CIVIL AND ENVIRONMENTAL ENGINEERING

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Courtesy Professors: Joel H. Ferziger, Thomas J. Hughes, Robert McGinn, Peter M. Pinsky, David Pollard, George S. Springer
Consulting Professors: John A. Blume, Roger D. Borcherdt, Ralph T. Cheng, Robert E. Clark, James E. Cloern, Russell G. Clough, Angelos N. Findikakis, Alan Douglas Jassby, Michael C. Kavanaugh, Francis L. Ludwig, W. Mike Martin, Tony Maxworthy, Martin W. McCann, Jr., Richard L. Meehan, Paul K. Meyer, Piotr D. Moncarz, Wayne R. Ott, Anshel J. Schiff, Avram S. Tucker, Brian E. Tucker, Michael W. Walton, Theodore C. Zsutty
Consulting Associate Professors: Steve Armfield, Mark N. Goltz, Michael E. London, Melody Spradling, Jane Woodward, Yan Zang
Consulting Assistant Professors: Ronald J. Calhoun, Olaf Cirpka, George Redden
Lecturers: Derek Fong, Renate Fruchter, Mark Kroll
Visiting Professor: Katsuhiko Ishida
Visiting Associate Professors: Amatzia Genin, Jerome F. Hajjar

The undergraduate Civil Engineering major provides a pre-professional program balancing the fundamentals common to many special fields of civil engineering with specialization in Environmental and Water Studies or Structures and Construction. The undergraduate Environmental Engineering major offers a more focused program in Environmental and Water Studies. Laboratory facilities are available to students in building energy, construction, environmental engineering and science, experimental stress analysis, fluid mechanics, and structural and earthquake engineering.

At least one year of graduate study is strongly recommended for professional practice. Students who contemplate advanced study at Stanford should discuss their plans with their advisers in the junior year. The coterminal B.S.-M.S. program should be considered by students who want an integrated five-year program. Potential coterminal students in Environmental Engineering and Science should be aware that applications are considered once a year, near the beginning of Winter Quarter.

The Department of Civil and Environmental Engineering (CEE), in collaboration with other departments of the University, offers graduate degree programs in:

Construction Engineering and Management
Design/Construction Integration
Environmental and Water Studies
  Environmental Engineering and Science
  Environmental Fluid Mechanics and Hydrology
Structural Engineering and Geomechanics
  Geomechanics
  Structural Engineering

Research work and instruction under these programs are carried out in the following facilities: Building Energy Laboratory, Environmental Fluid Mechanics Laboratory (EFML), Geotechnical Engineering Laboratory, Structural Engineering Laboratory, and water quality control research and teaching laboratories. Research in earthquake engineering is conducted in the John A. Blume Earthquake Engineering Center. Research on control of hazardous substances is coordinated within the Western Region Hazardous Substance Research Center.

In collaboration with the Department of Computer Science, the Center for Integrated Facility Engineering (CIFE) employs advanced CAD, artificial intelligence, communications concepts, and information management to integrate the presently fragmented participants in the facility development process and to support design and construction automation. CIFE is stimulating significant new research and educational activities in the two departments.

PROGRAMS OF STUDY

CONSTRUCTION

The Construction Engineering and Management program prepares technically qualified students for responsible management roles in all phases of the development of major constructed facilities. It emphasizes management techniques useful in planning, coordinating, and controlling the activities of diverse specialists (designers, contractors, subcontractors, and client representatives) within the unique project environment of the construction industry. In addition, the program offers subjects that focus on the engineering aspects of heavy, industrial, residential, and building construction. By appropriate choice of elective subjects, students wishing to work for a contractor, construction management consultant, design firm, or the facilities department of an owner's organization can design a program for their needs.

The construction curriculum includes core courses, construction engineering electives and construction management electives. Subjects offered include building systems, construction administration, construction finance and accounting, design and construction of housing, real estate development, equipment and methods, estimating, international construction, labor relations, managing human resources, planning and control techniques, productivity improvement, and project and company organizations. Additional related course work is available from other programs within the department, from other engineering departments, and from other schools in the University such as Earth Sciences and the Graduate School of Business.

The program leads to the degrees of Master of Science (M.S.), Engineer, and Ph.D. Students with undergraduate degrees in chemical, electrical, mechanical, mining, and petroleum engineering, or in architecture who do not wish to satisfy the undergraduate prerequisite courses for the M.S. in Civil and Environmental Engineering—Construction Engineering and Management have the option of meeting the same graduate course requirements as the above and obtaining the M.S. in Engineering—Construction Engineering and Management. A limited number of M.S.-level graduate students and most Ph.D. candidates are supported each year through the sponsored research and teaching activities and through industry-sponsored fellowships.

The Construction Program faculty and students are active participants in the Center for Integrated Facility Engineering (CIFE). CIFE conducts research on the automation, integration, and management of technology.

The program maintains close ties with the construction industry through the Stanford Construction Institute. Students participate in weekly discussions with visiting lecturers from all sectors of the U.S. construction industry.

DESIGN/CONSTRUCTION INTEGRATION

To better prepare graduates for successful careers as design and construction professionals making major contributions to integrated projects, the Department of Civil and Environmental Engineering offers a Master of Science degree field in Design/Construction Integration.

The purpose of the new degree field is to educate professionals who have a strong design or construction background, understand the goals and concerns of the many other project stakeholders, and are prepared for multidisciplinary collaborative teamwork in an integrated design and construction process.

The field of Design/Construction Integration is open to applicants with backgrounds in engineering and science. Applicants should also have a background in the planning, design, or construction of facilities by virtue of previous work experience and/or their undergraduate education. Knowledge in basic subjects from the traditional areas of civil engineering is necessary for students to receive the degree and to satisfy prerequisite requirements for some of the required graduate courses.

The field in Design/Construction Integration requires 45 quarter units, which are normally completed in one academic year. This includes core courses in design/construction integration, structural and geotechnical engineering, and construction engineering and management, along with approved electives.

The department offers three programs related to the design and construction of facilities: Structural Engineering and Geomechanics (S/G), Construction Engineering and Management (CEM), and Design/Construction Integration (DCI).

The S/G program prepares students to launch careers as designers, engineering analysts, engineering risk managers, specialty consultants, or tool developers. It encompasses structural analysis and design, dynamics, earthquake engineering, risk and reliability analysis, modern computational methods, and geomechanics.

The CEM program prepares technically qualified students for responsible management roles in all phases of the development of major constructed facilities. It emphasizes management techniques useful in organizing, planning, and controlling the activities of diverse specialists working within the unique project environment of the construction industry. The program also includes the engineering aspects of heavy, industrial, and building construction.

The DCI program prepares students for multidisciplinary collaborative teamwork in an integrated design and construction process. The program extends a student's design or construction background with core courses in each of these areas and develops the background needed to understand the concerns and expertise of the many project stakeholders. It includes a comprehensive project-based learning experience.

Prospective students should use their intended career path as the primary criterion in selecting between these three programs. S/G best fits students planning to focus on designing facilities; CEM is for students planning to emphasize building facilities or managing teams and operations. Both of these degree options provide background for many different types of careers in design and construction, with some emphasis on preparation for working on projects using the traditional form of contracting and organization that characterizes public works. Students planning careers with design or construction firms that emphasize design-build, EPC, or turnkey projects should consider DCI. All three of the degree options include substantial flexibility for students to tailor their program of study to career interests.

ENVIRONMENTAL AND WATER STUDIES

This program covers a broad spectrum of specialties, including environmental engineering and science, environmental fluid mechanics, environmental planning, and hydrology. Course offerings are scheduled to permit either intensive study in a single area or interrelated study between areas. Seminars provide a broad coverage of environmental problems. The programs are kept flexible to foster interaction among students and to encourage the development of individual programs suitable for a broad range of engineering and science backgrounds and career goals. The Stanford laboratories for water quality control and environmental fluid mechanics are well equipped and instrumented for advanced research and instruction.

Students with backgrounds in all areas of engineering and science who are interested in applying their specialized abilities to solving environmental and water problems are welcome. Comprehensive introductory courses in each major area of study are given to provide common understanding among those with dissimilar backgrounds. Courses from many other programs and departments both complement and supplement these course offerings. Some examples include Computer Science (numerical methods), Geological and Environmental Sciences (geostatistics, hydrogeology), Mechanical Engineering (applied math, experimental methods, fluid mechanics, heat transfer), Petroleum Engineering (reservoir engineering, well-test analysis), and Statistics (probability and statistics). The major areas of specialization in the two programs, environmental engineering and science, and environmental fluid mechanics and hydrology, are described below. Admissions to these two programs are handled separately; prospective students should clearly indicate their preference on their application by specifying one or the other area of specialization.

The Environmental Engineering and Science Program emphasizes the chemical and biological processes involved in pollution treatment, remediation, and control issues. Course offerings include the biological, chemical, and engineering aspects of water supply; the movement and fate of pollutants in surface and groundwaters, soil, and the atmosphere; hazardous substance control; molecular environmental biotechnology; and water and air pollution. Companion courses in the Environmental Fluid Mechanics and Hydrology Program include environmental planning and impact assessment, as well as environmental fluid mechanics, hydrology, and transport modeling. Research on hazardous substances is coordinated through the Western Region Hazardous Substance Research Center. The objective of this center, sponsored by the U.S. Environmental Protection Agency, is to promote through fundamental and applied research the development of alternative and advanced physical, chemical, and biological processes for the treatment of hazardous substances in the environment, with emphasis on groundwater contamination.

The Environmental Fluid Mechanics and Hydrology Program focuses on developing an understanding of the physical processes controlling the movement of mass, energy, and momentum in the water environment and the atmosphere. The program also considers environmental and institutional issues involved in planning water resources development projects. Environmental fluid mechanics courses address experimental methods; fluid transport and mixing processes; the fluid mechanics of stratified flows; natural flows in coastal waters, estuaries, lakes, and open channels; and turbulence and its modeling. Hydrology courses consider flow and transport in porous media, stochastic methods in both surface and subsurface hydrology, and watershed hydrology and modeling. Atmosphere-related courses deal with climate, weather, storms and air pollution and their modeling. Planning courses emphasize environmental policy implementation and sustainable water resources development. The research of this group is focused primarily in the Environmental Fluid Mechanics Laboratory, which includes the P. A. McCuen Environmental Supercomputer Center.

STRUCTURAL ENGINEERING AND GEOMECHANICS

Structural engineering at Stanford encompasses computational mechanics, computer-aided engineering, risk and reliability analysis, structural analysis and design, and teaching and research programs in earthquake engineering and structural dynamics. The programs are designed to provide a broad knowledge in these fields and to prepare students for industrial or academic careers. Academic programs can be designed to meet the needs of students wishing to launch careers as consultants on large and small projects, designers, and engineering analysts. Students have the opportunity to balance strong engineering fundamentals with modern computational methods.

Course work in earthquake engineering and structural dynamics provides an understanding of the earthquake phenomenon, the resulting ground shaking, and in-depth knowledge on the behavior, analysis, and design of various types of structures under seismic or other dynamic forces. Automated structural monitoring devices and control systems, and the utilization of advanced materials for civil infrastructures and seismic retrofits, are part of the ongoing research activities. Advanced analytical and experimental research in earthquake engineering is conducted at the John A. Blume Earthquake Engineering Center, which houses static and dynamic testing equipment including two shaking tables.

Reliability and risk analysis focuses on instruction and research in advanced methods for structural safety evaluation and design, including methods for loss estimation from damage and failures of structures and lifeline systems. Course work combines a strong background in structural analysis and design with probability theory and statistics. Research in this area deals with regional loss and damage evaluation, reliability of marine systems, seismic risk and reliability of large structural systems, and wind hazards.

Courses and research in structural analysis and design focus on the conceptual and detailed design of structural systems and on computational methods for predicting the static and dynamic, linear and non-linear response of structures. Included are courses that emphasize earthquake resistant design and computer-based design concepts. Related course work is available from other departments such as computer science, materials science and engineering, and mechanical engineering. In collaboration with CIFE, issues involving design for constructibility, engineering information management and collaborative engineering are addressed as an integral part of the research.

Computational mechanics emphasizes the application of modern computing methods to structural engineering and geomechanics. It draws on the disciplines of computer science, mathematics, and mechanics, and encompasses numerical structural and geotechnical analysis, including finite element analysis and boundary element methods. There is collaborative research in high performance computing with the Scientific Computing and Computational Mathematics Program.

Students with primary interests in the application of the principles of applied mechanics to problems involving geologic materials have the option of enrolling in a degree program in geomechanics. This program focuses on instruction and research in theoretical soil and rock mechanics, computational methods, and analysis and design of foundations and earth structures. In addition to the program's offerings, related courses are available in construction engineering, earth sciences, structural engineering, and the water resources program.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

Students who major in civil engineering or in environmental engineering must complete the appropriate requirements for the B.S. degree listed under Undergraduate Programs in the "School of Engineering" section of this bulletin. Elective units may be used in any way the student desires, including additional studies in civil and environmental engineering. Because the undergraduate engineering curriculum is designed to ensure breadth of study, students who intend to enter professional practice in civil or environmental engineering should plan to obtain their professional education at the graduate level.

A number of undergraduate programs at Stanford may be of interest to students seeking to specialize in environmental studies. In addition to the two majors offered within our own department, interested students should examine related programs such as Earth Systems, Geological and Environmental Sciences, Urban Studies, and Human Biology.

For information about a Civil Engineering minor, see the "School of Engineering" section of this bulletin.

HONORS PROGRAM

This program leads to a B.S. with Honors in Civil Engineering or in Environmental Engineering. It is designed to encourage highly qualified students to undertake a more intensive study of civil and environmental engineering than is required for the normal major via a substantial, independent research project.

The program involves an in-depth research study in an area proposed to and agreed to by a Department of Civil and Environmental Engineering (CEE) faculty adviser and completion of a thesis of high quality. A written proposal for the research to be undertaken must be submitted and approved in the fourth quarter prior to graduation. At the time of application, the student must have an overall grade point average (GPA) of at least 3.5 for course work at Stanford; this GPA must be maintained to graduation. The thesis is supervised by a CEE faculty adviser and must involve input from the School of Engineering Writing Program by means of Engineering 102S or its equivalent. Students are encouraged to present their results in a seminar for faculty and other students. Up to 10 units of CEE 199, Undergraduate Research in Civil and Environmental Engineering, may be taken to support the research and writing (not to duplicate Engineering 102S). These units are beyond the normal Civil Engineering or Environmental Engineering program requirements.

GRADUATE PROGRAMS

The University requirements governing the M.S., Engineer, and Ph.D. are described in the "Graduate Degrees" section of this bulletin.

Admission—Applications require submission of the application form, statement of purpose, three letters of recommendation, results of the General Section of the Graduate Record Examination, and transcripts of courses taken at colleges and universities. Policies for each of the department's programs are available from the Department of Civil and Environmental Engineering. Successful applicants are advised as to the degree and program for which they are admitted. If students wish to shift from one program to another after being accepted, an application for transfer must be filed with the department, and they are advised if the transfer is possible. If, after enrollment at Stanford, students wish to continue toward a degree beyond the one for which they were originally admitted, a written application must be made to the Department of Civil and Environmental Engineering.

Financial Assistance—The department maintains a large and continuing program of financial aid for graduate students. Applications for financial aid and assistantships should be filed by January 1; it is important that Graduate Record Examination scores be available at that time.

Teaching assistantships carry stipends for as much as one-half time work to assist with course offerings during the academic year. Research assistantships also are available. Engineer and Ph.D. candidates may be able to use research results as a basis for the thesis or dissertation. Assistantships and other basic support may be supplemented by fellowship and scholarship awards or loans. Continued support is generally provided for further study toward the Engineer or Ph.D. degree based on the student's performance, the availability of research funds, and requisite staffing of current projects.

MASTER OF SCIENCE

Programs are available leading to the M.S. degree in Civil and Environmental Engineering with the following special field designations on the diploma: Construction Engineering and Management, Design/Construction Integration, Environmental Engineering and Science, Environmental Fluid Mechanics and Hydrology, Geomechanics, and Structural Engineering. Detailed statements of the requirements for all master's degrees and the specific designation may be secured from the Department of Civil and Environmental Engineering.

Students admitted to graduate study with a B.S. in Civil Engineering (or its equivalent) from an accredited curriculum can satisfy the requirements for the M.S. degree in Civil and Environmental Engineering by completing a minimum of three quarters of full tuition registration and a minimum of 45 units of study beyond the B.S. At least 36 of the units must be taken at Stanford. A minimum 2.75 grade point average (GPA) is required for candidates to be recommended for the M.S. degree. No thesis is required.

The program of study must be approved by the faculty of the department and should include at least 45 units of courses in engineering, mathematics, science, and related fields unless it can be shown that other work is pertinent to the student's objectives.

Candidates for the M.S. in Civil and Environmental Engineering who do not have a B.S. in Civil Engineering may, in addition to the above, be required to complete those undergraduate courses deemed important to their graduate programs. In such cases, more than three quarters of residence is often required to obtain the degree.

ENGINEER

A student with an M.S. in Civil Engineering may satisfy the requirements of the degree of Engineer in Civil and Environmental Engineering by completing, in residence, 45 or more units of work (three quarters minimum) including an acceptable thesis (12 to 15 units) and maintaining a 'B' GPA average (3.0) or higher. The program of study must be approved by a faculty member in the department.

This degree is recommended for those desiring additional graduate education, especially those planning a career in professional practice. The thesis normally should be started in the first quarter of graduate study after the M.S. degree. Programs are offered in the fields of specialization mentioned for the M.S. degree.

DOCTOR OF PHILOSOPHY

The Ph.D. is offered under the general regulations of the University as set forth in the "Graduate Degrees" section of this bulletin. This degree is recommended for those who expect to engage in a professional career in research, teaching, or technical work of an advanced nature. The Ph.D. program is rigorous and should be undertaken only by students with ability for independent work. It requires a minimum of three years (nine quarters) of graduate study, at least two years of which must be at Stanford and a minimum GPA of 3.0 in post-MS course work. Experience has shown that few students complete the Ph.D. within the minimum residence period. Prospective doctoral students should anticipate the possibility of at least one extra year. All candidates for the Ph.D. degree are required to complete CEE 200 in conjunction with a one-quarter teaching assistantship/course assistantship to gain training and instructional experience. Further information about Ph.D. requirements and regulations is found in the department handbook.

The first year of graduate study can be represented by the M.S. program described above. The second year is devoted partly to additional graduate courses and partly to preliminary work toward a dissertation. The third and subsequent years are applied to further course work and to the completion of an acceptable dissertation.

The program of study is arranged by the prospective candidate at the beginning of the second year with the advice of a faculty committee whose members are nearest in the field of interest to that of the student. The chair of the committee serves as the student's pro tem adviser until such time as a member of the faculty has agreed to direct the dissertation research. Insofar as possible, the program of study is adapted to the interests and needs of the student within the framework of the requirements of the department and the University. In the second year of graduate study, the student is expected to pass the department's General Qualifying Examination to be admitted to candidacy. After completing their research, students are required to pass the University oral examination, which is a dissertation defense.

Ph.D. MINOR

A Ph.D. minor is a program outside a major department. A minor is not a requirement for any degree, but is available when agreed on by the student and the major and minor departments. Requirements for a minor are established by the minor department. Acceptance of the minor as part of the total Ph.D. program is determined by the major department. Application for candidacy must be approved by both the major and the minor department, and the minor department must be represented at the University oral examination.

A student desiring a Ph.D. minor in Civil and Environmental Engineering (CEE) must have a minor program adviser who is a regular CEE faculty member in the program of the designated subfield. This adviser must be a member of the student's University oral examination committee and the reading committee for the dissertation.

The program must include at least 20 units of graduate-level course work (that is, courses numbered 200 or above, excluding special studies and thesis) in CEE completed at Stanford University. The list of courses must form a coherent program and must be approved by the minor program adviser and the CEE chair. An average GPA of at least 3.0 must be achieved in these courses.

COURSES

(WIM) indicates that the course meets the Writing in the Major requirements.

UNDERGRADUATE

45Q. Stanford Introductory Seminar: Affordable Housing—A Social Entrepreneurship Start-up—Preference to sophomores. The model of a social entrepreneurship start-up is used to address the social, economic, planning, and design issues that have led to the housing affordability crisis in places like the San Francisco Bay Area. Students become familiar with housing needs, policies, and resources; learn about people most in need of housing; and examine organizations that work in affordable housing. With assistance from professionals, they perform research leading to a business plan for a venture that targets one or more key affordable housing problems selected by the class. Develops skills in organization, research, development of ideas, management, teamwork, presentation, and communication. GER:3B (DR:9)
4 units, Spr (Paulson, Behrman)

46Q. Stanford Introductory Seminar: Fail Your Way to Success—Preference to sophomores. Students examine real-world case studies of risk and failure with an emphasis on start-ups and small business risks. The reasons behind these failures and the applications to modern societal and student issues. Emphasis is on the people involved in each example and the lessons learned regarding risk willingness and problem solving leadership skills, e.g., the Titanic, Challenger Shuttle, and Hyatt Regency, and case studies from the professor's 30 years as a small business owner and construction engineer. At least four afternoon field trips to local sites. Prerequisites: creative thinking and problem-solving interests; willingness to visit chaotic construction sites.
3 units, Spr (Clough)

47Q. Stanford Introductory Seminar: Discovering Micro-Organization Theory for Fast-Paced Project Teams—Preference to sophomores. Students discover micro-organization theory for fast-paced projects and learn to manage them by running "virtual experiments" with the Virtual Design Team (VDT) computer model of project organizations. Introduces "information-processing" framework for understanding organizations performing knowledge work. Students work in teams of two to design and execute a series of computational experiments that develop and test hypotheses about the micro-organization theory of fast-paced product development teams. Enrollment limited to 12. Prerequisites: application; curiosity about how organizations work.
4 units, Win (Levitt)

61Q. Stanford Introductory Dialogue: Big Dams, the City Hall, and the Sierra Club—Preference to sophomores. Water and environmental policy issues: the beneficial and deleterious effects of large hydraulic structures, such as dams and aqueducts; urban infrastructure and the political process; irrigation and its lobby; flood protection; protected species and the environmentalist lobby. How do we balance the conflicting needs of supplying water and protecting from floods with the desire to maintain a livable environment? Changing public perceptions: the glory and shame of big dams. Emphasis is on discussing where we have been and where we are going in the U.S.
2 units, Aut (Kitanidis)

63. Weather and Storms—Survey of daily and severe weather, and global climate. Topics: structure and composition of the atmosphere, fog and cloud formation, rainfall, local winds, global circulation, jet streams, high and low pressure systems, inversions, El Niño, La Niña, atmosphere-ocean interactions, fronts, cyclones, thunderstorms, lightning, tornados, hurricanes, pollutant transport, global climate, and atmospheric optics. GER:2a (DR:5)
3 units, Aut (Jacobson)

64. Air Pollution: From Urban Smog to Global Change—Survey of urban through global-scale air pollution. Topics: the evolution of the

earth's atmosphere, indoor air pollution, urban smog formation, effects of exposure to air pollution, visibility, acid rain, global climate change, stratospheric ozone reduction, Antarctic ozone destruction, air pollution transport across political boundaries, the effects of meteorology on air pollution, and the effects of air pollution and stratospheric ozone on human exposure to ultraviolet radiation. GER:2a (DR:5)
3 units, Spr (Jacobson)

70. Environmental Science and Technology—For science and engineering majors. Introduction to environmental quality and the development of the background necessary for understanding environmental issues, controlling environmental degradation, and preserving air and water quality. Material balance concepts for tracking substances in the environment and in engineered systems. Environmental control systems for air and water quality engineering; solid and hazardous waste management and green design; environmental laws that relate to water and air quality and control of hazardous materials; the technical basis for policy and environmental risk.
3 units, Spr (Luthy)

80N. Stanford Introductory Seminar: Structures—Where Form is the Function—Preference to freshmen. What goes into designing the world's longest bridge or tallest building? The basic principles of structural engineering and structural forms through a series of illustrated case studies. Emphasis is on how various types of structures carry loads and other essentials of good design. Field trip to some landmark structures and a competition to design, build, and test a model bridge.
4 units, Win (Deierlein)

99A,B,C. Environmental Issues Seminar—Talks on a wide variety of environmental issues.
1 unit, Aut, Win, Spr (Monismith)

100. Managing Civil Engineering Projects—Introduction to the facility life cycle and project delivery process and organization. Techniques for planning, organizing, and executing civil engineering projects from conception to completion. Project objectives (scope, quality, cost, time, and safety) from multiple perspectives throughout the facility life cycle. Time and cost planning and control, including scheduling and cost estimating techniques using information technology. Small team projects, exposure to real world projects, and individual paper. (WIM)
4 units, Aut (Haymaker)

101A. Mechanics of Materials—Introduction to beam and column theory. Normal stress and strain in beams under various loading conditions; shear stress and shear flow; deflections of determinate and indeterminate beams; analysis of column buckling; structural loads in design; strength and serviceability criteria. Lab experiments; design project. Prerequisites: 100, Engineering 14.
4 units, Win (Menun)

101B. Mechanics of Fluids—Physical properties of fluids and their effect on flow behavior; equations of motion for incompressible ideal flow, including the special case of hydrostatics; continuity, energy, and momentum principles; control volume analysis; laminar and turbulent flows; internal and external flows in specific engineering applications including pipes, open channels, wind turbines, airplane wings, and baseballs. Prerequisites: Physics 41, Mathematics 51.
4 units, Spr (Monismith)

101C. Geotechnical Engineering—Introduction to the basic principles of soil mechanics. Soil classification, shear strength and stress-strain behavior of soils, consolidation theory, analysis and design of earth retaining structures, introduction to shallow and deep foundation design, slope stability. Lab projects. Prerequisites: Engineering 14. Recommended: 101A.
4 units, Aut (Borja)

101D. Seminar on Mathematical Laboratory Applications in Civil and Environmental Engineering—(Graduate students register for 201D.) Preference to juniors majoring in civil or environmental engineering. Use of commercial professional software in the design and analysis of civil and environmental engineering systems. MATLAB 5 is applied to relevant problems and issues that students encounter in subsequent courses and in engineering practice. Limited enrollment.
2 units, Win (Kitanidis)

101E. Analytical and Numerical Methods for the Environment—(Graduate students register for 201E.) Develops a working knowledge of the analytical and numerical techniques needed to solve a range of environmental problems. Application of these techniques to specific environmental problems. Governing equations plus appropriate boundary and/or initial conditions are derived from the physical contexts. Application of ordinary differential equation methods. Introduction to: method of characteristics, partial differential equation models of physical phenomena and solution of the models, solution of sets of linear and nonlinear equations, modeling of systems with uncertain inputs and data, role of probability. Prerequisites: 101B, 101D, Engineering 155A, or equivalents.
4 units, Aut (Street)

102. Legal Context of Civil Engineering—Introduction to the U.S. legal system as it applies to civil engineering and construction. Fundamental concepts of contract and tort law, claims, risk management, business formation and licensing, agency, insurance and bonding, and real property.
3 units, Win (London)

111. 3D and 4D Modeling of Civil Engineering Projects—(For undergraduates; same as 211.) Modeling, visualization, and graphical communication of civil engineering artifacts, 3D CAD, 4D modeling, introduction to underlying computer representations, applications of 3D CAD in design and construction, lab exercises, class project.
3 units, Win (Liston)

114. Symbolic Modeling in Engineering—(For undergraduates; same as 214.) Prerequisite: Computer Science 106A or equivalent.
4 units, Win (Kunz)

122A. Computer Integrated Architecture/Engineering/Construction (A/E/C)—Undergraduates serve as apprentices in 222A; see 222A. Enrollment limited and based on interviews.
2 units, Win (Fruchter)

122B. Computer Integrated Architecture/Engineering/Construction (A/E/C)—Undergraduates serve as apprentices in 222B; see 222B. Enrollment limited and based on interviews.
2 units, Spr (Fruchter)

141. Design and Construction of Concrete Canoe for ASCE Competition—Design, construction, and testing of canoe; structural and hydrodynamic analysis; selection of materials and construction methods; participation in regional canoe race.
1 unit, Aut, Win, Spr (Staff)

147. Cases in Personality, Leadership, and Negotiation—Graduate students register for 247; see 247.
3 units, Spr (Clough)

148. Design and Construction of Affordable Housing—Planning, design, engineering, and construction in the development of affordable housing. Topics: the socio-economic context of affordable housing; stages in property development; issues in design; types of structures, methods, and materials used in housing construction; and property management. Students apply what they learn in assignments where they interact with non-profit housing development, city planning officials, and architects. Prerequisites: junior or senior in Civil or Environmental Engineering, Urban Studies, or related fields.

4 units, Win (Paulson)

153. Construction Equipment and Methods—Methods to build projects planned by engineers and architects. Application of engineering fundamentals to the selection and design of equipment and systems to carry out production operations in construction; analysis of production output and costs; application of engineering economy to equipment and process decision making. Prerequisites: 100; Engineering 14, 60.

3 units, Spr (Paulson)

154. Cases in Estimating Costs—Graduate students register for 254; see 254.

3 units, Aut (Clough)

156. Building Systems Design—(Graduate students register for 256.) Design concepts, integration issues, materials of construction, and installation operations for conventional building systems. Lectures and group projects on heating, ventilation, and air conditioning systems. Student groups analyze selected building systems on active projects, and report on existing design, a redesigned portion of a system, materials of construction, and installation.

3 units, Win (Tatum)

160. Mechanics of Fluids Laboratory—Lab experiments/demonstrations illustrate conservation principles and flows of real fluids. Corequisite: 101B.

2 units, Spr (Monismith)

161. Open Channel and Pipe Flows—Introduction to the movement of water through natural and engineered channels, rivers, and pipe systems. Basic equations and theory (mass, momentum, and energy equations) for steady and unsteady descriptions of the flow. Discussion of theory and practice for the choice of pumps and the design of pumping systems. Application of theory to the design of flood-control and water-supply systems. Case studies dealing with flood-control issues in Palo Alto. Lab experiments illustrate concepts developed in class. Prerequisites: 101B, 160. Corequisite 101E.

4 units, Aut (Fong)

162. Hydrology and Water Resources—Introduction to the movement of water through natural and constructed environments. Storage and fluxes of water through the natural environment. Hydrologic processes, including precipitation, evaporation, transpiration, snowmelt, infiltration, subsurface flow, runoff, and streamflow. Emphasis is on measurement, data analysis, modeling, and the role of hydrologic processes in ecosystems. Technological systems associated with human use of water as a resource. Irrigation, hydroelectric power generation, rural and urban water supply systems, stormwater management, flood damage mitigation, water law and institutions. Emphasis is on engineering design and environmental impacts. Required field trips. Prerequisites: 161, Engineering 60.

4 units, Win (Freyberg)

164. Introduction to Physical Oceanography—(Same as Earth Systems 164.) Introduction to the dynamical basis of physical oceanography. Topics: a general description of the physical environment of the ocean; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; the thermohaline circulation of the deep oceans; and tides. Prerequisite: Physics 41.

4 units, Aut (Monismith)

169. Environmental and Water Studies Design—Seniors in Civil or Environmental Engineering only; alternates with 179B. The design of environmental and water resources systems. Design as a process. Application of fluid mechanics, hydrology, water resources, environmental sciences, planning, and engineering economy fundamentals to the design of an engineering system addressing a complex problem of water in the natural and constructed environment. The problem changes each time, generally drawn from a challenge confronting the University or a local community. Previous problems have included sediment management in Searsville Lake, improved operation of Lagunita, and a remedial design for the Santa Rosa outfall in San Pablo Bay. Student design teams prepare proposals, progress reports, oral presentations, and a final design report. Prerequisite: 162.

5 units, alternate years, given 2001-02

171. Environmental Planning Methods—For juniors and seniors. Use of microeconomics and mathematical optimization theory in the design of environmental regulatory programs; tradeoffs between equity and efficiency in designing regulations; techniques for predicting visual, noise, and traffic impacts in environmental impact assessments. Prerequisites: 70, Mathematics 51.

3 units, Win (Ortolano)

172. Air Quality Management—Quantitative introduction to the engineering methods used to study and seek solutions to current air quality problems. Topics: global atmospheric changes, urban sources of air pollution, indoor air quality problems, design and efficiencies of pollution control devices, and engineering strategies for managing air quality. Prerequisites: 70, Mathematics. 51.

3 units, Win (Hildemann)

173A. Energy Resources—(Formerly Petroleum Engineering 103; same as Earth Systems 103.) Overview of oil, natural gas, coal, nuclear, hydro, solar, geothermal, biomass, wind, and ocean energy resources in terms of supply, distribution, recovery and conversion, environmental impacts, economies, policy, and technology. The opportunities for energy efficiency, electric power basics, the changing role of electric utilities, transportation basics, and energy use in developing countries. Field trips. Recommended: 70.

4 units, Aut (Woodward)

173B. Seminar: The Coming Energy—(Formerly Petroleum Engineering 104; graduate students register for 207.) The three forces driving an energy revolution: environmental pressures, global social and economic revolution, and technological change. Assessment of evolution vs. revolution, developed vs. developing countries, transportation, electric power, resource development and extraction, end use technologies, deregulation, privatization and globalization, barriers to change, and assessment of the mechanisms to overcome them. Enrollment limited to 15; presentations every class. Prerequisite: 173A.

3 units (Woodward) alternate years, given 2001-02

175. Environmental Economics and Policy—(Enroll in Economics 155, Earth Systems 112.)

5 units, Spr (Goulder)

176A. Energy Efficient Buildings—Analysis and design of energy efficient buildings. Thermal analysis of building envelope, heating and cooling requirements, daylighting, efficient lighting systems, thermal storage, passive solar design, solar water heating. Lab. Recommended: 173A.

4 units, Win (Masters) alternate years not given 2001-02

176B. Electric Power: Renewables and Efficiency—Electric utility systems: generation, transmission, distribution, regulation, and power quality. Emphasis is on photovoltaics, wind turbines, and fuel cells on the supply side, and efficient lighting systems and electric motors on the demand side. Lab.

4 units (Masters) alternate years, given 2001-02

177. Aquatic Chemistry and Biology—Undergraduate-level introduction to the chemical and biological processes in the aqueous environment. Basic aqueous equilibria; the structure, behavior, and fate of major classes of chemicals that dissolve in water; redox reactions; the biochemistry of aquatic microbial life; and biogeochemical processes that govern the fate of nutrients and metals in the environment and in engineered systems. Prerequisite: Chemistry 31.

4 units, Aut (Criddle)

178. Introduction to Human Exposure Analysis—(Graduate students register for 276.) Scientific and engineering issues involved in quantifying human exposure to toxic chemicals in the environment. Pollutant behavior, inhalation exposure, dermal exposure, and assessment tools. Overview of the complexities; uncertainties; and physical, chemical and biological issues relevant to risk assessment. Lab projects. Prerequisite: Mathematics 51. Recommended: 172.

3 units, Spr (Leckie)

179A. Water Chemistry Laboratory—(Same as 273A.) For undergraduates. Laboratory application of techniques for the analysis of natural and contaminated waters, emphasizing instrumental techniques.

2 units, Win (Leckie)

179B. Process Design for Environmental Biotechnology—Alternates with 169. Preference given to juniors and seniors in Civil or Environmental Engineering. The design of a water or wastewater treatment system using biological processes to remove contaminants. Student teams characterize contaminants in water or wastewater, design and operate bench- and pilot-scale units, then develop a full-scale design. Limited enrollment. Prerequisites: 177, 179A.

3 units, Spr (Criddle), alternate years, not given 2001-02

180. Structural Analysis—(Formerly 180A.) Analysis of beams, trusses, frames; method of indeterminate analysis by consistent displacement, least work, superposition equations, moment distribution. Introduction to matrix methods and computer methods of structural analysis. Prerequisite: 101A.

4 units, Aut (Kiremidjian)

181. Design of Steel Structures—Concepts of the design of steel structures with a load and resistance factor design (LRFD) approach; types of loading; structural systems; design of tension members, compression members, beams, beam-columns, and connections; and design of trusses and frames. Comprehensive project on the structural design of an industrial building. Prerequisite: 180.

4 units, Win (Law)

182. Design of Reinforced Concrete Structures—Properties of concrete and reinforcing steel; behavior of structural elements subject to bending moments, shear forces, torsion, axial loads, and combined actions; design of beams, slabs, columns and footings; strength design and serviceability requirements; design of simple structural systems for buildings. Comprehensive project on the structural design of a reinforced concrete office building. Prerequisite: 180.

4 units, Spr (Krawinkler)

195. Structural Geology and Rock Mechanics—(Same as Geological and Environmental Sciences 111.) Observational techniques, analysis methods, and theoretical foundations of structural geology, engineering geology, and rock mechanics. Computer exercises are integrated with field data to understand the role of geologic structures in the evolution of the earth's crust (folding, faulting, flow, and fracturing of rock) and geologic hazards (earthquakes, landslides, and volcanoes). Topics: structural quantities and dimensional analysis; use of stress, strain, displacement, and velocity fields in structural analysis; the concept and measurement of deformation; mechanical properties of rock (elasticity, viscosity, strength, friction, fracture toughness); case studies of typical geologic structures using continuum mechanics. Computer labs. Prerequisites: Geological and Environmental Sciences 1, calculus, Macintosh skills.

5 units, Aut (Pollard)

196. Engineering Geology Practice—(Same as Geological and Environmental Sciences 115.) The application of geologic fundamentals to the planning and design of civil engineering projects. Emphasis is on development of geologic skills to identify, describe, and map earth materials and geologic structures as a means of determining the impact on site development. Topics: weathering and soil-forming processes, soil and rock mechanics, site investigation techniques, surface and groundwater regimes, stream and coastal processes, quaternary tectonics, deposits and geomorphology, environmental concerns, and geologic and geotechnical hazards. Field/lab exercises and case history studies emphasize the impact of site geology on the safe planning, design, and construction of civil engineering projects such as foundations, transportation facilities, excavations, tunnels and underground storage space, water supply facilities, and marine works. Prerequisite: 195 or consent of instructor.

3 units (Holzer) alternate years, not given 2001-02

197. Professional Development Seminar—Weekly presentations by practicing engineers on topics relevant to students planning to enter the engineering profession. Environmental, structural, and construction perspectives.

1 unit, Win (Tatum)

199. Undergraduate Research in Civil and Environmental Engineering—Participation in a research project in Civil and Environmental Engineering. Written report or oral presentation required. Students must obtain a faculty sponsor.

2-3 units, any quarter (Staff)

PRIMARILY FOR GRADUATE STUDENTS

200A,B,C. Teaching of Civil and Environmental Engineering—Required of all CEE Ph.D. students. Strategies for effective teaching and introduction to engineering pedagogy. Topics: problem solving techniques and learning styles, individual and group instruction, the role of TAs, balancing other demands, grading. Teaching exercises. Register for quarter of teaching assistantship.

200A. *1 unit, Aut (Staff)*
200B. *1 unit, Win (Staff)*
200C. *1 unit, Spr (Staff)*

201D. Seminar on Mathematical Laboratory Applications in Civil and Environmental Engineering—Undergraduates register in 101D; see 101D.

2 units, Win (Kitanidis)

201E. Analytical and Numerical Methods for the Environment—Undergraduates register for 101E; see 101E.

4 units, Aut (Street)

203. Probabilistic Models in Civil Engineering—Introduction to probability modeling and statistical analysis in civil engineering. Emphasis is on the practical issues of model selection, interpretation, and calibration. Recognition of intrinsic randomness and modeling uncertainty. Introduction to probability event and decision trees. Models of independent events; hazard rate models. Introduction to computational methods including Monte Carlo simulation and second-moment and full-distribution methods derived from structural reliability theory.

3-4 units, Aut (Menun)

204. Structural Reliability—Probability models for loads and resistance. Sources and estimation of uncertainties present in engineered systems. Definition of failure events and evaluation of reliability for structural components and systems. Exact solutions, first- and second-order reliability methods, simulation methods. Sensitivity analyses. Application to structural codes. Prerequisite: 203 or equivalent.

3-4 units (Menun) alternate years, given 2001-02

207. Seminar: The Coming Energy Revolution—Undergraduates register for 173B; see 173B.
3 units (Woodward), alternate years, given 2001-02

211. 3D and 4D Modeling of Civil Engineering Projects—(Undergraduates register for 111.) See 111.
3 units, Win (Liston)

214. Symbolic Modeling in Engineering—(Same as 114.) Issues concerning symbolic model-based reasoning systems in engineering. Lab to study and create symbolic models using Artifical Intelligence representation and reasoning techniques, and engineering principles and heuristics. Prerequisite: Computer Science 106A or equivalent.
4 units, Win (Kunz)

215. Social Entrepreneurship—(Same as Business 369S.) The efforts of private citizens to create effective responses to social needs and innovative solutions to social problems. Social entrepreneurs are increasingly blurring lines between the sectors, using for-profit and hybrid forms of organization to achieve social objectives. This creates new opportunities for applying business skills in the social sector. Objectives; introduce the concepts, practices, and challenges of social entrepreneurship in the U.S. and the world; provide frameworks and tools to become effective in their socially entrepreneurial pursuits; and engage students in a joint learning process.
4 units, Spr (Dees)

221. Project-Based Design/Construction Integration—Using examples from current construction projects in the Bay Area, students develop an understanding of the goals and concerns of each stakeholder in the facility development process. Emphasis is on the development of skills to identify, describe, and document important design and construction aspects of various types of projects. Integration issues are identified and discussed. Required construction field trips.
2 units, Aut (Miranda)

222A. Computer Integrated Architecture/Engineering/Construction (A/E/C)—Multi-disciplinary, collaborative, multi-site teamwork project environment. Round table A/E/C panel discussions, lectures, and labs on collaborative technologies provide a global perspective of the A/E/C industry and cutting edge information technologies. Students exercise the acquired theoretical discipline knowledge and the information technologies in a multi-disciplinary, collaborative context, and engage in hands-on case study projects to redesign parts of existing projects and work on the concept development phase of the comprehensive course project.
3 units, Win (Fruchter)

222B. Computer Integrated Architecture/Engineering/Construction (A/E/C)—Continuation of 222A. Students focus on the comprehensive team project, including project development and documentation, and final presentation of results. Design and construction alternatives are subject to rigorous examination by rapid computational prototyping, concurrent multi-disciplinary evaluation, and trade-off analysis. Prerequisite: 222A.
2 units, Spr (Fruchter)

223. Issues in Design/Construction Integration—The impact of design decisions on construction, with emphasis on integration issues. Topics: analysis of various delivery project alternatives; design and constructability of steel and concrete structural connections; design and detailing of penetrations through structural members required by various building systems, loads during construction and their possible impact on design, and examples of challenging erection problems. Required construction field trips.
3 units, Spr (Miranda)

237. Introduction to Biotechnology—(Same as Biochemistry 237, Chemical Engineering 450, Developmental Biology 237, Structural Biology 237.) Faculty from the departments of Biochemistry, Biological Sciences, Chemical Engineering, Civil and Environmental Engineering, Developmental Biology, Structural Biology, and invited industrial speakers review the interrelated elements of modern biotechnology. Topics: protein structure and dynamics, protein engineering, biocatalysis, gene expression, cellular metabolism and metabolic engineering, fermentation technology, and purification of biomolecules. Prerequisite: graduate student or upper-division undergraduate in the sciences or engineering.
3 units, Spr (Robertson, Swartz)

238. Frontiers in Interdisciplinary Biosciences—(Cross-listed in multiple departments in the schools of Humanities and Sciences, Engineering, and Medicine; students should enroll directly through their affiliated department, if at all possible.) Introduction to cutting-edge research involving interdisciplinary approaches to bioscience and biotechnology; for specialists and non-specialists. Associated with Stanford's Clark Center for Interdisciplinary Bioscience, and held in conjunction with a seminar series meeting twice monthly during 2000-01. Leading investigators from Stanford and throughout the world speak on their research; students also meet separately to present and discuss the ever-changing subject matter, related literature, and future directions. Prerequisite: keen interest in all of science, with particular interest in life itself. Recommended: basic knowledge of biology, chemistry, and physics.
2 units, Aut, Win, Spr (S. Block)

240. Analysis and Design of Construction Operations—Planning and management of construction work at the field operations level. Data collection, analysis, modeling, and design. Emphasis is on work methods development, productivity, safety, and total quality management. Students prepare studies of and reports about local construction projects.
3 units, Aut (Paulson)

240L. Applications of Operations Analysis and Design—Hands-on experience as a construction volunteer at a Bay Area low-cost housing project. Opportunities to apply planning and analysis skills learned in 240, while working with groups of volunteers performing specific field tasks. Corequisite: 240.
1 unit, Aut (Paulson)

241. Techniques of Project Planning and Control—Fundamental concepts of project planning and control; current and future project information technologies; project planning and control systems at the firm and project level. Topics: cost estimating at conceptual, schematic, detailed, and bid stages, measurement and pricing of work; work breakdown structures; planning and scheduling techniques, including CPM, PERT, LOB; resource allocation; project control; supply chain models; treatment of uncertainty; electronic integration of time and cost planning and control, and 4D modeling. Group term project including technical report and presentation.
3-4 units, Win (Staub)

242. Organization Design for Projects and Companies—Introduction to organizational behavior. In-depth contingency theory of organizational design for engineering and construction projects and firms. Computer-based organizational analysis tools. Case studies on facility design and construction organizations; concepts are applicable to project-focused teams and companies in other industries. Groups of 12 students practice running problem-focused meetings, one case study per week outside class.
4 units, Win (Levitt)

244A. Fundamentals of Construction Accounting and Finance—Introduces the concepts and fundamentals of financial accounting and economics in general, and specifically in the construction industry. Financial statement understanding and analysis, accounting concepts, project accounting methods, and the nature of project costs. Case study

of major construction contractor. Ownership structure, working capital, and the sources and uses of funds.
2 units, Aut (Tucker, Meyer)

244B. Advanced Construction Accounting, Financial Issues, and Claims—Continuation of 244A. Emphasis is on advanced construction accounting and economic issues, the recovery of project overruns, and the understanding of construction industry financial disclosures. Construction claims, project cost overrun analysis, and cost recovery methods related to: labor, equipment, indirect costs, overhead, cost of capital, and profit claims. Schedule delay analysis in the context of claims.
2 units, Win (Tucker, Meyer)

246. Managing Engineering and Construction Companies—Administration and management of design and construction companies in the architecture-engineering-construction industry. Focus is on management of risks inherent in the A-E-C industry: developing strategies to cope with cyclical demand, alternative contracting approaches, managing receivables and cash flow, administration of human resources, safety, quality, insurance, and bonding.
4 units, Spr (Levitt)

247. Cases in Personality, Leadership, and Negotiation—(Undergraduates register for 147.) Case studies and discussions regarding the management of projects, with an emphasis on start-ups and small business. Emphasis is on the understanding of personalities, thinking styles, negotiation, and working with difficult people. Cases are based on the professor's 30 years experience as a small business owner and construction engineer. At least five afternoon field trips to local sites. Limited enrollment and first class attendance mandatory.
3 units, Spr (Clough)

248. Real Estate Development—Overview of the real estate development process, emphasizing critical activities and key participants. Topics: conceptual and feasibility studies, market perspectives, the public roles, steps for project approval, project finance, contracting and construction, property management, and sales. Group term projects focus on actual developments now in the planning stage. Prerequisites: 244A or equivalent, Engineering 60.
3 units, Spr (Staff)

249. Labor and Industrial Relations in Construction—The history, laws, institutions, and social and economic forces affecting labor and industrial relations in construction, covering the union and open-shop sectors. Comparative labor relations (other nations), simulated collective bargaining and arbitration exercises; field trip.
3 units, Win (Clark, Walton)

250. International Construction and Project Finance—Prepares construction professionals for international projects; privatization of infrastructure, economic drivers of construction projects, risks, and risk management. Individual research paper, case studies, and class presentation.
3 units, Spr (Woods)

252. Fundamentals of Construction Engineering and Operations—Overview of key design requirements, materials, construction resources, and field operations required for constructed facilities. Introduction to construction engineering activities. Technical analysis of representative projects. Student groups present an analysis of a topic related to construction engineering or design-construction integration.
4 units, Aut (Korman, Tatum)

254. Cases in Estimating Costs—(Undergraduates register for 154.) Case studies and discussions of business decisions based on rational cost estimating in competitive markets. Emphasis is on the fundamental forces driving the construction industry as seen on site visits; the general principles studied are applicable to any competitive business. Cases are based on the professor's 30 years experience as a small business owner and construction engineer. At least five afternoon field trips to local sites. Limited enrollment and first class attendance mandatory.
3 units, Aut (Clough)

256. Building Systems Analysis—(Undergraduates register for 156.) Design concepts, integration issues, materials of construction, and installation for HVAC systems. Student groups analyze a specialized building system on a project.
3 units, Win (Tatum)

257. Development Strategies for High Tech Facilities—The development of complex facilities for biotech and semiconductor firms to satisfy demanding project objectives. Topics: the business aspects of the industry segments, basic technology, and production processes; projects and typical plants; and major process equipment and systems. Professionals from all types of firms participate in project teams for high tech facilities. Field trips to biotech labs and production facilities, semiconductor tool suppliers, and wafer fabs. Two student papers analyze development strategies through case studies of realistic situations.
3 units (Staff) not given 2000-01

258A,B,C. Donald R. Watson Seminar in Construction Engineering and Management—Weekly discussions of special topics with speakers from industry and government. Normally taken by construction graduate students each quarter for three quarters. Lecture builds on construction graduate courses. (AU)
258A. *1 unit, Aut (Clough)*
258B. *1 unit, Win (Paulson)*
258C. *1 unit, Spr (Levitt)*

259A,B,C. Construction Problems—Analysis of group-selected problems in construction techniques, equipment, or management, followed by preparation of oral and/or written reports. Students consult specialists from the construction industry and make use of University facilities. See 299 for alternative individual studies. Prerequisites: graduate standing in construction and consent of instructor.
259A. *1-3 units, Aut (Staff)*
259B. *1-3 units, Win (Staff)*
259C. *1-3 units, Spr (Staff)*

260A. Physical Hydrogeology—(Same as Geological and Environmental Sciences 230.) Theory of underground water, analysis of field data and pumping tests, geologic groundwater environments, solution of field problems, groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.
5 units, Aut (Gorelick)

260B. Surface and Near-Surface Hydrologic Response—(Same as Geological and Environmental Sciences 237.) Quantitative review of process-based hydrology and geomorphology. Introduction to finite-difference and finite-element methods of numerical analysis. Topics: biometeorology, unsaturated and saturated subsurface fluid flow, overland and open channel flow, erosion and mass wasting, and physically-based simulation of coupled surface and near-surface hydrologic response and landscape evolution. Links hydrogeology, soil physics, and surface water hydrology.
4 units (Loague) alternate years, given 2001-02

260C. Contaminant Hydrogeology—(Same as Geological and Environmental Sciences 231.) For earth scientists and engineers interested in environmental and water resource problems involving contaminated groundwater. The processes affecting contaminant migration through porous media, including interactions between dissolved substances and solid media. Conceptual and quantitative treatments of advective-dispersive transport with reacting solutes. Predictive models of contaminant behavior controlled by local equilibrium and kinetics. Modern methods

of contaminant transport simulation and optimal aquifer remediation. Recommended: 260A.
4 units, Spr (Gorelick)

261. Watershed and Wetlands Hydrology—Graduate seminar focusing on the hydrologic processes underlying the functioning, management, and restoration of important ecosystems. Possible topics: the hydrology of tidal salt and freshwater marshes, inland freshwater wetlands, riparian zones, wetland and upland forests, agricultural or urban watersheds. Readings from texts and journal literature. Each student prepares a research proposal on the quarter's topic. Enrollment limited. Prerequisite: consent of instructor. Recommended: 162, 260A, or equivalents.
3 units, Spr (Freyberg)

262A. Environmental Fluid Mechanics—The flow of incompressible viscous fluid; emphasis is on developing an understanding of fluid dynamics that can be applied to environmental flows. Topics: kinematics of fluid flow; equations of mass and momentum conservation (including density variations); some exact solutions to the Navier-Stokes equations; appropriate analysis of fluid flows including Stokes flows, potential flows, and laminar boundary layers; and an introduction to the effects of rotation and stratification through scaling analysis of fluid flows. Prerequisites: 101B or consent of instructor, and some knowledge of vector calculus.
3-4 units, Aut (Koseff)

262B. Transport and Mixing in Surface Water Flows—Application of fluid mechanics to problems of pollutant transport and mixing in the water environment. Mathematical and numerical models of advection, diffusion, and dispersion. Application of theory to problems of transport and mixing in rivers, estuaries, and lakes and reservoirs. Recommended: 262A and Engineering 155A or equivalents.
3-4 units, Win (Staff)

262C. Modeling Environmental Flows—Introduction to turbulence models, and to basic concepts of numerical simulation and computer modeling of turbulent flows. Application of models to open channel, estuary, and lake/reservoir simulations. Use of computer models for estuarine hydrodynamics, lake/reservoir dynamics, and stream water quality. The effects of rotation and stratification. Prerequisites: 262A, or consent of instructor.
3-4 units, Spr (Street)

263A. Air Pollution Modeling—Introduction to the numerical modeling of urban, regional, and global air pollution with a focus on gas chemistry and radiative transfer. Stratospheric, free-tropospheric, and urban chemistry. Methods for solving stiff systems of chemical ordinary differential, including the Multistep Implicit-Explicit method, Gear's method with sparse-matrix techniques, and the family method. Numerical methods of solving radiative transfer, coagulation, condensation, and chemical equilibrium problems. Project involves the development of a basic chemical ordinary differential equation solver. Prerequisite: Computer Science 106A or equivalent.
3-4 units, Win (Jacobson)

263B. Numerical Weather Prediction—Introduction to numerical weather prediction. Continuity equations for air and water vapor, the thermodynamic energy equation, and momentum equations are derived for the atmosphere. Numerical methods of solving partial differential equations, including finite-difference, finite-element, semi-Lagrangian, and pseudospectral methods. Time-stepping schemes: the forward-Euler, backward-Euler, Crank-Nicolson, Heun, Matsuno, leapfrog, and Adams-Bashforth schemes. Boundary-layer turbulence parameterizations, soil moisture, and cloud modeling. Project developing a basic mesoscale model. Prerequisite: Computer Science 106A or equivalent.
3-4 units (Jacobson) given 2001-02

263C. Weather and Storms—Undergraduates register for 63; see 63.
3 units, Aut (Jacobson)

263D. Air Pollution: From Urban Smog to Global Change—Undergraduates register for 64; see 64.
3 units, Spr (Jacobson)

263S. Climate Theory, Modeling, Applications, and Implications—(Enroll in Biological Sciences 217.)
3 units (Schneider) alternate years, given 2001-02

264. Sediment Transport Modeling—The physical processes and modeling of sediment transport in estuaries, rivers, and coastal zones. Modeling in one-, two-, and three-space dimensions and time. Hands-on sessions with actual development, modification, and application of analytical models and numerical codes for transport. Prerequisites: 201D, 262A, or equivalents.
3 units, Win (Street)

265. Sustainable Water Resources Development—Alternative criteria for judging the sustainability of projects. Application of criteria to evaluate sustainability of water resources projects in several countries. Case studies illustrate the role of political, social, economic, and environmental factors in decision making. Evaluation of benefit-cost analysis and environmental impact assessment as techniques for enhancing the sustainability of future projects. Limited enrollment. Prerequisite: graduate standing in Environmental and Water Studies, or consent of instructor.
3 units, Win (Ortolano)

266. Environmental Policy Design and Implementation—Regulation, market incentives, the courts, and negotiation as bases for environmental management programs. Case studies involve implementation of air and water pollution control laws, hazardous waste management programs, and environment impact assessment. Limited enrollment. Prerequisite: graduate standing in Environmental and Water Studies Program or consent of instructor.
4 units (Ortolano) given 2001-02

267. Interpolation and Inverse Problems—Understanding complex hydrologic processes by using measurements, mathematical models which describe groundwater flow and solute transport, and stochastic analysis of spatial variability and uncertainty. Topics: exploratory data analysis, generalized linear minimum-variance estimation, parameter estimation (or "model calibration"), model validation, accuracy of model predictions, optimal sampling. Emphasis is on linear "geostatistical" methods of estimation. Prerequisite: background in introductory statistics and linear algebra.
3-4 units, Spr (Kitanidis)

268. Groundwater Flow—Study of flow and mass transport in porous media through analytical techniques. Applications of potential flow theory to practical groundwater problems: flow to and from wells, rivers, lakes, drainage ditches; flow through and under dams; streamline tracing; capture zones of wells; and mixing schemes for in-situ remediation. Prerequisites: calculus andintroductory fluid mechanics.
3-4 units, Win (Kitanidis)

269. Water Resources Seminar—Problems in all branches of water resources, with talks by visitors, faculty, and students. (AU)
1 unit, Spr (Kitanidis)

270. Movement, Fate, and Effects of Contaminants in Surface Waters and Groundwater—Transport of chemical constituents in surface and groundwater, including advection, dispersion, sorption, interphase mass transfer, and transformation; water quality requirements for various beneficial uses. Emphasis is on the behavior of hazardous waste contaminants. Prerequisites: undergraduate chemistry and calculus. Recommended: 101B.
3 units, Aut (Luthy)

271A. Physical and Chemical Processes—Physical and chemical unit operations for water treatment, emphasizing process combinations for drinking water supply. Application of the principles of chemistry, rate processes, fluid dynamics, and process engineering to define and solve water treatment problems by flocculation, sedimentation, filtration, disinfection, oxidation, aeration, and adsorption. Investigative paper on water supply and treatment. Prerequisites: 101B, 270. Recommended: 273.

3 units, Win (Luthy)

271B. Environmental Biotechnology—Stoichiometry, kinetics, and thermodynamics of microbial processes for the transformation of environmental contaminants. Design of dispersed growth and biofilm-based processes. Applications include treatment of municipal and industrial wastewaters, detoxification of hazardous chemicals, and groundwater remediation. Prerequisites: 270; 177 or 274A (or equivalents).

4 units, Win (Criddle)

271C. Physiochemical Processes and Organic Contaminants—The major physical and chemical processes affecting anthropogenic organic compounds in aquatic systems. Review of concepts from physical organic chemistry and the relationships between chemical structure and physicochemical properties and the environmental behavior of organic compounds. The physicochemical processes important to phase partitioning, availability, transport, treatment, and abiotic transformation of specific organic compounds are addressed and applied to examples in water quality engineering, and soil and sediment quality. Prerequisite: 270.

3 units (Luthy) not given 2000-01

273. Aquatic Chemistry—(Same as Geological and Environmental Sciences 264.) Chemical principles and their application to the analysis and solution of problems in aqueous geochemistry (temperatures near 25°C and atmospheric pressure). Emphasis is on the analysis of natural water systems and the understanding and solution of specific chemical problems in water purification technology and water pollution control. Prerequisites: Chemistry 31 and 33, or equivalents.

3 units, Aut (Leckie)

273A. Water Chemistry Laboratory—Laboratory application of techniques for the analysis of natural and contaminated waters, emphasizing instrumental techniques.

2 units, Win (Leckie)

274A. Environmental Microbiology I—The fundamental aspects of microbiology and biochemistry. The biochemical and biophysical principles of biochemical reactions, energetics, and mechanisms of energy conservation. Composition of the bacterial cell, bacterial growth. Diversity of microbial catabolism, flow of organic matter in nature: the carbon cycle. Bacterial physiology, phylogeny, and the ecology of microbes in soil and marine sediments, bacterial adhesion, and biofilm formation. Microbes in the degradation of pollutants. Prerequisites: Chemistry 33, 35, or equivalents.

3 units, Aut (Spormann)

274B. Environmental Microbiology II—Biogeochemistry: microbial metabolism of inorganic matter. The sulfur-, nitrogen-, iron-, oxygen-cycle in nature. The interdependence of organic and inorganic food chains in soils, sediments, and lakes. Metabolic ecology: the impact of microbial activities on the environment and of the environment on microbial activities. Sensing the environment: regulation of gene expression, two component regulatory systems, gene regulation in response to light, O_2 partial pressure, osmolarity, nutrient limitation, induction of metabolic pathways, cell-cell communication, gene transfer in the environment. Detection of microorganisms in the environment (geneprobes, PCR as analytical technique, immunoprobes, enzyme-probes). Prerequisite: 274A.

3 units, Win (Spormann)

274C. Environmental Microbiology Laboratory—Microbiological, biochemical, and molecular techniques for characterizing microbes: enrichment and isolation of microorganisms, metabolic and phylogenetic characterization of isolates, determination of growth parameters (growth rate, growth yield, fermentation balance), enrichment and isolation of microorganisms degrading pollutants, detection of microorganisms in the environment, water quality parameters. Horizontal gene transfer. Prerequisites: 274A, 274B.

3 units (Spormann)

274D. Pathogens and Disinfection—Introduction to epidemiology, major pathogens and infectious diseases, the immune system, movement and survival of pathogens in the environment, transfer of virulence and antibiotic resistance genes, and pathogen control, with an emphasis on public health engineering measures (disinfection). Prerequisite: 274A.

3 units (Criddle) not given 2000-01

275A. Water Quality Control Processes I—Lab and pilot plant studies of the physical and chemical processes for the treatment of water and wastewaters. Prerequisites: 271A, 273, 273A.

3 units (Leckie) alternate years, given 2001-02

275B. Environmental Biotechnology Laboratory—Design of a water or wastewater treatment system using biological processes to remove contaminants. Student teams characterize contaminants in water or wastewater, design and operate bench- and pilot-scale units, then develop a full-scale design. Prerequisites: 271B, 273A.

3 units, Spr (Criddle) alternate years, not given 2001-02

276. Introduction to Human Exposure Analysis—(Undergraduates register for 178.) Scientific and engineering issues involved in quantifying human exposure to toxic chemicals in the environment. Pollutant behavior, inhalation exposure, dermal exposure, and assessment tools. Overview of the complexities; uncertainties; and physical, chemical, and biological issues relevant to risk assessment. Lab projects. Recommended: Mathematics 51.

3 units, Spr (Leckie)

278A. Air Pollution Physics and Chemistry—The sources and health effects of pollutants. The influence of meteorology on pollution: atmospheric energy balance, temperature profiles, stability classes, inversion layers, turbulence. Atmospheric diffusion equations, downwind dispersion of emissions from point and line sources. Tropospheric chemistry: mechanisms for ozone formation, photochemical reactions, radical chain mechanisms, heterogeneous chemical reactions. Prerequisites: Mathematics 51, Chemistry 31, or equivalents. Recommended: 101B, 273 or Chemistry 135, or equivalents.

3 units, Aut (Hildemann)

278B. Atmospheric Aerosols—The characterization of atmospheric particulate matter: size distributions, chemical composition, health effects. Atmospheric diffusion and transport of particles: removal by convection, impaction, gravitational settling. Effect of aerosols on visibility: light scattering and absorption, reduction of visual range. Mechanics influencing ambient size distributions: Brownian coagulation, laminar shear flow, homogeneous nucleation, heterogeneous condensation. Prerequisite: Mathematics 51, or equivalent. Recommended: 101B or equivalent.

3 units, Spr (Hildemann)

279. Environmental Engineering Seminar—Current research, practice, and thinking in environmental engineering and science. Attendance at seminars is self-directed, and may be accrued throughout the school year. See instructor for syllabus.

1 unit, Spr (Hildemann)

280. Advanced Structural Analysis—Theoretical development and computer implementation of direct stiffness method of structural analy-

sis; virtual work principles; computation of element stiffness matrices and load vectors; direct assembly procedures; equation solution techniques. Analysis of two- and three-dimensional truss and frame structures, thermal loads, and substructuring and condensation techniques for large systems. Practical modeling techniques and programming assignments. Introduction to nonlinear analysis concepts. Prerequisites: elementary structural analysis and matrix algebra.
3-4 units, Aut (Deierlein)

281. Finite Element Structural Analysis—Introduction to the finite element method for analysis of structural systems. Formulation and implementation of frame, plane stress, plane strain, axisymmetric, torsional, solid, plate, and shell elements. Topics: strong and weak forms of the problem, variational principles and the principle of minimum potential energy, the finite element method as an extension of the Rayleigh-Ritz method, shape functions, isoparametric mapping, numerical integration, convergence requirements, and error estimation. Techniques for application to modeling structural systems. Prerequisite: 280 or equivalent.
3-4 units, Win (Lowes)

282. Nonlinear Structural Analysis—(Formerly 283.) Introduction to methods of geometric and material nonlinear analysis, emphasizing modeling approaches for framed structures. Large-displacement analysis, concentrated and distributed plasticity models, and nonlinear solution methods. Applications to frame stability and performance-based seismic design. Assignments emphasize computer implementation and applications. Prerequisites: 280, 286 or equivalent.
3 units, Spr (Deierlein)

283. Structural Dynamics—(Formerly 296A.) Vibrations and dynamic response of simple structures under time dependent loads, dynamic analysis of single and multiple degrees of freedom systems, support motion, response spectra.
3-4 units, Aut (Law)

284. Computational Methods in Structural Dynamics—Methods of structural dynamics for discretized and continuous systems in free and forced vibration, modal analysis; numerical methods; introduction to nonlinear dynamics; advanced topics. Prerequisites: 280, 283.
3 units (Law) alternate years, given 2001-02

285. Behavior of Structural Systems for Buildings—Basic design concepts, performance criteria, loading, methods of design, types of structural systems behavior under gravity and lateral loads, approximate methods of analysis, preliminary design concepts and implementation, performance assessment, behavior of structural elements. Prerequisites: basic courses in design of steel and reinforced concrete structures.
3-4 units, Aut (Krawinkler)

286. Advanced Structural Design—Strength, stiffness, and ductility considerations in the design of structural elements and systems made of steel, reinforced concrete, and other materials. Concepts of redistribution (element vs. system behavior). Introduction to performance-based design. Prerequisites: basic courses in design of steel and reinforced concrete structures, 285 or equivalent.
3-4 units, Win (Krawinkler)

287. Earthquake Resistant Design—(Formerly 284). Earthquake motions and their engineering interpretations, design spectrum and design earthquakes, dynamic analysis of structures for earthquake loading, design of structures to minimize earthquake damage, design of protective systems, retrofit of existing structures, earthquake codes. Prerequisite: 286 or consent of instructor.
3 units, Spr (Lowes)

288. Earthquake Hazard and Risk Analysis—(Formerly 282.) Earthquake phenomena, faulting, ground motion, study of past major earthquakes, effects of earthquakes on man-made structures, response spectra, Fourier spectra, power spectra, random vibration analysis of single and multi-degree of freedom systems, soil effects on ground motion and structural damage, methods for structural damage evaluation, current research in earthquake engineering. Prerequisites: 203, 283.
3 units, Win (Staff)

289. Random Vibrations—Introduction to random processes. Correlation and power spectral density functions. Stochastic dynamic analysis of multi-degree-of-freedom structures subjected to stationary and non-stationary random excitations. Crossing rates, first-excursion probability, and distributions of peaks and extremes. Applications in earthquake, wind, and ocean engineering. Prerequisite: 203 or equivalent.
3-4 units, Spr (Menun) alternate years, not given 2001-02

290. Structural Performance and Failures—(Formerly 287.) Basic concepts in the definition of satisfactory structural performance; key elements in structural performance; types of failures, ranging from reduced serviceability to total collapse; failure sources and their root cause allocation, emphasizing design/construction process failures; failure prevention mechanisms; illustration with real life examples.
2 units, Spr (Moncarz)

291. Advanced Strength of Materials and Laboratory Testing—Experimental investigation and analytical modeling of new and traditional civil engineering materials. Laboratory testing to determine strength, deformation, and energy-dissipation characteristics. Review mechanics of materials, introduction to inelastic constitutive theory including plasticity theory, damage mechanics, fracture mechanics, viscoelasticity, and viscoplasticity. Readings from texts and journal literature. Possible topics: plain concrete, fiber-reinforced concrete, structural steel, fiber-reinforced composites, rubber and asphalt. Student paper discussing constitutive modeling.
3 units, Aut (Lowes)

292. Computer Methods in Structural Engineering—Introduction to basic techniques for the development of structural engineering analysis and design software. Topics: basic data structure; computer representation of engineering systems; implementation of advanced numerical methods and engineering software; automated conformance checking of design codes and standards. Prerequisites: Computer Science 106A or equivalent.
3 units, Win (Law) alternate years, not given 2001-02

293. Foundation Engineering—(Formerly 291.) Types, characteristics, analysis, and design of shallow and deep foundations; rigid and flexible retaining walls; braced excavations; settlement of footings in sands and clays; slope stability analysis by method of slices including search algorithms for the critical slip surface. Special seminars by guest speakers; computing assignment. Prerequisite: 101C or equivalent.
3 units, Win (Borja)

294. Computational Geomechanics—(Formerly 289.) Continuum and finite element formulations of steady-state and transient fluid conduction problems in geomechanics; elliptic, parabolic, and hyperbolic systems; variational inequality and free-boundary problems; three-dimensional consolidation theory; undrained condition, mesh locking, B-bar and strain projection methods; finite element formulations of multiphase dynamic problems. Computing assignments. Prerequisites: 101C, Mechanical Engineering 232A, or equivalents.
3 units (Borja) alternate years, given 2001-02

295. Plasticity in Geomechanics—(Formerly 290.) Theory of particulate media; micromechanics of granular materials; constitutive laws in geomechanics; plasticity; return-mapping algorithms; classical yield models: Mises, Mohr-Coulomb, Drucker-Prager; critical state theory and Cam-clay models; multi-surface and bounding surface models; localization and bifurcation theories in geomechanics. Prerequisites: 101C, Mechanical Engineering 238A, or equivalents.
3 units, Spr (Borja) alternate years, not given 2001-02

296. Experimental Soil Mechanics—(Formerly 293.) Lab determination of stress-strain-strength parameters for soils under drained and undrained loading conditions. Six lab experiments. Prerequisite: 101C or equivalent.
2 units, Win (Borja)

297. Issues in Geotechnical and Environmental Failures—(Formerly 294.) Causes and consequences of the failure of buildings, earth structures, waste storage, and high hazard facilities in contact with the environment; technical, ethical, economic, legal, and business aspects; failure analysis and forensic problems; prevention, liability, and dispute management. Case history approach based on the instructor's files including earthquake, flood, and hazardous waste facilities. Student observation, participation in active lawsuits where possible.
3 units, Spr (Meehan)

298. Structural Engineering and Geomechanics Seminar—Recommended for all graduate students. Lectures on topics of current interest in professional practice and research. (AU)
1 unit, Win (Staff)

299. Independent Study in Civil and Environmental Engineering—Directed study for graduate students on subjects of mutual interest to students and faculty. Student must obtain faculty sponsor.
1-3 units, any quarter (Staff)

300. Thesis—Investigation of an engineering problem; required of candidates for degree of Engineer.
Aut, Win, Spr (Staff)

310. Post-Master's Seminar—For post-master's students to serve as orientation to the selection of a research topic.
1 unit, Aut, Win, Spr (Staff)

320A,B,C. Integrated Facility Engineering—Individual and group presentations on goals, research, and state-of-practice of integrated facility engineering, including objectives for integrated computer systems. (AU)
1 unit, Aut, Win, Spr (Kunz, Levitt)

342. Computational Modeling of Organizations—For post-M.S. students interested in formal techniques for organization design. Computer simulation of organizations are used to conduct "virtual experiments" for developing organization theory or to analyze the performance of "virtual organizations" with different structures and decision support/communication technologies. Goals: introduce research on computational modeling and design of real-world organizations. Paper serves as a research proposal. Prerequisite: 242 or equivalent introductory organization design class.
4-5 units, Win (Levitt)

362. Advanced Topics in Subsurface Transport—Mathematical analysis of flow and transport in porous and fractured media. Topics vary each year, including: solution of flow and transport equations, stochastic analysis, homogenization, and estimation methods. Prerequisite: consent of instructor.
3 units (Kitanidis) alternate years, given 2001-02

363. Mechanics of Stratified Flows—The effects of density stratification on flows in the natural environment. Basic properties of linear internal waves in layered and continuous stratification. Flows established by internal waves. Internal hydraulics and gravity currents. Turbulence in stratified fluids. Prerequisites: 262A,B, Mechanical Engineering 200C.
3 units (Fong) alternate years, given 2001-02

364. Geophysical Fluid Dynamics—Focus is on fluid dynamics in natural systems where the influence of the earth's rotation is important. The basic processes such as geostrophic and quasi-geostrophic flows, planetary waves, and potential vorticity. Student-led lectures and discussions of current physical oceanographic research problems. Prerequisites: 262A, 363.
2 units, Win (Monismith, Fong)

370A,B,C. Environmental Research—Introductory research experience for first-year graduate students in the Environmental Engineering and Science program pursuing the Ph.D. 15-18 hrs/week on research over a 3-qtr. period. 370A requires written literature survey on a research topic; 370B requires oral presentation on experimental techniques and research progress; 370C requires written or oral presentation of preliminary doctoral research proposal. Students must obtain a faculty sponsor.
5-6 units, Aut, Win, Spr (Staff)

398. Report on Civil Engineering Training—On-the-job training under the guidance of experienced, on-site supervisors; meets the requirements for Curricular Practical Training for students on F-1 visas. Students submit a concise report detailing work activities, problems worked on, and key results. Prerequisite: written consent of adviser.
1 unit, any quarter (Staff)

399. Advanced Engineering Problems—Individual projects on selected topics. Independent graduate work under the direction of a faculty member on a subject of mutual interest. Student must obtain faculty sponsor. Written report usually required.
1-5 units, any quarter (Staff)

400. Thesis—Dissertation for Ph.D. degree.
1-15 units, any quarter (Staff)