CIVIL AND ENVIRONMENTAL ENGINEERING

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Assistant Professors: Jack W. Baker, Alexandria B. Boehm, Jennifer Davis, Oliver B. Fringer, John R. Haymaker
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Courtesy Assistant Professor: Margot G. Gerritsen
Consulting Professors: James E. Cloern, Russell G. Clough, Weimin Dong, Eric Elsesser, Angelos N. Findikakis, Robert F. Hickey, Alan D. Jassby, Michael C. Kavanaugh, 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, Avram S. Tucker, Michael W. Walton
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Consulting Assistant Professors: Cristina L. Archer, William J. Behrman, Murray D. Einarson, Edward S. Gross, Charles S. Han, Calvin K. Kam, Lisa V. Lucas, Michael L. MacWilliams
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Courses in Civil and Environmental Engineering have the subject code CEE. For a complete list of subject codes, see Appendix.

The undergraduate Civil Engineering major provides a pre-professional program balancing the fundamentals common to many special fields of civil engineering with specialization in Environmental and Water Studies or Structures and Construction. The undergraduate Environmental Engineering major offers a more focused program in Environmental and Water Studies. Laboratory facilities are available to students in building energy, construction, environmental engineering and science, experimental stress analysis, fluid mechanics, structural and earthquake engineering, and advanced sensing technologies. The department also hosts the School of Engineering pre-approved major in Architectural Design; see requirements in the "School of Engineering" section of this bulletin.

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

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

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

Atmosphere and Energy
Construction Engineering and Management
Design/Construction Integration
Environmental and Water Studies
- Environmental Engineering and Science
- Environmental Fluid Mechanics and Hydrology

Structural Engineering and Geomechanics
- Geomechanics
- Structural Engineering

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

PROGRAMS OF STUDY

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 Biological Sciences, 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).

CONSTRUCTION

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

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

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

The Construction Program faculty and students are active participants in the Center for Integrated Facility Engineering (CIFE). In collaboration with Computer Science and other departments, CIFE conducts research on the automation, integration, and management of technology in the construction industry. The Collaboratory for Research on Global Projects (CRGP) carries out research on the special challenges of international projects in partnership with CIFE.

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

DESIGN/CONSTRUCTION INTEGRATION

To better prepare graduates for successful careers as design and construction professionals making major contributions to integrated projects, the department offers a Master of Science (M.S.), Engineer, and Ph.D. degree field in Design/Construction Integration (DCI).

This program aims to educate design and construction professionals to understand the goals and concerns of the many other project stakeholders, and to prepare for multidisciplinary, collaborative teamwork to develop sustainable buildings and infrastructure facilities in an integrated design and construction process.

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

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

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

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

The CEM program prepares technically qualified students for responsible 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. The program also includes the engineering aspects of heavy, industrial, and building construction.

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

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

ENVIRONMENTAL AND WATER STUDIES

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

Students with backgrounds in all areas of engineering and science who are interested in applying their specialized abilities to solving environmental and water problems are welcome. Comprehensive introductory courses in each major area of study are given to provide common understanding among those with dissimilar backgrounds. Courses from many other programs and departments both complement and supplement these course offerings. 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 two programs are handled separately; prospective students should clearly indicate their preference on their application by specifying one or the other area of specialization.

The Environmental Engineering and Science Program (EES) 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, as well as environmental fluid mechanics, hydrology, and transport modeling. Research on hazardous substances is coordinated through the Western Region Hazardous Substance Research Center. The objective of this center, sponsored by the U.S. Environmental Protection Agency, is to promote through fundamental and applied research the development of alternative and advanced physical, chemical, and biological processes for the treatment of hazardous substances in the environment, with emphasis on groundwater contamination.

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

STRUCTURAL ENGINEERING AND GEOMECHANICS

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

Structural design and analysis focuses on the conceptual and detailed design of structural systems and on computational methods for predicting the static and dynamic, linear and nonlinear responses of structures. Some courses emphasize earthquake resistant design, design with high-performance materials, and concepts for computer-based design. Related course work is available from departments such as Computer Science, Materials Science and Engineering, and Mechanical Engineering. In collaboration with CIFE, research involving design for constructability, engineering information management, and collaborative engineering is being conducted.

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

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

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

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

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

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

1. To provide an understanding of engineering principles and the analytical, problem solving, design, and communication skills to continue succeeding and learning in diverse careers.
2. 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.
3. To prepare for possible graduate study in engineering or other professional fields.
4. 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. Elective units may be used in any way the student desires, including additional studies in civil and environmental engineering. Because the undergraduate engineering curriculum is designed to ensure breadth of study, students who intend to enter professional practice in civil or environmental engineering should plan to obtain their professional education at the graduate level.

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

HONORS PROGRAM

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

The program involves an in-depth research study in an area proposed to and agreed to by a Department of Civil and Environmental Engineering (CEE) faculty adviser and completion of a thesis of high quality. A written proposal for the research to be undertaken must be submitted and approved in the fourth quarter prior to graduation. At the time of application, the student must have an overall grade point average (GPA) of at least 3.3 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 102S 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 other 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 102S). These units are beyond the normal Civil Engineering (CE) or Environmental Engineering (EnvE) major program requirements.

MINOR IN CIVIL ENGINEERING OR ENVIRONMENTAL ENGINEERING

The department offers minor programs in both Civil Engineering and 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

The University requirements governing the M.S., Engineer, and Ph.D. 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 12, 2006; it is important that Graduate Record Examination scores be available at that time. Applicants not requesting financial assistance have until March 13, 2007 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.

MASTER OF SCIENCE

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.

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 (Terman M-42).

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. Students may, with the approval of their academic adviser, select a program that satisfies the requirements for the M.S. in Engineering.

Forms required for the degree may be secured from the department's office of student services.

ENGINEER

A student with an M.S. in Civil Engineering may satisfy the requirements of the degree of Engineer in Civil and Environmental Engineering by completing 45 unduplicated course work and research units for the degree and minimum residency of 90 total 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

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 two years of which must be at Stanford with a minimum GPA of 3.0 in post-M.S. course work. Experience has shown that few students complete the Ph.D. within the minimum residence period. Prospective doctoral students should anticipate the possibility of at least one extra year. All candidates for the Ph.D. degree are required to complete CEE 200 in conjunction with a one-quarter teaching assistantship/course assistantship to gain training and instructional experience. Further information on Ph.D. requirements and regulations is found in the department handbook.

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

The program of study is arranged by the prospective candidate at the beginning of the second year with the advice of a faculty committee whose members are nearest in the field of interest to that of the student. The chair of the committee serves as the student's pro tem adviser until such time as a member of the faculty has agreed to direct the dissertation research. Insofar as possible, the program of study is adapted to the interests and needs of the student within the framework of the requirements of the department and the University.

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

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 (that is, courses numbered 200 or above, excluding special studies and thesis) in CEE completed at Stanford University. The list of courses must form a coherent program and must be approved by the minor program adviser and the CEE chair. A minimum GPA of 3.0 must be achieved in these courses.

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.

COURSES

WIM indicates that the course satisfies the Writing in the Major requirements. (AU) indicates that the course is subject to the University Activity Unit limitations for undergraduates (8 units maximum).

UNDERGRADUATE

CEE 31. Accessing Architecture Through Drawing—Preference to Architectural Design and CEE majors; others by consent of instructor. Drawing architecture to probe 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.

4 units, Win (Barton, J)

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 (Walters, P)

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 48Q. Design Organizations to Execute Global Projects—Stanford Introductory Seminar. Confusion, misunderstanding, and conflict among multinational team members on global projects can cause significant delays and cost overruns. Challenges in carrying out global projects; theory, methods, and tools to enhance global project outcomes. Opportunities to participate in ongoing research in the Collaboratory for Research on Global Projects involving faculty from multiple Stanford departments and schools; see http://crgp.stanford.edu. Students teams model and simulate crosscultural teams engaged in global projects.

4 units, Win (Levitt, R)

CEE 63. Weather and Storms—(Graduate students register for 263C.) Daily and severe weather, and global climate. Topics: structure and composition of the atmosphere, fog and cloud formation, rainfall, local winds, global circulation, jet streams, high and low pressure systems, inversions, el Niño, la Niña, atmosphere-ocean interactions, fronts, cyclones, thunderstorms, lightning, 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—(Graduate students register for 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, global climate change, stratospheric ozone reduction, Antarctic ozone destruction, air pollution transport across political boundaries, the effects of meteorology on air pollution, and the effects of air pollution and stratospheric ozone on ultraviolet radiation. 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.

3 units, Aut (Kopperud, R)

CEE 80N. The Art of Structural Engineering—Stanford Introductory Seminar. Preference to freshmen. The history of modern bridges, buildings, and other large-scale structures. Principles of structural engineering through case studies. Analysis of structural form with scientific, social, and symbolic considerations. Field trip to Bay Area landmark and hands-on exercises including building and testing a model bridge. Modern structures, the social context in which they are built, and their symbolic value. Students from all backgrounds welcome. GER:DB-EngrAppSci

4 units, Win (Billington, S)

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; individual writing assignment related to a real world project. GER:DB-EngrAppSci, WIM

4 units, Aut (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. Prerequisite: ENGR 14. GER:DB-EngrAppSci

4 units, Win (Staff)

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. Mathematical Laboratory Applications in Civil and Environmental Engineering—(Graduate students register for 201D.) Use of commercial professional software in the design and analysis of civil and environmental engineering systems. MATLAB 5 is applied to relevant problems and issues that students encounter in subsequent courses and in engineering practice. Limited enrollment.

2 units, Aut (Snodgrass, M)

CEE 102. Legal Aspects of Engineering and Construction—(Graduate students register for 202.) Introduction to the U.S. legal system as it applies to civil engineering and construction. Fundamental concepts of contract and tort law, claims, risk management, business formation and licensing, agency, insurance and bonding, and real property.

3 units, Win (London, M)

CEE 110. Building Information Modeling—(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—(Graduate students register for 211.) Modeling, visualization, analysis, and graphical communication of building projects. Use of 3D models in laser scanning, rendering, animation, daylight, energy, cost, structural, and 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

3-4 units, Win (Haymaker, J)

CEE 115. Goals and Methods of Sustainable Building Projects—(Graduate students register for 215.) Design, constructon, and operation methods to enhance the economy, ecology, equity, and sustainability of building projects. Methods related to sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and other project-specific goals. USGBC's LEED rating system, project case studies, guest lecturers, and group project.

3-4 units, Spr (Haymaker, J)

CEE 122A. Computer Integrated Architecture/Engineering/Construction (A/E/C)—(Graduate students register for 222A.) (Undergraduates serve as apprentices.) Crossdisciplinary, collaborative, geographically distributed, project-based, teamwork environment. Round table A/E/C panel discussions, lectures, and labs on collaborative technologies provide a global perspective of the A/E/C industry and cutting edge information technologies. Students exercise theoretical discipline knowledge in architecture, structural, engineering, construction management, and the information technologies in a multidisciplinary context focusing on the concept development phase of a comprehensive building project. May be repeated for credit.

3 units, Win (Fruchter, R)

CEE 122B. Computer Integrated A/E/C—(Graduate students register for 222B.) (Undergraduates serve as apprentices.) Comprehensive team project, including project development and documentation, and final project presentation of product and process. Design and construction alternatives are subject to examination by rapid computational prototyping, concurrent multidisciplinary evaluation, and trade-off analysis. Prerequisite 222A.

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, Win, Spr (Staff)

CEE 130. Architectural Design: 3-D Modeling, Methodology, and Process—Preference to Architectural Design and CEE majors; others by consent of instructor. Incrementally staged design projects investigate form, space, and conceptual strategies. Making 3-D models. Students prepare graphic and written account of personal design process and intentions. Final project applies systems and strategies to the design of a simple building. Limited enrollment. Prerequisite: CEE 31, 31Q, or 131.

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, Aut (Blake, C)

CEE 132. Interplay of Architecture and Engineering—(Graduate students register for 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, Spr (Katz, G)

CEE 134A. Site and Space—Preference to Architectural Design and CEE majors; others by consent of instructor. Intermediate architectural studio. The design of smalll buildings. Emphasis is on design, form, space making, context; and structure; attention to program and sustainability. Limited enrollment. May be repeated for credit. Prerequisites: CEE 31 or 31Q, and 130.

4 units, Aut (Barton, J)

CEE 136. Green Architecture—(Graduate students register for 236.) Preference to Architectural Design and CEE majors; others by consent of instructor. Goal is to develop a working definition of ecologically sustainable design and strategies for greening the built environment. Research for an architectural design studio which explores the student and faculty inspired green dorm initiative. Limited enrollment. Prerequisites: 31 or 31Q, and 130, 131, or 132. GER:DB-EngrAppSci

4 units, Spr (Jacobson, B)

CEE 137A. Forms 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, Win (Staff)

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 with preference to students in CEE, Urban Studies, and Art. Prerequisites: two Art or Architecture studio courses, or consent of instructor.
3 units, Spr (Barton, J)

CEE 140. Field Surveying Laboratory—(Graduate students register for 240B.) 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 with an introduction to the newest generation of digital measuring, positioning, and mapping tools that are emerging as modern standards. Emphasis is on the concept of using the data collected in the field as the basis for subsequent engineering and economic decisions. GER:DB-EngrAppSci
3 units, Spr (Staff)

CEE 142A. Sustainable Development—(Graduate students register for 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—(Graduate students register for 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, Win (Kunz, J)

CEE 147. Cases in Personality, Leadership, and Negotiation—(Graduate students register for 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—(Graduate students register for 251; same as ME 207, MS&E 285.) Negotiation styles and processes to help students conduct and review negotiations. Workshop format integrating intellectual and experiential learning. Exercises, live and field examples, individual and small group reviews. Application required before first day of class; see http://www.stanford.edu/class/msande285/. Enrollment limited to 50.
3 units, Spr (Christensen, S)

CEE 154. Cases in Estimating Costs—(Graduate students register for 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 professor's experience as small business owner and construction engineer. Required full afternoon field trips to local sites. Mandatory first class attendance. GER:DB-EngrAppSci
3 units, Aut (Clough, R)

CEE 156. Building Systems—(Graduate students register for 256.) Design concepts, options for increased sustainability, integration issues, construction materials, and installation operations for heating, ventilating, and air conditioning systems. Overview of other building systems. GER:DB-EngrAppSci
4 units, Spr (Daly, A)

CEE 159. Career Skills Seminar—(Graduate students register for 259.) Factors required for successful careers. Guest speakers. Case studies. No auditors.
2 units, Aut (Clough, R)

CEE 160. Mechanics of Fluids Laboratory—Lab experiments/demonstrations illustrate conservation principles and flows of real fluids. Corequisite: 101B.
2 units, Spr (Monismith, S)

CEE 161A. Rivers, Streams, and Canals—(Graduate students register for 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. GER:DB-EngrAppSci
3-4 units, Aut (Fong, D)

CEE 161T. Physical Chemistry of Atmospheric Particles—(Graduate students register for 261T; same as GEOPHYS 136/236.) Thermodynamic principles and their application to approximate the phase behavior and surface properties of multi-component solution droplets in the atmosphere. Topics: water and its phase transformations; equilibrium models of electrolyte solutions; aerosol water uptake; relative humidity conditions for particle efflorescence (crystallization) and deliquescence; mechanisms of colloid formation and organic matter precipitation in aqueous particles; aerosol and cloud surface characterization using bulk composition and adsorption isotherms; and the role of aerosol surface tension in cloud activation.
3 units, Spr (Tabazadeh, A)

CEE 162. Modeling and Simulation for Civil and Environmental Engineers—(Graduate students register for 262C). Introduction to mathematical and computational methods for modeling and simulation, and 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 CME 104, or equivalents. GER: DB-EngrAppSci
3 units, Spr (Fringer, O), Sum (Staff)

CEE 164. Introduction to Physical Oceanography—(Graduate students register for 262D; same as 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 (Staff)

CEE 166A. Watersheds and Wetlands—(Graduate students register for 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. GER:DB-EngrAppSci
3 units, Aut (Freyberg, D)

CEE 166B. Floods and Droughts, Dams and Aqueducts—(Graduate students register for 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. GER:DB-EngrAppSci

3 units, Win (Freyberg, D)

CEE 166D. Water Resources and Water Hazards Field Trips—(Graduate students register for 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, 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 visual, noise, and traffic impacts in environmental impact assessments. 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)

CEE 172A. Indoor Air Quality—(Graduate students register for 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, not given this year

CEE 173A. Energy Resources—(Graduate students register for 207A; same as EARTHSYS 103.) Overview of oil, natural gas, coal, nuclear, hydro, solar, geothermal, biomass, wind, and ocean energy resources in terms of supply, distribution, recovery and conversion, environmental impacts, economics, policy, and technology. The opportunities for energy efficiency, electric power basics, the changing role of electric utilities, transportation basics, and energy use in developing countries. Field trips. Recommended: CEE 70. GER:DB-EngrAppSci

4-5 units, Aut (Woodward, J)

CEE 173B. The Coming Energy Revolution—(Graduate students register for 207B.) The forces driving an energy revolution: environmental pressures; global, social, and economic revolution; and technological change. Assessment of evolution versus revolution, developed versus developing countries, transportation, electric power, resource development and extraction, end use technologies, deregulation, privatization and globalization, barriers to change, and the mechanisms to overcome them. Enrollment limited to 15. Prerequisite: 173A. GER:DB-EngrAppSci

4 units, alternate years, not given this year

CEE 173L. Energy End-Use Efficiency: Technology, Implementation, and Implications—(Graduate students register for 273L.) Offered during Spring Break. End-use efficiency technologies, primarily for electricity and mobility fuels, focusing on techniques, design, and performance evaluation. Barriers, incentives, and strategies to implementing least-cost efficiency measures, including implications for energy supply and demand, business interests, and national security. Recommended: 173A.

1-3 units, Spr (Staff)

CEE 175A. California Coast: Science, Policy, and Law—(Graduate students register for 275A; same as EARTHSYS 175/275, LAW 514.) Interdisicplinary. 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 (Caldwell, M; Boehm, A; Sivas, D)

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 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 177S. Design for a Sustainable World—(Graduate students register for 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 written application and interview. See http://esw.stanford.edu for application.

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

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

3 units, Spr (Leckie, J)

CEE 179A. Water Chemistry Laboratory—(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—(Graduate students register for 275B.) 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, not given this year

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, Spr (Robertson, A)

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 (Baker, J)

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—Restricted to CE majors. Design decision making from conception through construction of civil infrastructure facilitites, considering sustainable design aspects. Execution of a design alternative through development of a structural system, considering integration with architecture, construction, and building systems. Prerequisites: 180, 181, 182.

4 units, Spr (Deierlein, G)

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.

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

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

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

PRIMARILY FOR GRADUATE STUDENTS

CEE 200A,B,C. 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.

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

CEE 201D. Mathematical Laboratory Applications in Civil and Environmental Engineering—(Undergraduates register for 101D; see 101D.)

2 units, Aut (Snodgrass, M)

CEE 202. Legal Aspects of Engineering and Construction—(Undergraduates register for 102; see 102.)

3 units, Win (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, not given this year

CEE 205. Structural Materials Testing and Simulation—Hands-on laboratory experience with fabrication, computer simulation, and experimental testing of material and small-scale structural components. Comparison of innovative and traditional structural materials. Behavior and application of high-performance fiber reinforced concrete materials for new design, fiber-reinforced polymeric materials for structural retrofits and fracture in metals and polymers.

3-4 units, Spr (Billington, S)

CEE 207A. Energy Resources—(Undergraduates register for 173A; see 173A; same as EARTHSYS 103.)

4-5 units, Aut (Woodward, J)

CEE 207B. The Coming Energy Revolution—(Undergraduates register for 173B; see 173B.)
4 units, alternate years, not given this year

CEE 210. Building Information Modeling—(Undergraduates register for 110; see 110.)
4 units, Aut (Katz, G)

CEE 211. Multidisciplinary Modeling and Analysis—(Undergraduates register for 111; see 111.)
3-4 units, Win (Haymaker, J)

CEE 215. Goals and Methods of Sustainable Building Projects—(Undergraduates register for 115; see 115.)
3-4 units, Spr (Haymaker, J)

CEE 222A. Computer Integrated Architecture/Engineering/Construction (A/E/C)—(Undergraduates register for 122A; see 122A.)
3 units, Win (Fruchter, R)

CEE 222B. Computer Integrated A/E/C—(Undergraduates register for 122B; see 122B.)
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 units, Win (Staff)

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, structural walls, coupled structural walls. Design and construction of precast and post-tensioned elements, and of connections in precast elements. Prerequisite: 182 or equivalent.
3 units, not given this year

CEE 224. Preconstruction Planning for Design/Construction Integration—Marketing, planning commission, fire and building codes, team building, schedule development, and budget development using the design construction integration approach. Projects studied include entertainment, museums, educational, high-tech, semi-conductor, housing, and biotech.
3 units, Win (Staff)

CEE 224A. Sustainable Development Studio—(Undergraduates register for 124; see 124.)
1-5 units, Aut, Win, Spr (Staff)

CEE 232. Interplay of Architecture and Engineering—(Undergraduates register for 132; see 132.)
4 units, Spr (Katz, G)

CEE 236. Green Architecture—(Undergraduates register for 136; see 136.)
4 units, Spr (Jacobson, B)

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; construction process modeling and simulation methods; and digital models for planning and executing site operations. Field and computer lab work. Prerequisite: 241 or consent of instructor.
3 units, Spr (Fischer, M)

CEE 240B. Field Surveying Laboratory—(Undergraduates register for 140; see 140.)
3 units, Spr (Staff)

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 variablility; and supply chain systems including made-to-stock, engineered-to-order, and made-to-order. Group term project. Prerequisite: 100 or consent of instuctor.
3-4 units, Win (Fischer, M)

CEE 242. Organization Design for Projects and Companies—Introduction to organizational behavior. Information-processing theory of organizational design for projects and companies and computer-based organizational analysis tools. Groups of 12 students practice running problem-focused meetings. Case studies focus on facility/product design and construction/manufacturing organizations; concepts are applicable to project-focused teams and companies in all industries.
4 units, Aut (Levitt, R)

CEE 242A. Sustainable Development—(Undergraduates register for 142A; see 142A.)
3 units, Win (Christensen, S)

CEE 243. Integrated Concurrent Engineering—(Undergraduates register for 143; see 143.)
3-4 units, Win (Kunz, J)

CEE 244A. 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 244B. Advanced Construction Accounting, Financial Issues, and Claims—Continuation of 244A. The recovery of project overruns, and construction industry financial disclosures. Construction claims, project cost overrun analysis, and cost recovery methods related to labor, equipment, indirect costs, overhead, cost of capital, and profit claims. Schedule delay analysis in the context of claims.
2 units, Win (Meyer, P; Tucker, A)

CEE 245A. Global Projects 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.
1 units, Aut (Orr, R)

CEE 245B. Global Projects: An Institutional Perspective—(Same as SOC 216B.) The multifaceted challenges of global projects that involve participants from multiple societal systems through the lens of institutional theory. Sources include sociology, economics, development and engineering literatures.
1-2 units, Spr (Orr, R)

CEE 245C. Project Finance—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.
1-5 units, Win (Orr, R)

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—(Undergraduates register for 147; see 147.)
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—(Undergraduates register for 151; see 151; same as ME 207, MS&E 285.)
3 units, Spr (Christensen, S)

CEE 252. Construction Engineering for Concrete and Steel Structures—Technical overview of materials, methods, and field operations required for construction of steel and concrete structures. Steel work includes detailing, fabricating, erecting, connecting. Concrete work includes batching, transporting, placing, finishing, curing, and formwork. Introduction to activities required to provide technical support for field operations. Group analysis of technical operation or support activity.
4 units, Aut (Tatum, C)

CEE 254. Cases in Estimating Costs—(Undergraduates register for 154; see 154.)
3 units, Aut (Clough, R)

CEE 255. Fostering Innovation in Organizations—Classification of technology and processes of innovation. Differences in innovative organizations, including competitive strategy, organization structure, organization culture, and roles such as innovation champions. Readings from economics and management; case studies of special innovations. Group analysis of an innovation in an organization and how it came about.
4 units, Spr (Tatum, C)

CEE 256. Building Systems—(Undergraduates register for 156; see 156.)
4 units, Spr (Daly, A)

CEE 257. Building Better: Technical and Sustainable Construction—Overview of design and construction for technical facilities and sustainable construction operations. Technical facilities include high purity systems, control systems, laboratories, biotech manufacturing facilitites, and semiconductor fabs. Sustainable construction includes sites, resources, and field operations. Field trips, reports, and papers on technical and sustainable construction.
3 units, Win (Tatum, C)

CEE 258. Donald R. Watson Seminar in Construction Engineering and Management—Required of graduate students in the CEM program; other students including undergraduates welcome. Weekly discussions with speakers from industry and government. Students interact with industry representatives in small group discussions at dinner after class. May be repeated for credit.
1 unit, Aut (Clough, R), Win (Fischer, M)

CEE 259. Career Skills Seminar—(Undergraduates register for 159; see 159.)
2 units, Aut (Clough, R)

CEE 259A,B,C. 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, **A:** *Aut,* **B:** *Win,* **C:** *Spr (Staff)*

CEE 260A. Physical Hydrogeology—(Same as GES 230.) Theory of underground water occurrence and flow, analysis of field data and aquifer tests, geologic groundwater environments, solution of field problems, groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.
4 units, Aut (Gorelick, S)

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 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 (Staff)

CEE 261T. Physical Chemistry of Atmospheric Particles—(Undergraduates register for 161T; see 161T; same as GEOPHYS 136/236.)
3 units, Spr (Tabazadeh, A)

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—(Undergraduates register for 162; see 162.)
3 units, Spr (Fringer, O), Sum (Staff)

CEE 262D. Introduction to Physical Oceanography—(Undergraduates register for 164; see 164; same as EARTHSYS 164.)
4 units, Win (Staff)

CEE 262E. Modeling Surface Water Flows
2 units, Spr (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, 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)

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

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

CEE 264A. Rivers, Streams, and Canals—(Undergraduates register for 161A; see 161A.)
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. Evaluation of benefit-cost analysis and environmental impact assessment as techniques for enhancing the sustainability of future projects. Limited enrollment. Prerequisite: graduate standing in Environmental and Water Studies, or consent of instructor.
3 units, Win (Ortolano, 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, Sum (Findikakis, A)

CEE 265D. Water and Sanitation in Developing Countries—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, Aut (Davis, J)

CEE 266A. Watersheds and Wetlands—(Undergraduates register for 166A; see 166A.)
3 units, Aut (Freyberg, D)

CEE 266B. Floods and Droughts, Dams and Aqueducts—(Undergraduates register for 166B; see 166B.)
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—(Undergraduates register for 166D; see 166D.)
2 units, Win (Freyberg, D)

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

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 272. Coastal Contaminants—Coastal pollution and its effects on ecosystems and human health. The sources, fate, and transport of human pathogens, nutrients, heavy metals, persistent organics, endocrine disrupters, and toxic algae. Background on coastal ecosystems and coastal transport phenomena including tides, waves, and cross shelf transport. Introduction to time series analysis with MATLAB. Undergraduates may enroll with consent of instructor.
3-4 units, Aut (Boehm, A)

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 (Staff)

CEE 273A. Water Chemistry Laboratory—(Undergraduates register for 179A; see 179A.)
3 units, Win (Robertson, A)

CEE 273L. Energy End-Use Efficiency: Technology, Implementation, and Implications—(Undergraduates register for 173L; see 173L.)
1-3 units, Spr (Staff)

CEE 273R. Energy End-Use Efficiency Opportunities at Stanford University—Project-based. Focus is on developing transdisciplinary analysis and recommendations for integrating energy efficiency, renewable energy, and carbon-management strategies into Stanford infrastructure. Limited enrollment; preference to graduate students concurrently enrolled in 273L.
2-4 units, Spr (Staff)

CEE 274A. Environmental Microbiology I—The fundamental aspects of microbiology and biochemistry. The biochemical and biophysical principles of biochemical reactions, energetics, and mechanisms of energy conservation. 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 BIOSCI 41, or equivalents.
3 units, Aut (Spormann, A), Sum (Staff)

CEE 274B. Environmental Microbiology II—Microbial biochemistry of organic pollutant degradation. Metabolic logic of biochemical pathways and predicting biodegradation. Metabolic ecology: reciprocal interactions of microbial activities and the environment. Microbial biofilms and biofilm communities. Cell-cell communication and gene transfer. Constructing microbial biofilms for pollutant degradation. Mechanisms of molecular evolution. Genomic evolution and microbial ecology. Detection of microorganisms in the environment (gene probes, immuno probes, enzyme probes). Prerequisite: 274A.
3 units, Spr (Spormann, A)

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—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— 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)

CEE 275A. California Coast: Science, Policy, and Law—(Undergraduates register for 175A; see 175A; same as EARTHSYS 175/275, LAW 514.)
3-4 units, Win (Caldwell, M; Boehm, A; Sivas, D)

CEE 275B. Process Design for Environmental Biotechnology—(Undergraduates register for 179B; see 179B.)
5 units, not given this year

CEE 276. Introduction to Human Exposure Analysis—(Undergraduates register for 178; see 178.)
3 units, Spr (Leckie, J)

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 277S. Design for a Sustainable World—(Undergraduates register for 177S; see 177S.)
1-5 units, Aut, Win, 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—(Undergraduates register for 172A; see 172A.)
2-3 units, 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 Structural Analysis—Formulation and implementation of frame, plane stress, plane strain, axisymmetric, torsional, solid, plate, and shell elements. Topics: strong and weak forms of the problem, variational principles and the principle of minimum potential energy, the finite element method as an extension of the Rayleigh-Ritz methods, shape functions, isoparametric mapping, numerical integration, convergence requirements, and error estimation. Techniques for application to modeling structural systems. Prerequisite: 280 or equivalent.
3-4 units, Spr (Staff)

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.
3 units, Win (Law, K), alternate years, not given next 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 286. Advanced Structural Design—Strength, stiffness, and ductility considerations in the design of structural elements and systems made of steel, reinforced concrete, and other materials. Concepts of redistribution and strength of structures (element versus system behavior). Design of two-way slab systems. Prerequisites: basic courses in design of steel and reinforced concrete structures.
3-4 units, Aut (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: 286, 288.
3 units, Spr (Aslani, H)

CEE 288. Earthquake Hazard and Risk Analysis—Earthquake phenomena, faulting, ground motion, study of past major earthquakes, effects of earthquakes on man-made 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. Prerequisites: 203, 283.
3-4 units, Win (Kiremidjian, A)

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 292. Computer Methods in Structural Engineering—Techniques for the development of structural engineering analysis and design software. Topics: basic data structure; computer representation of engineering systems; implementation of advanced numerical methods and engineering software; automated conformance checking of design codes and standards. Prerequisite: CS 106A or equivalent.
3 units, not given this year

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 Geomechanics—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, alternate years, not given this year

CEE 295. Plasticity Modeling and Computation—Theory of plasticity; micromechanical basis; classical yield models; return-mapping algorithm; multi-surface and bounding surface models; material instabilities; localization and bifurcation. Prerequisite: ME 338A or equivalent.
3 units, Spr (Borja, R), alternate years, not given next year

CEE 296. Modeling in Geotechnical Engineering—Physical and numerical modeling in geomechanics. Primitive geotechnical models illustrate three-dimensional seepage and strain localization in simple shear and triaxial devices. Finite element modeling and simulations conducted using ANSYS. Numerical simulations demonstrate the 3D, solid-mesh generation capabilities of the program and the limitations of deformation analysis in the softening regime. Prerequisite: 101C or equivalent. Corequisite: course in finite element method.
2 units, Win (Borja, R)

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 (Staff)

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, Win, Spr, Sum (Staff)

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

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

CEE 301. The Energy Seminar—Interdisciplinary exploration of current energy challenges and opportunities, with talks by faculty, visitors, and students.
1 unit, Aut, Win, (Staff)

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, Win, 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, Win (Levitt, R)

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, Win, 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, Aut (Haymaker, J)

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. Previous topics include water policy in California and developing countries.
1 unit, Spr (Freyberg, D)

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, Spr (Kitanidis, P)

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, Win (Fong, D)

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 365A,B,C,D. Advanced Topics in Environmental Fluid Mechanics and Hydrology—Students must obtain a faculty sponsor.
2-6 units, **A:** *Aut,* **B:** *Win,* **C:** *Spr,* **D:** *Sum (Staff)*

CEE 370A,B,C,D. 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, **A:** *Aut,* **B:** *Win,* **C:** *Spr,* **D:** *Sum (Staff)*

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CEE 371. Frontiers in Environmental Research—How to evaluate environmental research.

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

CEE 372. Environmental Informatics: Information and Knowledge Management in Environmental Engineering—(Formerly 374.) Information systems dealing with large amounts of environmental and sustainable development data at multiple spatial-temporal scales and from crossdisciplinary research activities. Topics include: domain information modeling and processing, and interoperability; information security; knowledge management and integration in environmental engineering domain; access to information for decision making; and systematic assessment in management and engineering. The use of IT and the Internet.

3 units, Spr (Wang, J)

CEE 374C. Introduction to Physiology of Microbes in Biofilms

1-6 units, Spr (Staff)

CEE 374S. Advanced Topics in Microbial Pollution—May be repeated for credit. Prerequisite: consent of instructor.

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

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, Spr (Reinhard, M)

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, Win, Spr, Sum (Staff)

CEE 385. Performance-Based Earthquake Engineering—Historic developments and current approaches. Emphasis is on a second-generation performance-based methodology for assessing existing structures and designing new structures, and facilitation of stakeholder decision making. Hazard analysis, response simulation, damage, and loss estimation. Case study. Prerequisites: 282, 287, and 288.

3 units, not given this year

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, Win, Spr, Sum (Staff)

CEE 399. Advanced Engineering Problems—Individual graduate work under the direction of a faculty member on a subject of mutual interest. Student obtains faculty sponsor. May be repeated for credit.

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

COGNATE COURSES

See respective department listings for course descriptions and General Education Requirements (GER) information. See degree requirements above or the program's student services office for applicability of these courses to a major or minor program.

ECON 155. Environmental Economics and Policy—(Same as EARTHSYS 112.)

5 units, Spr (Gurney, D)

GEOPHYS 162. Laboratory Methods in Geophysics

1-3 units, Spr (Staff)

GEOPHYS 190. Near-Surface Geophysics

3 units, Aut (Staff)

OVERSEAS STUDIES

Courses approved for the Civil and Environmental Engineering major and taught overseas can be found in the "Overseas Studies" section of this bulletin, or in the Overseas Studies Office, 126 Sweet Hall.

AUSTRALIA

CEE 168X. Coral Reef Ecosystems—(Same as BIOSCI 109Z, EARTHSYS 120X, HUMBIO 111X.) GER:DB-EngrAppSci

3 units, Aut (Ward, S; Fine, M; Anthony, K)

CEE 168Y. Coastal Resource Management—(Same as BIOSCI 110Z, EARTHSYS 121X, HUMBIO 112X.) GER:DB-EngrAppSci

3 units, Aut (Johnstone, R; Chiffings, T)

CEE 168Z. Coastal Forest Ecosystems—(Same as BIOSCI 111Z, EARTHSYS 122X, HUMBIO 113X.) GER:DB-EngrAppSci

3 units, Aut (Pole, M; Duke, N)

KYOTO

CEE 171X. Environmental Policy Design and Implementation in Japan, China, and the U.S.

3 units, Spr (Ortolano, L)