Either term. Three hours credit. Should be taken after, or concurrently with, course 30. Two recitations and one computing period a week. The course is largely devoted to the storage and conveyance of water, entering into a detailed examination of the methods and structures used, their design and construction, with special reference to public water supplies, power, irrigation, and navigation. Several extensive problems are worked, involving the preliminary examinations, explorations, and methods of surveys of a reservoir site, investigations of dam sites, design of a high masonry dam by Wegman's Method, and the study of all the factors which may affect the stability and section of a dam. The economics of storage, cost of storage, manipulation of storage and pondage are also studied in numerical problems, the data being taken from actual projects. Earthen dams and embankments, flashboards, and movable dams are also considered. A review of the theory and practice of irrigation engineering and the development of irrigation institutions occupy about half of the term, with some attention to the subject of river engineering as related to flood protection and the maintenance of navigable depths during low water, dredging, etc. Assistant Professoı SEERY.

32. **Water Power Engineering.** Elective for seniors and graduates. Either term; credit three hours. Preparation required: courses 23 and 40. Should be taken after, or concurrently with, course 30. Three recitations a week and the working of several extensive problems. General study of power

development on a stream, the factors affecting the engineering and commercial feasibility of developing power and the value of a mill site; effect of pondage, storage, and load factor on capacity and equipment and a detailed study of the characteristics of modern turbines, the selection of mechanical equipment, design of penstocks, and investigation of the speed regulation and governing of plant. Numerical applications of each of the important principles are made to existing plants or sites. Text: Mead's Water Power Engineering, supplemented by numerous assignments in engineering periodicals. Assistant Professor SEERY.

EXPERIMENTAL HYDRAULICS

41. **Hydraulic Measurements.** (As it will be given in 1912–13.) Elective. Seniors and graduates. First term, credit three hours. Preparation required: courses 23 and former course 40. The experimental portion of this course is intended to test the accuracy of measuring devices and methods as well as the exactness of hydraulic formulæ. The work includes: construction of pipe-flow diagrams; experiments with the Pitot tube; water-meters; nozzles; weirs; current-meters and floats in open channels; lectures on measurement of flowing water in large streams. Three afternoons a week. Professor HASKELL and Assistant Professors SCHODER and TURNER.

41. **Hydraulic Measurements.** (As it will be given in 1913–14 and thereafter.) Elective. Seniors and graduates. First term. Credit three hours. Preparation required: course 23. The work will include the principles and applications of logarithmic plotting and the construction of diagrams based thereon. The experimental portion of the course is intended primarily to familiarize the student with the use of those devices which are used in the measurement of flowing water and will include the following experiments: orifices, nozzles, the Venturi meter, Pitot tube, ordinary water meters, current meter rating, current meters and floats in open channels and friction head in pipes. Lectures on measurement of flowing water in large streams will comprise part of the course. Three three-hour periods a week. Professor HASKELL and Assistant Professors SCHODER and TURNER.

42. **Experimental Hydraulic Motors and Pumps.** Elective. Seniors and graduates. Second term, credit three hours. The determination of efficiency, capacity, and characteristics of hydraulic machinery. Assistant Professor SCHODER.

43. **Experimental Hydraulic Investigation.** Elective. Seniors and graduates. Second term, credit three hours. This course is intended for those students who desire to carry on experimental investigations in hydraulics under more immediate direction and supervision than prevails in case of thesis work. Written reports are required, but need not be typewritten nor bound in thesis style. These reports are kept by the department. It is often possible and desirable for two students to work together on the same investigation. The field and scope of the investigation should be selected during the first two weeks of the term. For the experimental portion of the work the equivalent of three three-hour periods a week is required. Assistant Professor SCHODER.

44. **Advanced Experimental Hydraulics.** The facilities of the hydraulic laboratory are available for thesis work and for experimental investigations by

graduate students; subject to special arrangements in each case. Professor HASKELL and Assistant Professor SCHODER.

MUNICIPAL AND SANITARY ENGINEERING

50. **Sanitary Biology.** Juniors. Throughout the year, credit three hours each term. Preparation required: Chemistry, course 6. Textbooks: Ellis's Bacteriology, first term; notes on Algæ and Protozoa, second term. In the second term the work will begin at the conclusion of the recitations in course 60 on earthwork and structures.

The course includes a study of the principles of microscopy, bacteriology, and algology with especial reference to sanitary engineering. Bacteriological and biological examinations of water supplies are made and the identification and control of the various plant forms which render water supplies objectionable, or which indicate dangerous pollution, are taken up. Two recitations and one laboratory period a week. Assistant Professor WALKER.

52. **Municipal Engineering.** Juniors. Second term, credit four hours. Preparation required: course 23. Four hours a week, divided between lectures and recitations, as follows: Fifteen lectures and forty-five recitations. The lectures are divided as follows:

Specifications, earthwork, trenching, rockwork, illustrated description of sewer construction and sewage disposal plants, garbage collection and disposal.

The recitations are on the following books: Ogden's Sewer Design; Spalding's Roads and Pavements; Notes on Sewage Disposal.

There are also required from the students problems (one for each week) illustrating the matters taken up in the lectures as follows: specifications of tennis court; city sewage flow; city outfall sewer; pipe flow diagram; septic tank design; sedimentation tanks; disposal plant; culvert design; road location; pavement designs; estimates and specifications. Professor OGDEN and Assistant Professor WALKER. Four sections in recitations.

53. **Purification and Control of Water Supplies.** Seniors and graduates. Second term, credit three hours. Preparation required: course 23. 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.

53a. **Sewage and Water Purification.** Seniors in the general group. Second term, credit three hours. Preparation required: course 52. A general course dealing with the principles and practices of filtration both of water and sewage. Lectures, recitations, and problems. Professor OGDEN.

54. **Sewerage Works.** Seniors and graduates. First term, credit three hours. Preparation required: course 52. Three hours a week for 15 weeks, divided between lectures and recitations. Textbooks: Ogden's Sewer Construction, Kinnicutt, Winslow, and Pratt's Sewage Disposal. 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; contact beds; and sprinkling filters. 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. Professor OGDEN.

55. **Sanitary Laboratory.** Seniors. First term, credit three hours. Preparation required; courses 50, 52, and Chemistry 6. This course offers a practical demonstration of some of the topics considered in courses 52, 53, and 54. 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. Examinations of samples of sand are made 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 are carried out and losses of head in columns of sand are found. Measurements of velocities and grades in the city sewers and a study of their interrelation with sizes of pipes and depths of flow are made. Nine hours a week. Professor OGDEN.

56. **Municipal Engineering.** Elective. Graduates. A discussion and study of questions other than water and sewerage dealing with the health of cities. Lectures, reports, and readings. Three hours. Professor OGDEN.

57. **Purification of Water.** Elective. Graduates. 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. Three hours. Professor OGDEN.

58. **Conference on present methods of sewage disposal.** Elective. Graduates. A critical study of the construction and operation of plants now in existence. Inspections and reports. Three hours. Professor OGDEN.

59. **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 ENGINEERING

60. **Railroad Surveying, Construction, and Economics.** Juniors. Throughout the year, credit four hours a term. Preparation required: courses 11, 12, and 13. The campus field work includes the laying out of circular and transition curves; the fixing of grade lines, cross sectioning, and the staking out of masonry structures; the realigning of track and the location of turnouts. The Saturday field work consists in making the reconnoissance, preliminary, and location surveys for some ten miles of railroad. The topography is taken, the line is cross sectioned, and data are obtained for estimates of cost, including the structures and rights of way. The drawing includes a map and a profile of the located line and a plan for one or more of the structures. The earthwork is computed from the cross

sections, and complete estimates are made of quantities and costs, including structures. The recitations and lectures take up the field problems; the computation of earthwork; the cost of graduation, including tunnels, sub grade, and track structures; track work; and the economics of railroad location and operation. Mimeograph notes on Railroad Surveying and on Railroad Construction, Crandall's Transition Curve and Earthwork Tables, Beahan's Railway Location, and Gotshall's Electric Railway Economics, form the bases of the work. Professor CRANDALL, Assistant Professor BARNES and Instructors BRAUNER, CONWELL, LAWRENCE, and WHITE. First term, two three-hour periods of field work a week, and alternate Saturdays. Six sections. Second term, three recitations a week, six sections; and one period of two and one-half hours a week in mapping, five sections.

61. **Railroad Maintenance of Way.** Elective. Seniors and graduates. First term, credit three hours. Preparation required: course 60. 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 alignment. Camp's Notes on Track is used as a text. Lectures and recitations three hours a week. Professor CRANDALL.

62. **Railroad Operation and Management.** Elective. Seniors and graduates. Second term, credit three hours. Preparation required: course 60. The course is based on Byer's Economics of Railway Operation and Adam's Block System, both of which are used as textbooks. Under organization the following subjects are treated. The 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. Assistant Professor BARNES.

63. **Railroad Construction and Maintenance.** Special course for students in Sibley College. Second term, credit two hours. Preparation recommended: course 10 or former course 12. Second term. Webb's Railroad Construction is used as a textbook. Railroad surveying; reconnoissance, preliminary survey and location; simple curves with methods of laying out; purpose and nature of transition and vertical curves. Railroad construction; earthwork, surveys, methods, and costs; rockwork; culverts and minor structures; trestles and bridges; and tunneling. Railroad maintenance; ballast, purposes, kinds, and

cross sections; ties, materials and treatment; rails and rail fastenings; joints; switches and crossings. Railroad economics; statistics; cost of distance, curvature, rise and fall and change in rate of ruling gradient and tonnage rating. Attention is given to comparing capitalized cost of structures, changes in weight of locomotives, etc. Two recitations a week. Assistant Professor BARNES.

BRIDGE ENGINEERING

71. **Structural Design.** Juniors. Throughout the year, credit four hours a term. Preparation required: course 20.

Structural Details. 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 drawing include complete detail designs and working drawings of wooden joints to resist large tensile stresses, and of a wooden roof truss for given specifications. The object of the course is to show how to apply the principles of mechanics to the design of every detail of the simple structures named, and to study the forms and strength of joints and fastenings used in heavy framing. The computations required are to be arranged in systematic order in the form of reports. Reference book: Jacoby's Structural Details. First term for 10 weeks. Computation and drawing, six 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. Each student is required to compute all the stresses in the main trusses and lateral bracing for a through Pratt truss railroad bridge which is to be designed subsequently. Textbooks: Merriman and Jacoby's Roofs and Bridges, Parts I and II. First term. Recitations two hours a week for 10 weeks, thereafter four hours a week.

Bridge Design. Computations and drawing for the complete design of a steel railroad bridge of six or seven panels, the stresses for which were computed in connection with the previous study of bridge stresses. The computations to determine the sections of all members and of 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. Second term. Computation and drawing, 12 hours a week. Professor JACOBY, Assistant Professor DERICKSON, and Instructors BURROWS, BUEHLER, URQUHART, and HITCHCOCK. First term, eight sections in recitations and six sections in computations. Second term, four sections.

72. **Reinforced Concrete Arch.** Elective. Either term, credit two or three hours as desired. Preparation required: course 20 and first part of course 71. The design of an arch of reinforced concrete including its abutments and centering. The general form and proportions are determined by

two preliminary investigations. The final investigations of the arch ring under partial and full live loading are made in accordance with the elastic theory. The design is supplemented by several illustrated lectures on the different types of concrete arch bridges of recent construction, their principal details, methods of erection, and influence on design. Lectures, computation, and drawing, six hours a week. Assistant Professor DERICKSON and Instructor BURROWS. Two sections in each term.

NOTE.—This course will be increased to three hours credit for those who desire to substitute it for engineering design.

73. **Higher Structures.** (As given in 1912–13.) Elective. Seniors and graduates. Either term, credit three hours. Preparation required: courses 20 and 71. 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. Professor JACOBY.

NOTE.—In 1913–14, course 73 will be given with a credit of four hours.

74. **Masonry and Foundations.** Seniors and graduates. Either term, credit three hours. Preparation required: course 20. Coffer dams, cribs, sheet piling, metal cylinder piers, pumping and dredging, the foundation, and the location and design of piers. Piles and pile driving. Pneumatic caissons. Open caissons. Caisson sinking. Deep and difficult foundations. Foundations of buildings: pile, caisson, steel, concrete. Underpinning. Examination of selected modern examples described and illustrated in the engineering periodicals and transactions. Recitations, collateral reading, and illustrated reports. Fowler's Ordinary Foundations. Three hours a week. Professor JACOBY,

76. **Steel Buildings.** Elective. Seniors and graduates. Second term, credit three hours. Preparation required: courses 20 and 71. Mill buildings and tall steel buildings. Framing, trusses, beams, and columns. Eccentric loading, wind bracing, connections, and details. Roofs and floors. Weights and costs. Specifications. Design of a small mill building. Investigation of the effect of wind on a knee-braced mill building bent. Recitations, lectures, and reports. Six hours a week for eleven weeks, after that three hours a week. Assistant Professor DERICKSON.

77. **Concrete Construction.** Seniors and graduates. Either term, credit three hours. The purpose of this course is to continue the study of reinforced construction and design begun in courses 20 and 25. While examples of actual construction are continually cited, special attention is paid to fundamental principles of design, to theoretical discussions, and to the interpretation of the results of experiments. It is the aim to give theory and practice equal weight, and to present the limitations as well as the advantages of this type of construction. The text used is Turneaure and Maurer's Principles of Reinforced Concrete Construction, of which all chapters excepting Chapter VIII (on the arch) are studied. The subject matter covered is as follows. Properties of the material;

general theory; tests of beams and columns; working stresses and general constructive details; formulae; diagrams and tables, building construction; retaining walls and dams; miscellaneous structures. At each recitation a problem is assigned, requiring about an hour's time to solve. One recitation and two drawing periods a week. Assistant Professor DERICKSON and Instructors BURROWS and HITCHCOCK. Four sections in recitations and three in computations and drawing for each term.

SPECIFICATIONS, DESIGNS, ETC.

89. **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. Assistant Professor BARNES.

90. **Specifications and Contracts.** Seniors. Second term, credit two hours. Synopsis of the law of contracts as applied to engineering work. Study of the general and of the special clauses in specifications; classification of specifications; typical contracts and specifications. Practice in writing specifications. Acquisition, ownership, and conveyance of land; rights and liabilities in streams, surface and underground waters; property rights defined by boundaries; and determination of boundaries of land. Johnson's Contracts and Specifications 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 CRANDALL and Assistant Professor BARNES. Six sections.

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

Engineering design for students in the general group (a) and in the geodetic group (b) may be taken in any one of the other groups by approval of the head of the department concerned.

(c) **Hydraulic Engineering.** Second term. Preparation required: courses 23 and 29. Design of hydraulic works, plants, and appliances, such as aqueducts, canals, irrigation works, locks, lift-locks, lock-gates, dams, reservoirs, stand-pipes, elevated tanks, systems of water works (gravity, pneumatic, or pumping systems), drainage works, power plants, water turbines, and other hydraulic motors and machinery, etc. Professor CHURCH and Assistant Professor GEORGE.

(d) **Sanitary Engineering.** First term. This course must be preceded by or taken at the same time with course 54 and may not otherwise be elected. 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 section.

2. Computations, design, and detail drawings for a pile foundation to support sewers from 3 to 10 feet diameter.

3. Design and detail drawings for patterns of cast iron manhole covers.

4. Computations, design, and detail drawings for flap valve at 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 Engineering.** Second term. Must be preceded by or taken with course 61. Individual problems are assigned in conference with the student. These include: designs for track layouts and details, small depot buildings and freight houses, culverts, bridge masonry, subway construction; grade separation structures; water tanks, track and elevated, of steel, timber, or reinforced concrete; coaling plants, etc. Bills of material and estimates of cost are usually required. Professor CRANDALL.

(f) **Bridge Engineering.** Second term. Course 71 is required as general preparation for engineering design in bridges and buildings. Course 73 is required in preparation for designs relating to draw, cantilever, suspension, and metallic arch bridges. Course 77 is similarly required for designs of bridges and buildings in reinforced concrete, course 72 being taken at the same time as engineering design, or previously. Professor JACOBY and Assistant Professor DERICKSON.

92. **Thesis.** Seniors. Credit three hours. The thesis is intended to demonstrate the ability of the student for independent investigation, or his capacity 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 Dean of the College 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 completed thesis is June 1. Regarding the approval of the subject or substitution for thesis see notes under the requirements for the four-year course.

SPECIAL AND GRADUATE COURSES

All of 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 being usually free from the restrictions of the class room and working either independently or in conjunction with others taking the same course.