CIVIL AND ENVIRONMENTAL ENGINEERING

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Associate Professors: Sarah L. Billington (on leave Autumn, Winter, Spring), David L. Freyberg, Lynn M. Hildemann, Eduardo Miranda
Assistant Professors: Jack W. Baker, Alexandria B. Boehm, Jennifer Davis, Oliver B. Fringer, John R. Haymaker, Michael D. Lepech
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Consulting Professors: James E. Cloern, Russell G. Clough, Curtis R. Cook, Angelos N. Findikakis, Amatzia Genin, Robert F. Hickey, Michael C. Kavanaugh, Michael E. London, Francis L. Ludwig, Douglas M. MacKay, Martin W. McCann, Jr., Richard L. Meehan, Paul K. Meyer, Piotr D. Moncarz, Wayne R. Ott, Ingo Pinnau, Harry E. Ridgway, Benedict R. Schwegler, Jr., Avram S. Tucker, Antonio L. Vives, Michael W. Walton
Consulting Associate Professors: Olaf A. Cirpka, Edward S. Gross, Charles S. Han, Thomas L. Holzer, Jonathan G. Koomey, Lisa V. Lucas, Colin Ong, Adina Paytan, Joel N. Swisher, Jie Wang, Jane Woodward
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Courses offered by the Department of Civil and Environmental Engineering have the subject code CEE, and are listed in the "Civil and Environmental Engineering (CEE) Courses" section of this bulletin.

The primary mission of Civil and Environmental Engineering (CEE) at Stanford is the execution of basic and applied research that advances the civil and environmental engineering professions, the education of future academic and industry leaders, and the preparation of students for careers in professional practice. Civil and environmental engineers work to sustain the natural environment while creating and maintaining the built environment. Civil and environmental engineers are essential to providing the necessities of human life, including water, air, shelter, the infrastructure, energy, and food, increasingly in more efficient and renewable ways.

The department focus is on the theme of engineering for sustainability, including three focus areas: the built environment, environmental and water studies, and atmosphere and energy. The built environment includes creating processes, techniques, materials, and monitoring technologies for planning, design, construction and operation of environmentally sensitive, economically efficient, performance-based built systems, and managing associated risks from natural and man-made hazards. Built environment research and teaching is conducted primarily within the programs of Construction Engineering and Management, Design-Construction Integration, and Structural Engineering and Geomechanics and Sustainable Design Construction. The water environment includes creating plans, policies, science-based assessment models and engineered systems to manage water in ways that protect human health, promote human welfare, and provide freshwater and coastal ecosystem services. Water environment research and teaching is conducted primarily within the programs of Environmental Engineering and Sciences and Environmental Fluid Mechanics and Hydrology. Atmosphere and Energy includes studying fundamental energy and atmospheric engineering and science, assessing energy-use effects on atmospheric processes and air quality, and analyzing and designing energy-efficient generation and use systems with minimal environmental impact.

UNDERGRADUATE PROGRAMS IN CIVIL AND ENVIRONMENTAL ENGINEERING

The undergraduate Civil Engineering major provides a pre-professional program balancing the fundamentals common to many special fields of civil engineering with a field of study 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, structural and earthquake engineering, and advanced sensing technologies. The department hosts the School of Engineering pre-approved majors in Architectural Design and Atmosphere/Energy; see requirements in the "School of Engineering" section of this bulletin.

At least one year of graduate study is 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; applications are considered once a year near the beginning of Winter Quarter.

For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING

The B.S. in Civil Engineering and the B.S. in Environmental Engineering are ABET accredited programs, which place high priority on integrating research with engineering education. Four major objectives structure both degree programs:

To provide an understanding of engineering principles and the analytical, problem solving, design, and communication skills to continue succeeding and learning in diverse careers.

1. To prepare for successful engineering practice with a longer term perspective that takes into account new tools such as advanced information technology and biotechnology, and increasingly complex professional and societal expectations.
2. To prepare for possible graduate study in engineering or other professional fields.
3. To develop the awareness, background, and skills necessary to become responsible citizens and leaders in service to society.

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. Each student has elective units, which may be used in any way the student desires, including

additional studies in Civil and Environmental Engineering or any other school or department in the university. Because the undergraduate engineering curriculum provides 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 in the department, students should examine related programs such as Earth Systems, Geological and Environmental Sciences, Urban Studies, and Human Biology.

HONORS PROGRAM

This program leads to a B.S. with honors for undergraduates majoring in Civil Engineering or in Environmental Engineering. It is designed to encourage qualified students to undertake a more intensive study of civil and environmental engineering than is required for the normal majors through 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 faculty adviser and completion of a thesis of high quality. A written proposal for the research to be undertaken must be submitted and approved by the faculty advisor 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 3.3 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 ENGR 202S or its equivalent. The written thesis must be approved by the thesis adviser. Students are encouraged to present their results in a seminar for faculty and students. Up to 10 units of CEE 199H, Undergraduate Honors Research in Civil and Environmental Engineering, may be taken to support the research and writing (not to duplicate ENGR 202S). These units are beyond the normal Civil Engineering or Environmental Engineering major program requirements.

MINOR IN CIVIL ENGINEERING OR ENVIRONMENTAL ENGINEERING

The department offers minor programs in Civil Engineering and in Environmental Engineering. Departmental expertise and undergraduate course offerings are available in the areas of architectural design, construction engineering, construction management, structural/geotechnical engineering, environmental engineering and science, environmental fluid mechanics and hydrology, and atmosphere/energy. The courses required for the minors typically have prerequisites. Minors are not ABET-accredited programs. Further details on minors are provided in the "School of Engineering" section of this Bulletin.

GRADUATE PROGRAMS IN CIVIL AND ENVIRONMENTAL ENGINEERING

The Department of Civil and Environmental Engineering (CEE), in collaboration with other departments, offers eight graduate degrees structured in three degree programs described below. The Atmosphere/Energy Program offers degrees with that designation. The Built Environment Program offers degrees with five designations: Construction Engineering and Management, Design/Construction Integration, Geomechanics, and Structural Engineering and Sustainable Design Construction. The Environmental and Water Studies Program offers degrees with two designations: Environmental Engineering and Science, and Environmental Fluid Mechanics and Hydrology. The final portion of this section describes University and departmental requirements for graduate degrees.

Research work and instruction under the three programs are carried out in these facilities: Building Energy Laboratory; Environmental Engineering and Science Laboratory; Environmental Fluid Mechanics Laboratory (EFML); Geotechnical Engineering Laboratory; Structural Engineering Laboratory; and water quality control research and teaching laboratories. The John A. Blume Earthquake Engineering Center conducts research on earthquake engineering including advanced sensing and control, innovative materials, and risk hazard assessment. Research and advanced global teamwork education is conducted in the Project Based Learning (PBL) Laboratory. 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 participants in the facility development process and to support design and construction automation. The Collaboratory for Research on Global Projects (CRGP) is a multi-school, multi-university research program aimed at improving the performance of global engineering and construction projects, with a special focus on sustainable infrastructure in developing countries.

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

Admission—Applications require online submission of the application form and statement of purpose, followed by three letters of recommendation, results of the General Section of the Graduate Record Examination, and transcripts of courses taken at colleges and universities. See http://gradadmissions.stanford.edu. Policies for each of the department's programs are available by referring to http://cee.stanford.edu.

Successful applicants are advised as to the degree and program for which they are admitted. If students wish to shift from one CEE program to another after being accepted, an application for the intradepartmental change must be filed within the department; they will then be advised whether the change 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 continuing program of financial aid for graduate students. Applications for financial aid and assistantships should be filed by December 16, 2008; it is important that Graduate Record Examination scores be available at that time. Applicants not requesting financial assistance have until March 17, 2009 for the online submission.

Teaching assistantships carry a salary for as much as one-half time work to assist with course offerings during the academic year. Up to half-time 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.

HONORS COOPERATIVE PROGRAM

Some of the department's graduate students participate in the Honors Cooperative Program (HCP), which makes it possible for academically qualified engineers and scientists in industry to be part-time graduate students in Civil and Environmental Engineering while continuing professional employment. Prospective HCP students follow the same admissions process and must meet the same admissions requirements as full-time graduate students. For more information regarding the Honors Cooperative Program, see the "School of Engineering" section of this bulletin.

PROGRAMS OF STUDY IN CIVIL AND ENVIRONMENTAL ENGINEERING

ATMOSPHERE/ENERGY

Energy and Atmosphere are linked in two primary ways. First, fossil-fuel derived energy use contributes to air pollution and climate change. Second, atmospheric winds and solar radiation are major sources of renewable energy. Because atmospheric problems can be mitigated best by increasing the efficiency with which energy is used, optimizing the use of natural energy resources, and understanding the effects of energy technologies on the atmosphere, the areas of Energy and Atmosphere are naturally coupled together.

Students in this program receive a transcript designation of Atmosphere/Energy. Courses include those in energy resources, indoor and outdoor air pollution, energy efficient buildings, climate

change, renewable energy, weather and storm systems, energy technologies in developing countries, energy systems, and air quality management.

Current research in the program includes projects on wind energy distribution and statistics, indoor exposure to air pollutants, the effects of a hydrogen economy on atmospheric pollution and climate, measurements of particulate matter and vehicle exhaust, hydrogen and other fuel generation by bacteria, numerical modeling of the effects of vehicles and power plants on climate, numerical weather prediction, improving the energy efficiency of buildings, improving the links between wind farms and the transmission grid, and studying the effects of aerosol particles on UV radiation and climate, among others.

Within the department, the program links to studies of water quality, environmental biotechnology, environmental fluid mechanics, sustainable construction, green buildings, and risk management. Outside the department, it links to Earth Systems, Management Science and Engineering, Mechanical Engineering, Energy Resources Engineering, Urban Studies, Aeronautics and Astronautics, and Biology, among others. In addition, the program has natural connections with the Woods Institute for the Environment, the Interdisciplinary Graduate Program in Environment and Resources (IPER), and the Global Climate and Energy Program (GCEP).

SUSTAINABLE BUILT ENVIRONMENT

The Sustainable Built Environment group in the department includes faculty from structural engineering and geomechanics, construction engineering and management, and design-construction integration. Our focus is on educating practitioners and researchers who can play a variety of roles in planning, designing, building and operating more sustainable buildings and infrastructure. The Structural Engineering and Geomechanics (SEG) program educates designers who want to progress beyond traditional life safety code-based design, to develop and disseminate "performance-based" structural and geotechnical engineering methods and tools that maximize the life-cycle economic value of facilities. The Construction Engineering and Management (CEM) program prepares students for careers with progressive construction firms worldwide, interested in building more sustainable buildings and infrastructure using advanced modeling and visualization methods and tools that we call "Virtual Design and Construction". The Design-Construction Integration (DCI) program combines courses from CEM and SEG, along with additional DCI courses, to educate professionals for design construction firms that provide integrated design-build project delivery, construction management and pre-construction services. Our new program (starting in 2008-2009) in Sustainable Design and Construction (SDC) expands the breadth of the DCI program with courses in sustainable, multi-stakeholder design methods and tools that incorporate lifecycle cost analysis, green architectural design, lighting and energy analysis, to educate students from a variety of undergraduate backgrounds interested in promoting more sustainable development of buildings and infrastructure. Each program offers MS, Engineer and Ph.D degrees. Admissions to these programs are handled separately; prospective students should indicate their preference on their application.

CONSTRUCTION ENGINEERING AND MANAGEMENT

The Construction Engineering and Management (CEM) program prepares technically qualified students for responsible engineering and 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, and it covers construction engineering aspects of heavy, industrial and building construction. The CEM concentration offers courses in: building systems, construction administration, construction law, project finance, accounting, real estate development, structural design, HVAC design and construction, 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 CEM program allows students substantial flexibility to tailor their program of study for careers with general contractors, specialty contractors, real estate or infrastructure developers or facility owners and operators.

DESIGN-CONSTRUCTION INTEGRATION

The Design-Construction Integration (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. The field of study in 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 work experience and/or their undergraduate education. Knowledge in 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. Students with an undergraduate degree in civil engineering, and who expect to pursue careers with design or construction firms that emphasize design-build, EPC, or turnkey projects should consider DCI.

STRUCTURAL ENGINEERING AND GEOMECHANICS

The Structural Engineering and Geomechanics (SEG) program encompasses teaching and research programs in structural design and analysis, structural materials, earthquake engineering and structural dynamics, advanced sensing and structural health monitoring, risk and reliability analysis, computational science and engineering, and geotechnical engineering including geomechanics. The SEG programs prepare students for industrial or academic careers. Students can balance engineering fundamentals with modern computational and experimental methods to customize programs to launch careers as consultants on large and small projects, designers, and engineering analysts.

Structural design and analysis focuses on the conceptual design of structural systems and on computational methods for predicting the static and dynamic, linear and nonlinear responses of structures. Structural materials research and teaching focuses on the design and analysis of high-performance materials and materials targeting a reduced environmental impact.

Earthquake engineering and structural dynamics addresses earthquake phenomena, ground shaking, and the behavior, analysis, and design of structures under seismic and other dynamic forces. The John A. Blume Earthquake Engineering Center conducts advanced analytical and experimental research in earthquake engineering and houses static and dynamic testing equipment including two shaking tables. Reliability and risk analysis focuses on advanced methods for structural safety evaluation and design, including methods for loss estimation from damage and failures of structures and lifeline systems. Computational science and engineering emphasizes the application of modern computing methods to structural engineering and geomechanics and encompasses numerical, structural, and geotechnical analysis, including finite element analysis and boundary element methods. The geomechanics program focuses on the application of the principles of applied mechanics to problems involving geologic materials and includes theoretical soil and rock mechanics, computational methods, and analysis and design of foundations and earth structures.

SUSTAINABLE DESIGN AND CONSTRUCTION

The Sustainable Design and Construction (SDC) program prepares students for careers in planning, designing, building and operating sustainable buildings and infrastructure to maximize their life-cycle economic value, their net contribution to environmental functions and services, and their social equity. The program offers courses in: project finance; sustainable multidisciplinary, multi-stakeholder planning and design processes; green architecture; performance-based structural design; building energy systems; and sustainable construction processes and materials. Classes on strategy, economics and organization design for new businesses, and corporate or governmental initiatives focusing on enhancing the

sustainability of buildings and infrastructure round out the program. This degree program is being launched in 2008-2009 and is intended for students with undergraduate degrees in architecture, engineering, science, construction management, economics or business who wish to pursue careers that enhance the sustainability of the built environment. Potential employers include architectural or engineering design firms, sustainability consultants. construction firms focusing on green buildings, green-tech start-ups and green-tech venture funds.

ENVIRONMENTAL AND WATER STUDIES

Environmental and water studies include environmental engineering and science, environmental fluid mechanics, environmental planning, and hydrology. Course offerings permit intensive study in a single area or interrelated study between areas. Programs are flexible to foster interaction among students and encourage the development of individual programs. The Stanford laboratories for water quality control and environmental fluid mechanics are well equipped for advanced research and instruction.

Courses from other programs and departments complement these course offerings. Examples include Computer Science (numerical methods), Geological and Environmental Sciences (geostatistics, hydrogeology), Mechanical Engineering (applied math, experimental methods, fluid mechanics, heat transfer), Energy Resources 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 programs are handled separately; prospective students should indicate their preference on their application.

ENVIRONMENTAL ENGINEERING AND SCIENCE

The Environmental Engineering and Science (EES) program emphasizes the chemical and biological processes involved in water quality engineering, pollution treatment, remediation, and environmental protection. Course offerings include: the biological, chemical, and engineering aspects of water supply; the movement and fate of pollutants in surface and ground waters, 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 (EFMH) include environmental planning and impact assessment, and environmental fluid mechanics, hydrology, and transport modeling.

ENVIRONMENTAL FLUID MECHANICS AND HYDROLOGY

The Environmental Fluid Mechanics and Hydrology (EFMH) program focuses on understanding 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 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 in the Environmental Fluid Mechanics Laboratory, which includes the P. A. McCuen Environmental Computer Center.

MASTER OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING

The following programs are available leading to the M.S. degree in Civil and Environmental Engineering: Atmosphere/Energy, Construction Engineering and Management, Design/Construction Integration, Environmental Engineering and Science, Environmental Fluid Mechanics and Hydrology, Geomechanics, and Structural Engineering and Sustainable Design Construction.

Students admitted to graduate study with a B.S. in Civil Engineering, or equivalent, from an accredited curriculum can satisfy the requirements for the M.S. degree in Civil and Environmental Engineering by completing a minimum of 45 units beyond the B.S. All 45 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. Additional program area requirements are available from the department's student services office (Y2E2 room 316).

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 is often required to obtain the degree.

ENGINEER IN CIVIL AND ENVIRONMENTAL ENGINEERING

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 45 unduplicated course work and research units for a total of 90 units. Engineer candidates must submit an acceptable thesis (12 to 15 units) and maintain a minimum GPA of 3.0. 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. The Engineer thesis topic, for students who will continue study toward a CEE Ph.D., must be significantly different from their doctoral research.

DOCTOR OF PHILOSOPHY IN CIVIL AND ENVIRONMENTAL ENGINEERING

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 requires a total of 135 units of graduate study, at least 90 units of which must be at Stanford. Up to 45 units of graduate study can be represented by the M.S. program described above. Students must maintain a minimum GPA of 3.0 in post-M.S. course work. 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 on Ph.D. requirements and regulations is found in the department handbook.

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 interim 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.

By the end of the second year of graduate study (or by the end of the first year for students who enroll at Stanford with an M.S.), the student is expected to pass the department's General Qualifying Examination (GQE) to be admitted to candidacy for the doctoral degree. The purpose of the GQE is to ensure that the student is adequately prepared to undertake doctoral research and has a well planned research topic. The exam may take the form of (1) a written and/or oral general examination of the candidate's major field, (2) a presentation and defense of the candidate's doctoral research dissertation proposal, or (3) a combination research proposal and general examination. The GQE is administered by an advisory committee consisting of at least three Stanford faculty members, including a chair who is a faculty member in Civil and Environmental Engineering. All members are normally on the Stanford Academic Council. A petition for appointment of one advisory committee member who is not on the Academic Council may be made if the proposed person contributes an area of expertise

that is not readily available from the faculty. Such petitions are subject to approval by the department chair. When the primary research adviser is not a member of the CEE Academic Council faculty, the committee must consist of four examiners, with two members from the CEE department.

PH.D. MINOR IN CIVIL AND ENVIRONMENTAL ENGINEERING

A Ph.D. minor is a program outside a major department. 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 the Ph.D. minor 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 doctoral dissertation.

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

CIVIL AND ENVIRONMENTAL ENGINEERING (CEE) COURSES

For information on undergraduate and graduate programs in the Department of Civil and Environmental Engineering, see the "Civil and Environmental Engineering" and "School of Engineering" sections of this bulletin.

UNDERGRADUATE COURSES IN CIVIL AND ENVIRONMENTAL ENGINEERING

CEE 31Q. Accessing Architecture Through Drawing
Stanford Introductory Seminar. Preference to sophomores. Drawing architecture provides a deeper understanding of the intricacies and subtleties that characterize contemporary buildings. How to dissect buildings and appreciate the formal elements of a building, including scale, shape, proportion, colors and materials, and the problem solving reflected in the design. Students construct conventional architectural drawings, such as plans, elevations, and perspectives. Limited enrollment. GER:DB-EngrAppSci

4 units, Aut (Barton, J), Spr (Barton, J)

CEE 46Q. Fail Your Way to Success
Stanford Introductory Seminar. Preference to sophomores. How to turn failures into successes; cases include minor personal failures and devastating engineering disasters. How personalities and willingness to take risks influence the way students approach problems. Field trips, case studies, and guest speakers applied to students day-to-day interactions and future careers. Goal is to redefine what it means to fail. GER:DB-EngrAppSci

3 units, Spr (Clough, R)

CEE 48N. Organizing Global Projects
Stanford Introductory Seminar. Preference to freshmen. Challenges associated with planning and managing both commercial and governmental/non-profit global projects; theory, methods, and tools to enhance global project outcomes. Students teams model and simulate crosscultural teams engaged in global projects. Opportunities to participate in research in the Collaboratory for Research on Global Projects involving faculty from Stanford departments and schools; see http://crgp.stanford.edu.

4 units, Aut (Levitt, R)

CEE 63. Weather and Storms
(Same as CEE 263C.) Daily and severe weather and global climate. Topics: structure and composition of the atmosphere, fog and cloud formation, rainfall, local winds, wind energy, global circulation, jet streams, high and low pressure systems, inversions, el Niño, la Niña, atmosphere/ocean interactions, fronts, cyclones, thunderstorms, lightning, tornadoes, hurricanes, pollutant transport, global climate and atmospheric optics. GER:DB-NatSci

3 units, Aut (Jacobson, M)

CEE 64. Air Pollution: From Urban Smog to Global Change
(Same as CEE 263D.) Survey of urban- through global-scale air pollution. Topics: the evolution of the Earth's atmosphere, indoor air pollution, urban smog formation, history of discovery of atmosphere chemicals, visibility, acid rain, the greenhouse effect, historical climate, global warming, stratospheric ozone reduction, Antarctic ozone destruction, air pollution transport across political boundaries, the effects of air pollution on ultraviolet radiation, and impacts of energy systems on the atmosphere. GER:DB-NatSci

3 units, Win (Jacobson, M)

CEE 70. Environmental Science and Technology
Introduction to environmental quality and the technical background necessary for understanding environmental issues, controlling environmental degradation, and preserving air and water quality. Material balance concepts for tracking substances in the environmental and engineering systems. GER:DB-EngrAppSci

3 units, Spr (Kopperud, R; Walton, K; Strickfaden, R)

CEE 100. Managing Sustainable Building Projects
Managing the life cycle of buildings from the owner, designer, and contractor perspectives emphasizing sustainability goals; methods to define, communicate, coordinate, and manage multidisciplinary project objectives including scope, quality, life cycle cost and value, schedule, safety, energy, and social concerns; roles, responsibilities, and risks for project participants; virtual design and construction methods for product, organization, and process modeling; lifecycle assessment methods; individual writing assignment related to a real world project. GER:DB-EngrAppSci

4 units, Spr (Fischer, M)

CEE 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. Prerequisites: ENGR 14. GER:DB-EngrAppSci

4 units, Win (Baker, J)

CEE 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, estuaries, and wind turbines. Prerequisites: PHYSICS 41 (formerly 53), MATH 51. GER:DB-EngrAppSci

4 units, Spr (Koseff, J)

CEE 101C. Geotechnical Engineering
Introduction to the 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.

Prerequisite: ENGR 14. Recommended: 101A. GER:DB-EngrAppSci

3-4 units, Aut (Borja, R)

CEE 101D. Computations in Civil and Environmental Engineering

(Same as CEE 201D.) Computational and visualization methods in the design and analysis of civil and environmental engineering systems. Focus is on applications of MATLAB. How to develop a more lucid and better organized programming style.

3 units, Aut (Kitanidis, P; Liu, X)

CEE 102. Legal Aspects of Engineering and Construction

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. (London)

3 units, Win (London, M)

CEE 110. Building Information Modeling

(Same as CEE 210. Graduate students register for 210.) Creation, management, and application of building information models. Process and tools available for creating 2D and 3D computer representations of building components and geometries. Organizing and operating on models to produce architectural views and construction documents, renderings and animations, and interface with analysis tools. Lab exercises, class projects. Limited enrollment.

4 units, Aut (Katz, G)

CEE 111. Multidisciplinary Modeling and Analysis

(Same as CEE 211. Graduate students register for 211.) Computer modeling, visualization, analysis, and graphical communication of building projects. Use of 3D models in laser scanning, rendering, animation, daylight, energy, cost, structural, lighting analysis, and computer controlled fabrication. Underlying 3D computer representations, and analysis tools and their applications. Guest lectures, lab exercises, class project. Prerequisite: 110 or CAD experience. GER:DB-EngrAppSci

4 units, Win (Kunz, J)

CEE 115. Goals and Methods of Sustainable Building Projects

(Same as CEE 215. Graduate students register for 215.) Goals related to sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and economic and social sustainability. Methods to integrate these goals and enhance the economic, ecological, and equitable value of building projects. Industry and academic rating systems, project case studies, guest lecturers, and group project.

3 units, Aut (Haymaker, J)

CEE 122A. Computer Integrated Architecture/Engineering/Construction (A/E/C)

Undergraduates serve as apprentices to graduate students in the AEC global project teams in CEE 222A. Apprentices participate in all activities of the AEC team, including the goals, objectives, constraints, tasks, and process of a crossdisciplinary global AEC teamwork in the concept development phase of a comprehensive building project. Prerequisite: consent of instructor.

2 units, Win (Fruchter, R)

CEE 122B. Computer Integrated A/E/C

Undergraduates serve as apprentices to graduate students in the AEC global project teams in CEE 222B. Project activity focuses on modeling, simulation, life-cycle cost, and cost benefit analysis in the project development phase. Prerequisite: CEE 122A.

2 units, Spr (Fruchter, R)

CEE 124. Sustainable Development Studio

(Graduate students register for 224A.) Project-based. Sustainable design, development, use and evolution of buildings; connections of building systems to broader resource systems. Areas include architecture, structure, materials, energy, water, air, landscape, and food. Projects use a cradle-to-cradle approach focusing on technical and biological nutrient cycles and information and knowledge generation and organization. May be repeated for credit.

1-5 units, Aut (Lin, M), Win (Staff), Spr (Staff)

CEE 130. Architectural Design: 3-D Modeling, Methodology, and Process

Preference to Architectural Design majors; others by consent of instructor. Projects investigate conceptual approaches to the design of key architectural elements, such as wall and roof. Functional and structural considerations. Focus is on constructing 3-D models in a range of materials; 3-D computer modeling. Students keep a graphic account of the evolution of their design process. Final project entails design of a simple structure. Limited enrollment. Pre- or corequisite: CEE 31 or 31Q.

4 units, Win (Walters, P)

CEE 131. Architectural Design Process

Preference to Architectural Design and CEE majors; others by consent of instructor. Issues in the architectural profession including programming, site analysis, design process, and professional practice concerns. Building/landscape design case study project using architectural graphics and models. Limited enrollment.

4 units, not given this year

CEE 131A. Introduction to the Design Professions

Seminar. Paths to careers that contribute to the design and construction of the built environment, including architecture, landscape architrecture, project management, construction management, civil engineering, urban planning, and sustainability coordination. Guest lecturers present their work, background, roles and relationships to the other disciplines. Field trips, written and oral presentations, and four Wednesday evening lectures of the Spring Architecture and Landscape Architecture series.

2 units, Spr (Blake, C)

CEE 132. Interplay of Architecture and Engineering

(Same as CEE 232.) The range of requirements that drive a building's design including architecture, engineering, constructability, building codes, and budget. Case studies illustrate how structural and mechanical systems are integrated into building types including residential, office, commercial, and retail. In-class studio work.

4 units, not given this year

CEE 134A. Site and Space

Preference to Architectural Design and CEE majors; others by consent of instructor. An architectural design studio exploring the Stanford Green Dorm project. Initial sessions develop a working definition of sustainable design and strategies for greening the built environment in preparation for design studio work. Enrollment limited to 14. Prerequisites: 31 or 31Q, and 110 and 130.

4 units, not given this year

CEE 134B. Architectural Studio: Special Topic

Preference to Architectural Design majors; others by consent of Instructor. Multi-view drawing and quick sketching. Drawings such as section cuts to enable development of designs. Functional, structural, site, and sustainable considerations. Final project entails design of a simple structure. Limited enrollment.

4 units, Spr (Staff)

CEE 135A. Parametrics: Applications in Architecture and Product Design

(Same as CEE 235A.) Precedents in architecture and product design; methods for modeling, prototyping, and fabrication. How to combine design intentions and digital logics with physical and material constraints. Students develop a case study and small design projects using a parametric approach at the scales of architecture and product.

4 units, Aut (Flager, F)

CEE 136. Green Architecture

(Same as CEE 236.) Preference to Architectural Design and CEE majors; others by consent of instructor. An architectural design studio exploring the Stanford Green Dorm project. Initial sessions develop a working definition of sustainable design and strategies for

greening the built environment in preparation for design studio work. Enrollment limited to 14. Prerequisites: 31 or 31Q, and 110 and 130. GER:DB-EngrAppSci

4 units, not given this year

CEE 137A. Form and Structure

Preference to Architectural Design and CEE majors; others by consent of instructor. Intermediate architectural studio. The integration of structure, form, site, and program. Emphasis is on developing a schematic design in the context of site topography and structural systems. Limited enrollment. Prerequisites: 31 or 31Q, and 130.

4 units, not given this year

CEE 137B. Intermediate Architecture Studio

Studio design project focus is on a building of intermediate complexity, focusing on how design meets the requirements of economy, ecology and society. Taught by guest architects. May be repeated once for credit. Prerequisites: CEE 31 or 31Q, and CEE 110 and 130.

5 units, Win (Staff)

CEE 138A. Contemporary Architecture: Materials, Structures, and Innovations

Structural and material bases for contemporary architecture; its roots in modern innovations. Recent technological developments; new materials and structural expressions. Sources include specific buildings and construction techniques. How to think critically about design strategies, material properties, and structural techniques.

3 units, Aut (Johnson, M)

CEE 139. Design Portfolio Methods

Students present designs completed in other studio courses to communicate design intentions and other aspects of their work. Instruction in photography; preparation of a design portfolio; and short essays that characterize portfolio contents. Oral presentation workshops offered through the Center for Teaching and Learning. Limited enrollment. Prerequisites: two Art or Architecture studio courses, or consent of instructor.

2 units, Spr (Barton, J)

CEE 140. Field Surveying Laboratory

(Same as CEE 225.) Graduate students register for 225. Friday afternoon laboratory provides practical surveying experience. Additional morning classes to prepare for the afternoon sessions. Hands-on operation of common traditional field survey tools ; introduction to the newest generation of digital measuring, positioning, and mapping tools. Emphasis is on the concept of using the data collected in the field as the basis for subsequent engineering and economic decisions.

3 units, Spr (Redd, T)

CEE 142A. Creating Sustainable Development

(Same as CEE 242A.) How the built environment influences the way people interact with each other in communities. Case studies. How tradeoffs among economic, ecological, and social benefits can be managed. Frameworks for managing stakeholder processes including negotiating multiparty processes. Group project. Enrollment limited to 50.

3 units, Win (Christensen, S)

CEE 143. Integrated Concurrent Engineering

(Same as CEE 243.) Computer-based models in building design and construction. Virtual design and construction (VDC): the use of multidisciplinary performance models of design-construction projects, including the product (facilities), work processes, organization of the design-construction-operation team, and economic impact (model of both cost and value of capital investments) to support business objectives. Opportunity for 4-day mini-internship at an A/E/C company over Spring break. Prerequisite for undergraduates: 100 or consent of instructor. Recommended for graduate students: 241, 242.

3-4 units, not given this year

CEE 147. Cases in Personality, Leadership, and Negotiation

(Same as CEE 247.) Case studies target personality issues, risk willingness, and life skills essential for real world success. Failures, successes, and risk willingness in individual and group tasks based on the professor's experience as small business owner and construction engineer. Required full afternoon field trips to local sites. Application downloaded from coursework must be submitted before first class: mandatory first class attendance. No auditors.

3 units, Spr (Clough, R)

CEE 151. Negotiation

(Same as CEE 251, ME 207, MS&E 285.) Negotiation styles and processes to help students conduct and review negotiations. Workshop format integrating intellectual and experiential learning. Exercises, presentations, live and field examples, and individual and small group reviews. Application required before first day of class; see Coursework.

3 units, Aut (Christensen, S), Spr (Christensen, S)

CEE 154. Cases in Estimating Costs

(Same as CEE 254.) Students participate in bidding contests requiring cost determination in competitive markets. Monetary forces driving the construction industry as general principles applicable to any competitive business. Cases based on field trips and professor's experience as small business owner and construction engineer. Required full afternoon field trips to local sites. Limited enrollment; no auditors. Prerequisites: consent or intructor and application downloaded from CourseWork prior to start of class. GER:DB-EngrAppSci

3 units, Aut (Clough, R)

CEE 156. Building Systems

(Same as CEE 256.) HVAC, lighting, and envelope systems for commercial and institutional buildings, with a focus on energy efficient design. Knowledge and skills required in the development of low-energy buildings that provide high quality environment for occupants. GER:DB-EngrAppSci

4 units, Spr (Kolderup, E)

CEE 159. Career Skills Seminar

(Same as CEE 259. Graduate students register for 259.) Factors required for successful careers. Guest speakers. Case studies. Participation in real world corporate interviews, testing, and reviews conducted by industry trainers. Limited enrollment; no auditors. Prerequisite: application downloaded from CourseWork prior to start of class.

2 units, Aut (Clough, R)

CEE 160. Mechanics of Fluids Laboratory

Lab experiments/demonstrations illustrate conservation principles and flows of real fluids. Corequisite: 101B. (Monismith)

2 units, Spr (Monismith, S)

CEE 161A. Rivers, Streams, and Canals

(Same as CEE 264A.) The movement of water through natural and engineered channels, streams, and rivers. Equations and theory (mass, momentum, and energy equations) for steady and unsteady descriptions of the flow. Design of flood-control and canal systems. Flow controls such as weirs and sluice gates; gradually varied flow; Saint-Venant equations and flood waves; and method of characteristics. Open channel flow laboratory experiments: controls such as weirs and gates, gradually varied flow, and waves. Students taking lab section register for 4 units. Prerequisites: 101B, 160. (Fong) GER:DB-EngrAppSci

3-4 units, Aut (Fong, D)

CEE 164. Introduction to Physical Oceanography

(Same as CEE 262D, EARTHSYS 164.) The dynamic basis of oceanography. Topics: physical environment; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 41 (formerly 53). GER:DB-NatSci

4 units, Win (Fong, D)

CEE 165D. Water and Sanitation in Developing Countries

(Same as CEE 265D.) Economic, social, political, and technical aspects of sustainable water supply and sanitation service provision in developing countries. Case studies from Asia, Africa, and Latin America. Service pricing, alternative institutional structures

including privatization, and the role of consumer demand and community participation in the planning process. Environmental and public health considerations, and strategies for serving low-income households. Limited enrollment. Prerequisite: consent of instructor.

3 units, Spr (Davis, J)

CEE 166A. Watersheds and Wetlands
(Same as CEE 266A.) Introduction to the occurrence and movement of water in the natural environment and its role in creating and maintaining terrestrial, wetland, and aquatic habitat. Hydrologic processes, including precipitation, evaporation, transpiration, snowmelt, infiltration, subsurface flow, runoff, and streamflow. Rivers and lakes, springs and swamps. Emphasis is on observation and measurement, data analysis, modeling, and prediction. Prerequisite: 101B or equivalent. (Freyberg) GER:DB-EngrAppSci

3 units, Aut (Freyberg, D)

CEE 166B. Floods and Droughts, Dams and Aqueducts
(Same as CEE 266B.) Sociotechnical systems associated with human use of water as a resource and the hazards posed by too much or too little water. Potable and non-potable water use and conservation. Irrigation, hydroelectric power generation, rural and urban water supply systems, storm water management, flood damage mitigation, and water law and institutions. Emphasis is on engineering design. Prerequisite: 166A or equivalent. (Freyberg) GER:DB-EngrAppSci

3 units, Win (Freyberg, D)

CEE 166D. Water Resources and Water Hazards Field Trips
(Same as CEE 266D.) Introduction to water use and water hazards via weekly field trips to local and regional water resources facilities (dams, reservoirs, fish ladders and hatcheries, pumping plants, aqueducts, hydropower plants, and irrigation systems) and flood damage mitigation facilities (storm water detention ponds, channel modifications, flood control dams, and reservoirs). Each trip preceded by an orientation lecture.

2 units, Win (Freyberg, D)

CEE 169. Environmental and Water Resources Engineering Design
Application of fluid mechanics, hydrology, water resources, environmental sciences, and engineering economy fundamentals to the design of a system addressing a complex problem of water in the natural and constructed environment. Problem changes each year, generally drawn from a challenge confronting the University or a local community. Student teams prepare proposals, progress reports, oral presentations, and a final design report. Prerequisite: senior in Civil Engineering or Environmental Engineering; 166B.

5 units, alternate years, not given this year

CEE 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 adverse effects in environmental impact assessments; information disclosure requirements; and voluntary compliance of firms with international regulating norms. Prerequisites: MATH 51. Recommended: 70. GER:DB-EngrAppSci

3 units, Win (Ortolano, L)

CEE 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, MATH 51. GER:DB-EngrAppSci

3 units, Win (Hildemann, L), Sum (Kopperud, R)

CEE 172A. Indoor Air Quality
(Same as CEE 278C.) Factors affecting the levels of air pollutants in the built indoor environment. The influence of ventilation, office equipment, floor coverings, furnishings, cleaning practices, and human activities on air quality including carbon dioxide, VOCs, resuspended dust, and airborne molds and fungi. Recommended: 172 or 278A.

2-3 units, alternate years, not given this year

CEE 172M. Quantitative Methods for Forecasting Energy Futures
(Same as CEE 272M.) Quantitative methods for assessing the economics of greenhouse gas emissions reductions. Historical success of previous energy and carbon emissions forecasting efforts, top-down and bottom-up modeling methods, and the implications of market imperfections and regulatory distortions. Analytic techniques to explore the future in the face of rapid technological changes.

3 units, Aut (Koomey, J), given once only

CEE 172P. Distributed Generation and Grid Integration of Renewables
(Same as CEE 272P.) Renewable generation technologies and their use in the electric power system. Conventional electricity generation systems and the historical development of renewables. Development and operation of the electric power system for high penetrations of renewables and demand side participation. Wind energy and wind farms. Design of wind turbines. Photovoltaic systems (grid connected), micro-hydro and marine renewables (wave and tidal stream devices). Analysis of the electric power system and the integration of renewable energy generators.

3-4 units, Win (Staff)

CEE 173A. Energy Resources
(Same as CEE 207A, EARTHSYS 103.) Fossil and renewable energy resources: oil, natural gas, coal, nuclear, hydropower, solar, geothermal, biomass, wind, ocean energy, and energy efficiency. Topics for each resource: resource abundance, location, recovery, conversion, consumption, end-uses, environmental impacts, economics, policy, and technology. Buildings, transportation, the electricity industry, and energy in the developing world. Required field trips to local energy facilities. Optional discussion section for extra unit. GER:DB-EngrAppSci

4-5 units, Aut (Woodward, J)

CEE 175A. Law and Science of California Coastal Policy
(Same as CEE 275A, EARTHSYS 175, EARTHSYS 275.) Interdisciplinary. The legal, science, and policy dimensions of managing California's coastal resources. Coastal land use and marine resource decision making. The physics, chemistry, and biology of the coastal zone, tools for exploring data from the coastal ocean, and the institutional framework that shapes public and private decision making. Field work: how experts from different disciplines work to resolve coastal policy questions.

3-4 units, Win (Boehm, A; Sivas, D; Caldwell, M)

CEE 176A. Energy Efficient Buildings
Analysis and design. Thermal analysis of building envelope, heating and cooling requirements, HVAC, and building integrated PV systems. Emphasis is on residential passive solar design and solar water heating. Lab. GER:DB-EngrAppSci

3-4 units, Win (Masters, G)

CEE 176B. Electric Power: Renewables and Efficiency
Renewable and efficient electric power systems emphasizing analysis and sizing of photovoltaic arrays and wind turbines. Basic electric power generation, transmission and distribution, distributed generation, combined heat and power, fuel cells. End use demand, including lighting and motors. Lab. GER:DB-EngrAppSci

3-4 units, Spr (Masters, G)

CEE 176F. Energy Systems Field Trips
(Same as CEE 276F.) Energy resources and policies in use and under development in China. 12-day field trip to China during Spring Break 2008. One unit for seminar and readings; one unit for field trip. Prerequisite: consent of instructor for field trip.

1-2 units, alternate years, not given this year

CEE 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: CHEM 31. GER:DB-EngrAppSci

4 units, Aut (Criddle, C)

CEE 177P. Sustainability in Theory and Practice

The multidimensional concept of sustainable development. Students evaluate engineered systems using tools such as cost-benefit analysis, trade-off analysis, and lifecycle analysis. How to make judgments about sustainable and unsustainable courses of action. Case studies dealing with contemporary environmental and economic challenges.

3 units, not given this year

CEE 177S. Design for a Sustainable World

(Same as CEE 277S.) Technology-based problems faced by developing communities worldwide. Student groups partner with organizations abroad to work on concept, feasibility, design, implementation, and evaluation phases of various projects. Past projects include a water and health initiative, a green school design, seismic safety, and medical device. Admission based on application and interview. See http://esw.stanford.edu for application.

1-5 units, Aut (Staff), Spr (Staff)

CEE 178. Introduction to Human Exposure Analysis

(Same as CEE 276. 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. Recommended: MATH 51. GER:DB-EngrAppSci

3 units, Spr (Kopperud, R), Sum (Canales, R)

CEE 179A. Water Chemistry Laboratory

(Same as CEE 273A. Graduate students register for 273A.) Laboratory application of techniques for the analysis of natural and contaminated waters, emphasizing instrumental techniques.

3 units, Win (Robertson, A)

CEE 179B. Process Design for Environmental Biotechnology

(Same as CEE 275B.) Alternates with 169. Preference 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, and develop a full-scale design. Limited enrollment. Prerequisites: 177, 179A. GER:DB-EngrAppSci

5 units, Spr (Criddle, C)

CEE 179C. Environmental Engineering Design

Application of engineering fundamentals including environmental engineering, hydrology, and engineering economy to a design problem. 2005-06 project was green water for a green dorm. Enrollment limited; preference to seniors in Civil and Environmental Engineering.

5 units, not given this year

CEE 180. Structural Analysis

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 and ENGR 14. GER:DB-EngrAppSci

4 units, Spr (Kiremidjian, A)

CEE 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. Prerequisite: 180. GER:DB-EngrAppSci

4 units, Aut (Law, K)

CEE 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. Prerequisite: 180. GER:DB-EngrAppSci

4 units, Win (Staff)

CEE 183. Integrated Building Design

Studio format. Design concepts for building systems from schematic design through construction, taking into account sustainable engineering issues. Design exercises culminating in the design of a building project, emphasizing structural systems and materials and integration with architecture, construction, and building mechanical systems. Prerequisites: CEE 180, 181, 182; civil engineering major; architectural design majors require consent of instructor.

4 units, Spr (Miranda, E)

CEE 195A. Fundamentals of Structural Geology

(Same as GES 111A.) Techniques for structural mapping; using differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; measurement and analysis of stress. Sources include field and laboratory data integrated with conceptual and mechanical models. Models of tectonic processes are constructed and solutions visualized using MATLAB. Prerequisites: GES 1, MATH 51, 52. GER:DB-NatSci

3 units, Aut (Pollard, D)

CEE 195B. Fundamentals of Structural Geology

(Same as GES 111B.) Continuation of GES 111A/CEE 195A. Conservation of mass and momentum in a deformable continuum; linear elastic deformation and elastic properties of rock; brittle deformation including fracture and faulting; linear viscous flow including folding and magma dynamics; model development and methodology. Sources include field and laboratory data integrated with conceptual and mechanical models. Models of tectonic processes are constructed and solutions visualized using MATLAB. Prerequisite: GES 111A/CEE 195B.

3 units, Win (Pollard, D)

CEE 196. Engineering Geology Practice

(Same as GES 115.) The application of geologic fundamentals to the planning and design of civil engineering projects. Field exercises and case studies emphasize the impact of site geology on the planning, design, and construction of civil works such as buildings, foundations, transportation facilities, excavations, tunnels and underground storage space, and water supply facilities. Topics: Quaternary history and tectonics, formation and physical properties of surficial deposits, site investigation techniques, geologic hazards, and professional ethics. Prerequisite: GES 1 or consent of instructor. GER:DB-NatSci

3 units, alternate years, not given this year

CEE 198. Directed Reading or Special Studies in Civil Engineering

Written report or oral presentation required. Students must obtain a faculty sponsor.

1-4 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 199. Undergraduate Research in Civil and Environmental Engineering

Written report or oral presentation required. Students must obtain a faculty sponsor.

1-4 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 199A. Special Projects in Architecture

Faculty-directed study or internship. May be repeated for credit. Prerequisite: consent of instructor.

1-4 units, Aut (Staff), Win (Staff), Spr (Staff)

CEE 199B. Directed Studies in Architecture

Projects may include studio-mentoring activities, directed reading and writing on topics in the history and theory of architectural design, or investigations into design methodologies.

1-4 units, Aut (Staff), Win (Staff), Spr (Staff)

CEE 199H. Undergraduate Honors Thesis

For students who have declared the Civil Engineering B.S. honors major and have obtained approval of a topic for research under the guidance of a CEE faculty adviser. Letter grade only. Written thesis or oral presentation required.

2-3 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

GRADUATE COURSES IN CIVIL AND ENVIRONMENTAL ENGINEERING

Primarily for graduate students; undergraduates may enroll with consent of instructor.

CEE 200A. Teaching of Civil and Environmental Engineering
Required of 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. Aut, 200B. Win, 200C. Spr

1 unit, Aut (Chui, T)

CEE 200B. Teaching of Civil and Environmental Engineering
Required of 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. May be repeated for credit. 200A. Aut, 200B. Win, 200C. Spr

1 unit, Win (Chui, T)

CEE 200C. Teaching of Civil and Environmental Engineering
Required of 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. May be repeated for credit. 200A. Aut, 200B. Win, 200C. Spr

1 unit, Spr (Chui, T)

CEE 201D. Computations in Civil and Environmental Engineering
(Same as CEE 101D.) Computational and visualization methods in the design and analysis of civil and environmental engineering systems. Focus is on applications of MATLAB. How to develop a more lucid and better organized programming style.

3 units, Aut (Kitanidis, P; Liu, X)

CEE 202. Construction Claims Analysis and Resolution
Concepts include cost overrun and schedule delay analysis, contracts and other legal topics, and resolution of construction disputes. Introduction to construction law.

3-4 units, Win (Groves, R; Tucker, A; London, M)

CEE 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. Application of common probability models used in civil engineering including Poisson processes and extreme value distributions. Parameter estimation. Linear regression.

3-4 units, Aut (Baker, J)

CEE 204. Structural Reliability
Procedures for evaluating the safety of structural components and systems. First-and second-order estimates of failure probabilities of engineered systems. Sensitivity of failure probabilities to assumed parameter values. Measures of the relative importance of random variables. Reliability of systems with multiple failure modes. Reliability updating. Simulation methods and variance reduction techniques. Prerequisite: 203 or equivalent.

3-4 units, alternate years, not given this year

CEE 206. Decision and Stochastic Processes Models in Civil Engineering
Current challenges in selecting an appropriate site, alternate design, or retrofit strategy based on environmental, economic, and social factors through applications of decision science. Basics of decision theory with examples from civil engineering problems. Theory and methods for modeling of loads, structural parameters, environmental effects, rainfall, and other processes in civil engineering. Stochastic models include Poisson, compound Poisson, filtered Poisson, non-homogenous Poisson, and Markov processes. Prerequisite: CEE 203 or equivalent.

3-4 units, Aut (Kiremidjian, A)

CEE 206A. Decision Models in Civil Engineering
For advanced graduate students in CEE. Applications of decision science to address current challenges in selecting an appropriate site and appropriate design or retrofit strategy based on environmental, economic, and social factors. Examples from everyday civil and environmental engineering problems. Prerequisite: CEE 203 or equivalent.

2 units, Aut (Kiremidjian, A)

CEE 207A. Energy Resources
(Same as CEE 173A, EARTHSYS 103.) Fossil and renewable energy resources: oil, natural gas, coal, nuclear, hydropower, solar, geothermal, biomass, wind, ocean energy, and energy efficiency. Topics for each resource: resource abundance, location, recovery, conversion, consumption, end-uses, environmental impacts, economics, policy, and technology. Buildings, transportation, the electricity industry, and energy in the developing world. Required field trips to local energy facilities. Optional discussion section for extra unit.

4-5 units, Aut (Woodward, J)

CEE 210. Building Information Modeling
(Same as CEE 110. Graduate students register for 210.) Creation, management, and application of building information models. Process and tools available for creating 2D and 3D computer representations of building components and geometries. Organizing and operating on models to produce architectural views and construction documents, renderings and animations, and interface with analysis tools. Lab exercises, class projects. Limited enrollment.

4 units, Aut (Katz, G)

CEE 211. Multidisciplinary Modeling and Analysis
(Same as CEE 111. Graduate students register for 211.) Computer modeling, visualization, analysis, and graphical communication of building projects. Use of 3D models in laser scanning, rendering, animation, daylight, energy, cost, structural, lighting analysis, and computer controlled fabrication. Underlying 3D computer representations, and analysis tools and their applications. Guest lectures, lab exercises, class project. Prerequisite: 110 or CAD experience.

4 units, Win (Kunz, J)

CEE 215. Goals and Methods of Sustainable Building Projects
(Same as CEE 115. Graduate students register for 215.) Goals related to sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and economic and social sustainability. Methods to integrate these goals and enhance the economic, ecological, and equitable value of building projects. Industry and academic rating systems, project case studies, guest lecturers, and group project.

3 units, Aut (Haymaker, J)

CEE 222A. Computer Integrated Architecture/Engineering/Construction (AEC) Global Teamwork
Crossdisciplinary, collaborative, geographically distributed, and multicultural project-based teamwork. AEC teams exercise their domain knowledge and information technologies in a multidisciplinary context focusing on the design and construction concept development phase of a comprehensive building project. Prerequisite: interview with instructor in Autumn Quarter.

3 units, Win (Fruchter, R)

CEE 222B. Computer Integrated Architecture/Engineering/Construction (AEC) Global Teamwork
Global AEC student teams continue their project activity focusing on the most challenging concept developed in 222A and chosen jointly

with their client. Comprehensive team project focusing on design and construction, including: project development and documentation; detailing, 3D and 4D modeling, simulation, sustainable concepts, cost benefit analysis, and life-cycle cost analysis; and final project presentation of product and process. Prerequisite: CEE 222A.

2 units, Spr (Fruchter, R)

CEE 223A. Design and Construction of Steel Structures
Using a 15-story steel building project, students analyze the implications of design decisions on the fabrication and erection of steel structures. Emphasis is on integration of design and construction of different types of steel structures. The implications on structural performance, cost and construction schedule, and evaluation of design alternatives. Economic considerations. Other topics include planning for lead times, floor systems and lateral load resisting systems, composite floor systems, innovative lateral load resisting systems, economics of steel structures, design and construction of steel connections, implication of design decisions related to welding and bolting. Prerequisite: 181 or equivalent.

3-4 units, Aut (Miranda, E)

CEE 223B. Design and Construction of Concrete Structures
Implications of design decisions in the structural performance, cost, and construction schedule of concrete structures. Emphasis is on integration of design and construction of concrete structures and on economic considerations. Reinforced concrete and pre-stressed concrete structures. Evaluation of design alternatives. Economic considerations in the selection of floor systems and lateral resisting systems for buildings. Design and construction of beams, one way slabs, post-tensioned slabs, beam-column joints and structural walls. Design and construction of precast and post-tensioned elements, and of connections in precast elements. Prerequisite: 182 or equivalent.

3-4 units, not given this year

CEE 224A. Sustainable Development Studio
(Undergraduates, see 124.) Project-based. Sustainable design, development, use and evolution of buildings; connections of building systems to broader resource systems. Areas include architecture, structure, materials, energy, water, air, landscape, and food. Projects use a cradle-to-cradle approach focusing on technical and biological nutrient cycles and information and knowledge generation and organization. May be repeated for credit.

1-5 units, Aut (Lin, M), Win (Staff), Spr (Staff)

CEE 225. Field Surveying Laboratory
(Same as CEE 140.) Graduate students register for 225. Friday afternoon laboratory provides practical surveying experience. Additional morning classes to prepare for the afternoon sessions. Hands-on operation of common traditional field survey tools ; introduction to the newest generation of digital measuring, positioning, and mapping tools. Emphasis is on the concept of using the data collected in the field as the basis for subsequent engineering and economic decisions.

3 units, Spr (Redd, T)

CEE 226. Life Cycle Assessment for Complex Systems
Life cycle modeling of products, industrial processes, and infrastructure/building systems; material and energy balances for large interdependent systems; environmental accounting; and life cycle costing. These methods, based on ISO 14000 standards, are used to examine emerging technologies, such as biobased products, building materials, building integrated photovoltaics, and alternative design strategies, such as remanufacturing, dematerialization, LEED, and Design for Environment: DfE. Student teams complete a life cycle assessment of a product or system chosen from industry.

3-4 units, Aut (Staff)

CEE 226E. Advanced Topics in Integrated, Energy-Efficient Building Design
Innovative methods and systems for the integrated design and evaluation of energy efficient buildings. Guest practitioners and researchers in energy efficient buildings. Student initiated final project.

2 units, Spr (Staff)

CEE 227. Global Project Finance
(Same as GSBGEN 394.) Public and private sources of finance for large, complex, capital-intensive projects in developed and developing countries. Benefits and disadvantages, major participants, risk sharing, and challenges of project finance in emerging markets. Financial, economic, political, cultural, and technological elements that affect project structures, processes, and outcomes. Case studies.

3-5 units, Win (Orr, R)

CEE 228. Innovative Global Construction Technology
(Formerly 245T.) Five-week class. How innovative companies invent new construction processes based on relative local labor, and materials and equipment cost, availability, and capabilities, and developed from experience and knowledge of construction technology in bridge, tunnel, and high-rise building. The process of generating new ideas. Industry guest speakers address the link between product/process innovation and construction technology.

2 units, Win (Brockmann, C)

CEE 232. Interplay of Architecture and Engineering
(Same as CEE 132.) The range of requirements that drive a building's design including architecture, engineering, constructability, building codes, and budget. Case studies illustrate how structural and mechanical systems are integrated into building types including residential, office, commercial, and retail. Studio work.

4 units, not given this year

CEE 235A. Parametrics: Applications in Architecture and Product Design
(Same as CEE 135A.) Precedents in architecture and product design; methods for modeling, prototyping, and fabrication. How to combine design intentions and digital logics with physical and material constraints. Students develop a case study and small design projects using a parametric approach at the scales of architecture and product.

4 units, Aut (Flager, F)

CEE 236. Green Architecture
(Same as CEE 136.) Preference to Architectural Design and CEE majors; others by consent of instructor. An architectural design studio exploring the Stanford Green Dorm project. Initial sessions develop a working definition of sustainable design and strategies for greening the built environment in preparation for design studio work. Enrollment limited to 14. Prerequisites: 31 or 31Q, and 110 and 130.

4 units, not given this year

CEE 240. Design and Management of Construction Operations
Designing on-site construction processes including: goals, roles, responsibilities, performance metrics; inputs/outputs; labor and capital intensive construction methods, task assignments and crew instructions, safety management and site supervision, and productivity measurement; value stream modeling, materials management, daily and weekly progress, and financial reports; site operations and management; observation methods for field operations; construction process modeling and simulation methods; and digital models for planning and executing site operations. Field and computer lab work. Prerequisite: 100 or equivalent or consent of instructor. Recommended corequisite: 241.

3 units, Win (Fischer, M)

CEE 241. Managing Fabrication and Construction
Methods to manage the physical production of construction projects; design, analysis, and optimization of the fabricate-assemble process including performance metrics. Project management techniques and production system design including: push versus pull methods;

master scheduling and look-ahead scheduling; scope, cost, and schedule control; earned value analysis; critical path method; location-based scheduling; 4D modeling; workflow; trade coordination; methods to understand uncertainty and reduce process variability; and supply chain systems including made-to-stock, engineered-to-order, and made-to-order. Prerequisite: 100 or consent of instructor. Recommended corequisite: 240.

3 units, Aut (Fischer, M)

CEE 242. Organization Design for Projects and Companies
Introduction to organizational behavior. Information-processing theory and computer analysis tools to design organizations for projects and companies; practice facilitating 12-person case study discussion groups. Cases focus primarily on engineering and construction organizations, but applicable to project-based organizations in all industries.

3-4 units, Aut (Levitt, R)

CEE 242A. Creating Sustainable Development
(Same as CEE 142A.) How the built environment influences the way people interact with each other in communities. Case studies. How tradeoffs among economic, ecological, and social benefits can be managed. Frameworks for managing stakeholder processes including negotiating multiparty processes. Group project. Enrollment limited to 50.

3 units, Win (Christensen, S)

CEE 243. Integrated Concurrent Engineering
(Same as CEE 143.) Computer-based models in building design and construction. Virtual design and construction (VDC): the use of multidisciplinary performance models of design-construction projects, including the product (facilities), work processes, organization of the design-construction-operation team, and economic impact (model of both cost and value of capital investments) to support business objectives. Opportunity for 4-day mini-internship at an A/E/C company over Spring break. Prerequisite for undergraduates: 100 or consent of instructor. Recommended for graduate students: 241, 242.

3-4 units, not given this year

CEE 244. Fundamentals of Construction Accounting and Finance
Concepts of financial accounting and economics emphasizing the construction industry. Financial statements, 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, A; Meyer, P)

CEE 245A. Global Project Seminar
Issues related to large, complex, global development projects including infrastructure development, urban and rural development, and the development of new cities. Guest presentations by industry practitioners and academics, including: Sabeer Bhatia, founder of Hotmail and architect of NanoCity; Ian Bremmer, CEO of the Eurasia Group, and Greg Huger, managing director of AirliePartners. May be repeated for credit.

3 units, not given this year

CEE 246. Managing Engineering and Construction Companies
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 business strategies and organizations to cope with cyclical demand, alternative contracting approaches, managing receivables and cash flow, administration of human resources, safety, quality, insurance, and bonding. Students play different management roles in a computer simulation of a construction company. Prerequisites: introductory accounting course such as ENGR 60, CEE 244A, or MS&E 140.

4 units, Spr (Levitt, R)

CEE 246A. Engineering Economy Primer
Satisfies the engineering economy prerequisite for 246 or 253. Application of engineering economy concepts and principles to the construction industry. Equivalence concept; interest formulas; value of money across time; present value, annual cash flow, internal rate of return and benefit-cost methods; retirement and replacement; depreciation; capital budgeting; and sensitivity and risk analysis. Construction finance concepts, loans, mortgages, and construction pro formas.

2 units, Aut (Koen Cohen, N)

CEE 247. Cases in Personality, Leadership, and Negotiation
(Same as CEE 147.) Case studies target personality issues, risk willingness, and life skills essential for real world success. Failures, successes, and risk willingness in individual and group tasks based on the professor's experience as small business owner and construction engineer. Required full afternoon field trips to local sites. Application downloaded from coursework must be submitted before first class; mandatory first class attendance. No auditors.

3 units, Spr (Clough, R)

CEE 248. Real Estate Development
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 projects focus on actual developments now in the planning stage. Enrollment limited to 24; priority to graduate majors in the department's CEM and GSB programs. Prerequisites: 241, 244A or equivalent, ENGR 60.

3 units, Spr (Kroll, M)

CEE 249. Labor and Industrial Relations: Negotiations, Strikes, and Dispute Resolution
Labor/management negotiations, content of a labor agreement, strikes, dispute resolution, contemporary issues affecting labor and management, and union versus open shop competitiveness in the marketplace. Case studies; presentations by union leaders, legal experts, and contractor principals. Simulated negotiation session with union officials and role play in an arbitration hearing.

2 units, Win (Walton, M)

CEE 251. Negotiation
(Same as CEE 151, ME 207, MS&E 285.) Negotiation styles and processes to help students conduct and review negotiations. Workshop format integrating intellectual and experiential learning. Exercises, presentations, live and field examples, and individual and small group reviews. Application required before first day of class; see Coursework.

3 units, Aut (Christensen, S), Spr (Christensen, S)

CEE 252. Technical Fundamentals of Sustainable Construction
Balancing sustainability and traditional project objectives in providing technical support for concrete and steel construction operations. Concrete materials, properties of fresh concrete. Resources and methods for batching, transporting, placing, finishing, and curing concrete. Design, fabrication, and use of formwork. Detailing, fabricating, erecting, and connecting structural steel. Lifting equipment and lift planning. Welding processes, operations, and quality control. Group field trip reports, course projects. Corequisite: 258.

3 units, Win (Tatum, C)

CEE 253A. Sustainable Earthwork Construction
Balancing sustainability and traditional project objectives in planning and providing technical support for earthwork construction operations. Construction properties of soil. Technical fundamentals and description of earthwork equipment and operations. Planning, selecting equipment, estimating production rates.

1 unit, Spr (Tatum, C)

CEE 254. Cases in Estimating Costs
(Same as CEE 154.) Students participate in bidding contests requiring cost determination in competitive markets. Monetary forces driving the construction industry as general principles applicable to any competitive business. Cases based on field trips

and professor's experience as small business owner and construction engineer. Required full afternoon field trips to local sites. Limited enrollment; no auditors. Prerequisites: consent or intructor and application downloaded from CourseWork prior to start of class.

3 units, Aut (Clough, R)

CEE 256. Building Systems

(Same as CEE 156.) HVAC, lighting, and envelope systems for commercial and institutional buildings, with a focus on energy efficient design. Knowledge and skills required in the development of low-energy buildings that provide high quality environment for occupants.

4 units, Spr (Kolderup, E)

CEE 257. Building Systems Practice

Technical fundamentals, major components, connecting elements, field operations for active building systems: HVAC, electric power, water and waste, fire protection, control and instrumentation and vertical transportation. Sustainability, integration and coordination, commissioning.

1 unit, Spr (Tatum, C)

CEE 258. Donald R. Watson Seminar in Construction Engineering and Management

Seminar; field trips. Focus is on technical aspects of concrete construction, steel construction, and earthwork. May be repeated for credit.

1 unit, Win (Tatum, C)

CEE 259. Career Skills Seminar

(Same as CEE 159. Graduate students register for 259.) Factors required for successful careers. Guest speakers. Case studies. Participation in real world corporate interviews, testing, and reviews conducted by industry trainers. Limited enrollment; no auditors. Prerequisite: application downloaded from CourseWork prior to start of class.

2 units, Aut (Clough, R)

CEE 259A. Construction Problems

Group-selected problems in construction techniques, equipment, or management; preparation of oral and written reports. Guest specialists from the construction industry. See 299 for individual studies. Prerequisites: graduate standing in CEM program and consent of instructor.

1-3 units, Aut (Staff)

CEE 259B. Construction Problems

Group-selected problems in construction techniques, equipment, or management; preparation of oral and written reports. Guest specialists from the construction industry. See 299 for individual studies. Prerequisites: graduate standing in CEM program and consent of instructor.

1-3 units, Win (Staff)

CEE 259C. Construction Problems

Group-selected problems in construction techniques, equipment, or management; preparation of oral and written reports. Guest specialists from the construction industry. See 299 for individual studies. Prerequisites: graduate standing in CEM program and consent of instructor.

1-3 units, Spr (Staff)

CEE 260A. Physical Hydrogeology

(Same as EESS 220. Formerly GES 230.) Theory of underground water occurrence and flow, analysis of field data and aquifer tests, geologic groundwater environments, solution of field problems, and groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.

4 units, Aut (Gorelick, S; Walker, K)

CEE 260B. Surface and Near-Surface Hydrologic Response

(Same as GES 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, and physically-based simulation of coupled surface and near-surface hydrologic response. Links hydrogeology, soil physics, and surface water hydrology.

3 units, alternate years, not given this year

CEE 260C. Contaminant Hydrogeology

(Same as EESS 221. Formerly GES 231.) For earth scientists and engineers. 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 treatment 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. Prerequisite: GES 230 or CEE 260A or equivalent.

4 units, Spr (Gorelick, S)

CEE 262A. Hydrodynamics

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 and differential equations.

3-4 units, Aut (Monismith, S)

CEE 262B. Transport and Mixing in Surface Water Flows

Application of fluid mechanics to problems of pollutant transport and mixing in the water environment. Mathematical 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 CME 102 (formerly ENGR 155A), or equivalents.

3-4 units, Win (Monismith, S)

CEE 262C. Modeling and Simulation for Civil and Environmental Engineers

Mathematical and computational methods for modeling and simulation. The use of Matlab for topics including predator-prey problems, buckling, transport and mixing, wave modeling, flow reactors, and traffic flow. Prerequisites: CME 102 and 104, or equivalents.

3 units, Spr (Fringer, O), Sum (Staff)

CEE 262D. Introduction to Physical Oceanography

(Same as CEE 164, EARTHSYS 164.) The dynamic basis of oceanography. Topics: physical environment; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 41 (formerly 53).

4 units, Win (Fong, D)

CEE 262E. Lakes and Reservoirs

Physics and water quality dynamics in lakes and reservoirs. Implementation of physical and biogeochemical processes in 1-D models. Recommended: 262B.

2-3 units, Spr (Fong, D)

CEE 262F. Ocean Waves

The fluid mechanics of surface gravity waves in the ocean of relevance to engineers and oceanographers. Topics include irrotational waves, wave dispersion, wave spectra, effects of bathymetry (shoaling), mass transport, effects of viscosity, and mean currents driven by radiation stresses. Prerequisite: CEE 262A or a graduate class in fluid mechanics.

3 units, Win (Monismith, S)

CEE 263A. Air Pollution Modeling

The numerical modeling of urban, regional, and global air pollution focusing 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 developing a basic chemical ordinary differential equation solver. Prerequisite: CS 106A or equivalent.

3-4 units, alternate years, not given this year

CEE 263B. Numerical Weather Prediction
Numerical weather prediction. Continuity equations for air and water vapor, the thermodynamic energy equation, and momentum equations 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 weather prediction model. Prerequisite: CS 106A or equivalent.

3-4 units, Spr (Jacobson, M), alternate years, not given next year

CEE 263C. Weather and Storms
(Same as CEE 63.) Daily and severe weather and global climate. Topics: structure and composition of the atmosphere, fog and cloud formation, rainfall, local winds, wind energy, global circulation, jet streams, high and low pressure systems, inversions, el Niño, la Niña, atmosphere/ocean interactions, fronts, cyclones, thunderstorms, lightning, tornadoes, hurricanes, pollutant transport, global climate and atmospheric optics.

3 units, Aut (Jacobson, M)

CEE 263D. Air Pollution: From Urban Smog to Global Change
(Same as CEE 64.) Survey of urban- through global-scale air pollution. Topics: the evolution of the Earth's atmosphere, indoor air pollution, urban smog formation, history of discovery of atmosphere chemicals, visibility, acid rain, the greenhouse effect, historical climate, global warming, stratospheric ozone reduction, Antarctic ozone destruction, air pollution transport across political boundaries, the effects of air pollution on ultraviolet radiation, and impacts of energy systems on the atmosphere.

3 units, Win (Jacobson, M)

CEE 264A. Rivers, Streams, and Canals
(Same as CEE 161A.) The movement of water through natural and engineered channels, streams, and rivers. Equations and theory (mass, momentum, and energy equations) for steady and unsteady descriptions of the flow. Design of flood-control and canal systems. Flow controls such as weirs and sluice gates; gradually varied flow; Saint-Venant equations and flood waves; and method of characteristics. Open channel flow laboratory experiments: controls such as weirs and gates, gradually varied flow, and waves. Students taking lab section register for 4 units. Prerequisites: 101B, 160. (Fong)

3-4 units, Aut (Fong, D)

CEE 265A. 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. Influence of international aid agencies and NGOs on water projects. 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, Spr (Ortolano, L)

CEE 265C. Water Resources Management
Principles of surface and ground water resources management in the context of water scarcity and hydrologic uncertainty. Topics include reservoir, river basin, and aquifer management, conjunctive use of surface and ground water, wastewater reuse, and demand management. Technical, economic, social, and political elements of water management.

3 units, Spr (Findikakis, A)

CEE 265D. Water and Sanitation in Developing Countries
(Same as CEE 165D.) Economic, social, political, and technical aspects of sustainable water supply and sanitation service provision in developing countries. Case studies from Asia, Africa, and Latin America. Service pricing, alternative institutional structures including privatization, and the role of consumer demand and community participation in the planning process. Environmental and public health considerations, and strategies for serving low-income households. Limited enrollment. Prerequisite: consent of instructor.

3 units, Spr (Davis, J)

CEE 266A. Watersheds and Wetlands
(Same as CEE 166A.) Introduction to the occurrence and movement of water in the natural environment and its role in creating and maintaining terrestrial, wetland, and aquatic habitat. Hydrologic processes, including precipitation, evaporation, transpiration, snowmelt, infiltration, subsurface flow, runoff, and streamflow. Rivers and lakes, springs and swamps. Emphasis is on observation and measurement, data analysis, modeling, and prediction. Prerequisite: 101B or equivalent. (Freyberg)

3 units, Aut (Freyberg, D)

CEE 266B. Floods and Droughts, Dams and Aqueducts
(Same as CEE 166B.) Sociotechnical systems associated with human use of water as a resource and the hazards posed by too much or too little water. Potable and non-potable water use and conservation. Irrigation, hydroelectric power generation, rural and urban water supply systems, storm water management, flood damage mitigation, and water law and institutions. Emphasis is on engineering design. Prerequisite: 166A or equivalent. (Freyberg)

3 units, Win (Freyberg, D)

CEE 266C. Advanced Topics in Hydrology and Water Resources
Graduate seminar. Focus is on one or more hydrologic processes or water resources systems. Topics vary based on student and instructor interest. Examples include freshwater wetland hydrology, watershed-scale hydrologic modeling, renaturalization of stream channels, reservoir sediment management, and dam removal. Enrollment limited. Prerequisites: 266A,B, or equivalents. Recommended: 260A or equivalent.

3 units, Spr (Freyberg, D), alternate years, not given next year

CEE 266D. Water Resources and Water Hazards Field Trips
(Same as CEE 166D.) Introduction to water use and water hazards via weekly field trips to local and regional water resources facilities (dams, reservoirs, fish ladders and hatcheries, pumping plants, aqueducts, hydropower plants, and irrigation systems) and flood damage mitigation facilities (storm water detention ponds, channel modifications, flood control dams, and reservoirs). Each trip preceded by an orientation lecture.

2 units, Win (Freyberg, D)

CEE 268. Groundwater Flow
Flow and mass transport in porous media. Applications of potential flow theory and numerical modeling methods 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 and introductory fluid mechanics.

3-4 units, Win (Kitanidis, P)

CEE 269. Environmental Fluid Mechanics and Hydrology Seminar
Problems in all branches of water resources. Talks by visitors, faculty, and students. May be repeated for credit.

1 unit, Spr (Monismith, S)

CEE 270. Movement and Fate of Organic Contaminants in Waters
Transport of chemical constituents in surface and groundwater including advection, dispersion, sorption, interphase mass transfer, and transformation; impacts on water quality. Emphasis is on

physicochemical processes and the behavior of hazardous waste contaminants. Prerequisites: undergraduate chemistry and calculus. Recommended: 101B.

3 units, Aut (Luthy, R), Sum (Robertson, A)

CEE 271A. Physical and Chemical Treatment 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, R)

CEE 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 waste waters, detoxification of hazardous chemicals, and groundwater remediation. Prerequisites: 270; 177 or 274A or equivalents.

4 units, Win (Criddle, C)

CEE 271Y. Environmental Policy Design and Implementation in the U.S and Asia
In Singapore, September 11 to 16, 2008. Preference to M.S. students in Environmental and Water Studies. How the design and implementation of policy instruments to control air and water pollution are influenced by administrative and legal structures and by interplay among participants such as regulators, polluters, and nongovernmental organizations. Prerequisite: consent of instructor.

2 units, Aut (Ortolano, L), given once only

CEE 272. Coastal Contaminants
Coastal pollution and its effects on ecosystems and human health. The sources, fate, and transport of human pathogens and nutrients. Background on coastal ecosystems and coastal transport phenomena including tides, waves, and cross shelf transport. Introduction to time series analysis with MATLAB. Undergraduates require consent of instructor.

3-4 units, Aut (Boehm, A)

CEE 272M. Quantitative Methods for Forecasting Energy Futures
(Same as CEE 172M.) Quantitative methods for assessing the economics of greenhouse gas emissions reductions. Historical success of previous energy and carbon emissions forecasting efforts, top-down and bottom-up modeling methods, and the implications of market imperfections and regulatory distortions. Analytic techniques to explore the future in the face of rapid technological changes.

3 units, Aut (Koomey, J), given once only

CEE 272P. Distributed Generation and Grid Integration of Renewables
(Same as CEE 172P.) Renewable generation technologies and their use in the electric power system. Conventional electricity generation systems and the historical development of renewables. Development and operation of the electric power system for high penetrations of renewables and demand side participation. Wind energy and wind farms. Design of wind turbines. Photovoltaic systems (grid connected), micro-hydro and marine renewables (wave and tidal stream devices). Analysis of the electric power system and the integration of renewable energy generators.

3-4 units, Win (Staff)

CEE 273. Aquatic Chemistry
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 natural water systems and the solution of specific chemical problems in water purification technology and water pollution control. Prerequisites: CHEM 31 and 33, or equivalents.

3 units, Aut (Leckie, J)

CEE 273A. Water Chemistry Laboratory
(Same as CEE 179A. Graduate students register for 273A.) Laboratory application of techniques for the analysis of natural and contaminated waters, emphasizing instrumental techniques.

3 units, Win (Robertson, A)

CEE 273C. Introduction to Membrane Technology for Water/Wastewater Treatment
Membrane separation processes focusing on their use for water and wastewater purification. Topics will include membrane types and materials; transport across and rejection by membranes; membrane fouling, cleaning and degradation; and design and operation of membrane systems.

1 unit, Spr (Leckie, J)

CEE 274A. Environmental Microbiology I
(Same as CHEMENG 174, CHEMENG 274.) Basics of microbiology and biochemistry. The biochemical and biophysical principles of biochemical reactions, energetics, and mechanisms of energy conservation. Diversity of microbial catabolism, flow of organic matter in nature: the carbon cycle, and biogeochemical cycles. 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: CHEM 33, 35, and BIO 41, CHEMENG 181 (formerly 188), or equivalents.

3 units, Aut (Krieger, C), Sum (Staff)

CEE 274B. Metabolic Biochemistry of Microorganisms
(Same as CHEMENG 456.) Microbial metabolism, biochemical and metabolic principles, unity and diversity of metabolic pathways, evolution of enzymes and metabolic pathways, microbial degradation of natural and anthropogenic organic compounds, predicting biodegradation, and metabolic origin of life.

3 units, Win (Spormann, A), alternate years, not given next year

CEE 274C. Microbial Ecology and Evolution
(Same as CHEMENG 457.) Structure/function relationship of microbial communities; metabolic and ecological basis of interactions in microbial communities; microbial ecology and population biology in natural and human host systems; and evolution of microbial life. Prerequisite: CEE 274A, CHEMENG 281 (formerly 288), or equivalent.

3 units, not given this year

CEE 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, Spr (Criddle, C), alternate years, not given next year

CEE 274E. Pathogens in the Environment
Sources, fates, movement, and ecology of waterborne pathogens in the natural environment and disinfection systems; epidemiology and microbial risk assessment. No microbiology background required; undergraduates may enroll with consent of instructor.

3 units, not given this year

CEE 274P. Environmental Health Microbiology Lab
Microbiology skills including culture-, microscope-, and molecular-based detection techniques. Focus is on standard and EPA-approved methods to enumerate and isolate organisms used to assess risk of enteric illnesses, such as coliforms, enterococci, and coliphage, in drinking and recreational waters including lakes, streams, and coastal waters. Student project to assess the microbial water quality of a natural water. Limited enrollment; priority to CEE graduate students.

3-4 units, Spr (Boehm, A)

CEE 274S. Hopkins Microbiology Course
(Same as BIO 274S, BIOHOPK 274, EESS 253S. Formerly GES 274S.) Four-week, intensive. The interplay between molecular, physiological, ecological, evolutionary, and geochemical processes that constitute, cause, and maintain microbial diversity. How to

isolate key microorganisms driving marine biological and geochemical diversity, interpret culture-independent molecular characterization of microbial species, and predict causes and consequences. Laboratory component: what constitutes physiological and metabolic microbial diversity; how evolutionary and ecological processes diversify individual cells into physiologically heterogeneous populations; and the principles of interactions between individuals, their population, and other biological entities in a dynamically changing microbial ecosystem. Prerequisites: CEE 274A,B, or equivalents.

9-12 units, Sum (Spormann, A; Francis, C)

CEE 275A. Law and Science of California Coastal Policy
(Same as CEE 175A, EARTHSYS 175, EARTHSYS 275.) Interdisciplinary. The legal, science, and policy dimensions of managing California's coastal resources. Coastal land use and marine resource decision making. The physics, chemistry, and biology of the coastal zone, tools for exploring data from the coastal ocean, and the institutional framework that shapes public and private decision making. Field work: how experts from different disciplines work to resolve coastal policy questions.

3-4 units, Win (Boehm, A; Sivas, D; Caldwell, M)

CEE 275B. Process Design for Environmental Biotechnology
(Same as CEE 179B.) Alternates with 169. Preference 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, and develop a full-scale design. Limited enrollment. Prerequisites: 177, 179A.

5 units, Spr (Criddle, C)

CEE 276. Introduction to Human Exposure Analysis
(Same as CEE 178. 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. Recommended: MATH 51.

3 units, Spr (Kopperud, R), Sum (Canales, R)

CEE 276E. Environmental Toxicants
Chemicals in the environment that pose toxicity risk. Introduction to environmental toxicology principles for identifying and characterizing toxicants based on sources, properties, pathways, and toxic action. Past and present environmental toxicant issues.

2 units, Spr (Ong, C)

CEE 276F. Energy Systems Field Trips
(Same as CEE 176F.) Energy resources and policies in use and under development in China. 12-day field trip to China during Spring Break 2008. One unit for seminar and readings; one unit for field trip. Prerequisite: consent of instructor for field trip.

1-2 units, alternate years, not given this year

CEE 277A. Teaching Science Literacy for a Sustainable Society
Teaching science to nontechnical audiences emphasizing technologies and science for the sustainable use of water. Guest lecturers. Learning styles, and the role of engineers and scientists in K-12 and media communication. Students develop teaching modules to be used in educational settings involving nontechnical audiences.

2-4 units, Win (Staff)

CEE 277B. Knowledge Systems in Engineering and Management for Sustainable Development
Knowledge frameworks and systems dealing with large amounts of complex information from crossdisciplinary collaborative activities in sustainable development. Topics include: domain information and knowledge representation and processing; knowledge management and integration in engineering and management domains; access to information for problem solving, planning, and decision making; knowledge management for environmentally friendly manufacturing and business activities; systematic assessment in management and engineering; and the use of IT and the Internet for collaboration and learning.

3 units, Spr (Staff), Sum (Staff)

CEE 277S. Design for a Sustainable World
(Same as CEE 177S.) Technology-based problems faced by developing communities worldwide. Student groups partner with organizations abroad to work on concept, feasibility, design, implementation, and evaluation phases of various projects. Past projects include a water and health initiative, a green school design, seismic safety, and medical device. Admission based on written application and interview. See http://esw.stanford.edu for application.

1-5 units, Aut (Staff), Spr (Staff)

CEE 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: MATH 51, CHEM 31, or equivalents. Recommended: 101B, 273 or CHEM 135, or equivalents.

3 units, Aut (Hildemann, L)

CEE 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: MATH 51, or equivalent. Recommended: 101B or equivalent.

3 units, Spr (Hildemann, L)

CEE 278C. Indoor Air Quality
(Same as CEE 172A.) Factors affecting the levels of air pollutants in the built indoor environment. The influence of ventilation, office equipment, floor coverings, furnishings, cleaning practices, and human activities on air quality including carbon dioxide, VOCs, resuspended dust, and airborne molds and fungi. Recommended: 172 or 278A.

2-3 units, alternate years, not given this year

CEE 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.

1 unit, Spr (Hildemann, L)

CEE 280. Advanced Structural Analysis
Theoretical development and computer implementation of direct stiffness method of structural analysis; 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, G)

CEE 281. Finite Element Methods in Structural Engineering
Finite element formulation and implementation of frame, solid, plate, and shell elements for numerical methods. Modeling of structural systems, statics and dynamics, structural analysis. Prerequisites: 280, 283.

4 units, Spr (Law, K)

CEE 282. Nonlinear Structural Analysis
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, Win (Deierlein, G)

CEE 283. Structural Dynamics
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, K)

CEE 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. (Law)
3 units, not given this year

CEE 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 conceptual design, performance assessment, behavior of structural elements. Prerequisites: basic courses in design of steel and reinforced concrete structures.
3-4 units, Win (Krawinkler, H)

CEE 287. Earthquake Resistant Design and Construction
Evaluation, design, and construction of structures in seismic regions. Factors influencing earthquake ground motions, design spectra, design of linear and nonlinear single- and multiple-degree-of-freedom-system structures, design of structures to minimize damage, force-based and displacement-based design methods, capacity design, detailing and construction of steel and reinforced concrete structures, performance-based design, seismic isolation, and energy dissipation. Prerequisites: 283, 285. Recommended: 282, 288.
3-4 units, Win (Miranda, E)

CEE 288. Earthquake Hazard and Risk Analysis
Earthquake phenomena, faulting, ground motion, earthquake hazard formulation, effects of earthquakes on manmade structures, response spectra, Fourier spectra, soil effects on ground motion and structural damage, methods for structural damage evaluation, and formulation of the performance-based earthquake engineering problems. Prerequisites: 203, 283.
3-4 units, Win (Kiremidjian, A)

CEE 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 (Baker, J)

CEE 290. Structural Performance and Failures
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, P)

CEE 293. Foundation Engineering
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, R)

CEE 294. Computational Poromechanics
Continuum and finite element formulations of steady-state and transient fluid conduction problems on 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. Prerequisite: ME 335A or equivalent.
3 units, not given this year

CEE 296. Special Topics in Fluid-Solid Interactions
Civil, mechanical, and biomedical engineering. Topics include surge and wave impact on structures, tsunami induced sediment transport and scour, wave-soil interactions, dam-reservoir-foundation interactions, shock and blast loads on composite structures, hydroelastic tailoring of composite structures, and blood-vessel interactions. Term project.
2 units, not given this year

CEE 297. Issues in Geotechnical and Environmental Failures
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 histories including earthquake, flood, and hazardous waste facilities. Student observation, participation in active lawsuits where possible.
3 units, Spr (Meehan, R)

CEE 297G. Structural Geology and Rock Mechanics
(Same as GES 215A.) Quantitative field and laboratory data integrated with solutions to initial and boundary-value problems of continuum mechanics introduce tectonic processes in Earth's crust that lead to the development of geological structures including folds, faults, fractures and fabrics. Topics include: techniques and tools for structural mapping; using differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; traction and stress analysis. Data sets analyzed using MATLAB. Prerequisites: GES 1, MATH 53, MATLAB or equivalent.
3-5 units, Aut (Pollard, D)

CEE 297H. Structural Geology and Rock Mechanics
(Same as GES 215B.) Field equations for elastic solids and viscous fluids derived from conservation laws to develop mechanical models for tectonic processes and their structural products. Topics include: conservation of mass and momentum in a deformable continuum; linear elastic deformation and elastic properties of rock; brittle deformation including fracture and faulting; linear viscous flow including folding, model development, and methodology. Models constructed and solutions visualized using MATLAB. Prerequisite: GES 215A.
3-5 units, Win (Pollard, D)

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

CEE 299. Independent Study in Civil Engineering
Directed study for graduate students on subjects of mutual interest to students and faculty. Student must obtain faculty sponsor.
1-5 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 299S. Independent Project in Civil and Environmental Engineering
Prerequisite: consent of instructor.
1-4 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 300. Thesis (Engineer Degree)
Research by Engineer candidates.
1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 301. The Energy Seminar
(Same as ENERGY 301.) Interdisciplinary exploration of current

energy challenges and opportunities, with talks by faculty, visitors, and students. May be repeated for credit.

1 unit, Aut (Horne, R), Win (Horne, R), Spr (Horne, R)

CEE 310. Post-Master's Seminar
For post-master's students to serve as orientation to the selection of a research topic.

1 unit, Aut (Staff), Win (Staff), Spr (Staff)

CEE 316. Research Methods in Facility Engineering
For CEE Ph.D. students. Facility planning, design, management, and operation. Research philosophy and methods. Experimental design: ethnography, case study, survey, classical experiment (natural, synthetic, or computational). Data analysis: ANOVA, regression, correlation. Introduction to modeling social systems. Publication strategies. Final project to develop and refine research proposal and publication plan.

3-4 units, given next year

CEE 320. Integrated Facility Engineering
Individual and group presentations on goals, research, and state-of-practice of virtual design and construction in support of integrated facility engineering, including objectives for the application and further development of virtual design and construction technologies. May be repeated for credit.

1 unit, Aut (Kunz, J; Fischer, M), Win (Kunz, J), Spr (Kunz, J)

CEE 321. Formal Models for Design
Theories, methods, and formal systems to support the design of buildings. Academic and industrial frameworks to represent and manage the products, organizations, and processes of building projects. May be repeated for credit.

3 units, Spr (Staff)

CEE 333. Water Policy Colloquium
(Same as GES 333, IPER 333.) Student-organized interdisciplinary colloquium. Creation, implementation, and analysis of policy affecting the use and management of water resources. Weekly speakers from academia and local, state, national, and international agencies and organizations.

1 unit, Spr (Freyberg, D)

CEE 341P. Politics and Infrastructure Investment
Political and social challenges awaiting global infrastructure investors. Sources include literature in economic history, international business, development, political economy, sociology. and communications. Foundations of conflict between external stakeholders and investors/operators, and best practice tools and frameworks for mitigating conflict. Students draft a research proposal or a project-specific political and social risk mitigation proposal.

2-4 units, Aut (Staff)

CEE 342. Computational Modeling of Organizations
For post-M.S. students interested in formal techniques for organization design. Computer simulations 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 and communication technologies. 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 units, not given this year

CEE 362. Numerical Modeling of Subsurface Processes
Numerical modeling including: problem formulation, PDEs and weak formulations, and choice of boundary conditions; solution using the finite-element code COMSOL Multiphysics with a variety of solvers and pre- and postprocessing of data; and interpretation of results. Problems include: flow in saturated porous media with complex boundaries and heterogeneities; solute transport with common reaction models; effects of heterogeneity on dispersion, dilution, and mixing of solutes; variable-density flow and seawater intrusion; upscaling or coarsening of scale; and biofilm modeling. Enrollment limited to 5.

3-4 units, alternate years, not given this year

CEE 362G. Stochastic Inverse Modeling and Data Assimilation Methods
Stochastic methods for the solution of inverse problems that are algebraically underdetermined or have solutions that are sensitive to data. Emphasis is on geostatistical methods that, in addition to using data, incorporate information about structure such as spatial continuity and smoothness. Methods for real-time processing of new data. Prerequisite: consent of instructor.

3-4 units, Spr (Kitanidis, P), alternate years, not given next year

CEE 363A. 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, CME 204.

3 units, alternate years, not given this year

CEE 363B. Geophysical Fluid Dynamics
(Formerly 364B.) Focus is on fluid dynamics of the ocean at scales where the influence of the earth's rotation is important. Topics include geostrophic and quasi-geostrophic flows, planetary waves, potential vorticity, the Rossby adjustment problem, effects of stratification, and flows on the sea plane. Hydrodynamic stability of rotating and stratified flows. Prerequisite: 363A.

3 units, alternate years, not given this year

CEE 363C. Ocean and Estuarine Modeling
Advanced topics in modeling for ocean and estuarine environments, including methods for shallow water, primitive, and nonhydrostatic equations on Cartesian, curvilinear, and unstructured finite-volume grid systems. Topics include free-surface methods, nonhydrostatic solvers, and advanced Eulerian and Lagrangian advection techniques. Focus is on existing techniques and code packages, and their methodologies, including POM, ROMS, TRIM, ELCOM, and SUNTANS. Prerequisites: CME 200, 206, or equivalents.

3 units, Win (Fringer, O)

CEE 364Y. Advanced Topics in Coastal Oceanography
The dynamics and transport implications of features in estuaries and coastal oceans characterized by sharp gradients: fronts, interfaces, and layers. Analytic framework to describe the formation, maintenance, and dissipation of such features. Examples include tidal mixing fronts, buoyant plume fronts and tidal intrusions, biological thin layers, and axial convergent fronts. Second unit for students who give a presentation.

1-2 units, not given this year

CEE 365A. Advanced Topics in Environmental Fluid Mechanics and Hydrology
Students must obtain a faculty sponsor

2-6 units, Aut (Staff)

CEE 365B. Advanced Topics in Environmental Fluid Mechanics and Hydrology
Students must obtain a faculty sponsor

2-6 units, Win (Staff)

CEE 365C. Advanced Topics in Environmental Fluid Mechanics and Hydrology
Students must obtain a faculty sponsor.

2-6 units, Spr (Staff)

CEE 365D. Advanced Topics in Environmental Fluid Mechanics and Hydrology
Students must obtain a faculty sponsor.

2-6 units, Sum (Staff)

CEE 370A. Environmental Research
Introductory research experience for first-year Ph.D. students in the Environmental Engineering and Science program. 15-18 hours/week on research over three quarters. 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 (Staff)

CEE 370B. Environmental Research

Introductory research experience for first-year Ph.D. students in the Environmental Engineering and Science program. 15-18 hours/week on research over three quarters. 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, Win (Staff)

CEE 370C. Environmental Research

Introductory research experience for first-year Ph.D. students in the Environmental Engineering and Science program. 15-18 hours/week on research over three quarters. 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, Spr (Staff)

CEE 370D. Environmental Research

Introductory research experience for first-year Ph.D. students in the Environmental Engineering and Science program. 15-18 hours/week on research over three quarters. 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.

3-6 units, Sum (Staff)

CEE 371. Frontiers in Environmental Research

How to evaluate environmental research.

1-2 units, Aut (Staff), Win (Staff), Spr (Staff)

CEE 374B. Introduction to Physiology of Microbes in Biofilms

Diversification of biofilm populations, control of gene expression in biofilm environments, and evolution of novel genetic traits in biofilms.

1-6 units, Win (Staff)

CEE 374C. Introduction to Physiology of Microbes in Biofilms

Diversification of biofilm populations, control of gene expression in biofilm environments, and evolution of novel genetic traits in biofilms.

1-6 units, Spr (Staff)

CEE 374D. Introduction to Physiology of Microbes in Biofilms

Diversification of biofilm populations, control of gene expression in biofilm environments, and evolution of novel genetic traits in biofilms.

1-6 units, Sum (Staff)

CEE 374S. Advanced Topics in Microbial Pollution

May be repeated for credit. Prerequisite: consent of instructor.

1-5 units, Aut (Boehm, A), Win (Boehm, A), Spr (Boehm, A), Sum (Boehm, A)

CEE 374T. Advanced Topics in Coastal Pollution

May be repeated for credit. Prerequisite: consent of instructor.

1-5 units, Aut (Boehm, A), Win (Boehm, A), Spr (Boehm, A), Sum (Boehm, A)

CEE 374U. Advanced Topics in Submarine Groundwater Discharge

May be repeated for credit. Prerequisite: consent of instructor.

1-5 units, Aut (Boehm, A), Win (Boehm, A), Spr (Boehm, A), Sum (Boehm, A)

CEE 374V. Advanced Topics in Microbial Source Tracking

May be repeated for credit. Prerequisite: consent of instructor.

1-5 units, Aut (Boehm, A), Win (Boehm, A), Spr (Boehm, A), Sum (Boehm, A)

CEE 376. Organic Analyses in Environmental Sciences

Theory and practice of instrumental methods used in environmental engineering and sciences, emphasizing determination of organic substances by gas chromatography, mass spectrometry, and high pressure liquid chromatography. Interpretation of mass spectra adaptation of techniques to specific environmental matrices. Case studies. Prerequisite: consent of instructor.

2-3 units, not given this year

CEE 377. Research Proposal Writing in Environmental Engineering and Science

For first- and second-year post-master's students preparing for thesis defense. Students develop progress reports and agency-style research proposals, and present a proposal in oral form. Prerequisite: consent of thesis adviser.

1-3 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 378. Statistical Analysis of Environmental Data: Tools and Applications

Preference to Environmental Engineering and Science Ph.D. students. Practical data analysis techniques applicable to environmental engineering. The role of statistics in data collection, experimental design, data exploration, and effective communication of results. Use of statistical packages such as Excel, Matlab, and R. Discussions partially based on student interest and available datasets. Topics may include summarizing data, hypothesis testing, nonparametric statistics, regression analysis, classification and regression trees, cluster analysis, and computationally intensive methods. Limited enrollment.

2-3 units, not given this year

CEE 381. Advanced Engineering Informatics

1-4 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 385. Performance-Based Earthquake Engineering

Synthesis and application of approaches to performance-based design and assessment that recently have been developed or are under development. Emphasis is on quantitative decision making based on life-cycle considerations that incorporate direct losses, downtime losses, and collapse, and the associated uncertainties. Hazard analysis, response simulation, damage and loss estimation, collapse prediction. Case studies. Prerequisites: 282, 287, and 288.

2-3 units, Aut (Krawinkler, H)

CEE 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: qualified offer of employment and consent of adviser as per I-Center procedures.

1 unit, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 399. Advanced Engineering Problems

Individual graduate work under the direction of a faculty member on a subject of mutual interest. Student obtain faculty sponsor. May be repeated for credit.

1-10 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CEE 400. Thesis (Ph.D. Degree)

For students who have successfully completed the department general qualifying examination. Research and dissertation for the Ph.D. degree.

1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

OVERSEAS STUDIES COURSES IN CIVIL AND ENVIRONMENTAL ENGINEERING

For course descriptions and additional offerings, see the respective "Overseas Studies" courses section of this bulletin or http://bosp.stanford.edu. Students should consult their program's student services office for applicability of Overseas Studies courses to a major or minor program.

AUSTRALIA CIVIL AND ENVIRONMENTAL ENGINEERING COURSES

OSPAUSTL 10. Coral Reef Ecosystems
3 units, Aut (Hoegh-Guldberg, O; Ward, S; Arrigo, K)

OSPAUSTL 20. Coastal Resource Management
3 units, Aut (Johnstone, R)

OSPAUSTL 30. Coastal Forest Ecosystems
3 units, Aut (Hall, J)