Civil and Environmental Engineering


The Department of Civil and Environmental Engineering (CEE) at Stanford conducts fundamental and applied research to advance the civil and environmental engineering professions, educate future academic and industry leaders, and prepare students for careers in professional practice. Civil and environmental engineers work to sustain the natural environment while creating and maintaining the built environment. Civil and environmental engineers are essential to providing the necessities of human life, including water, air, shelter, the infrastructure, energy, and food in increasingly more efficient and renewable ways.

The department focuses on the theme of engineering for sustainability, including three core areas: built environment, environmental and water studies, and atmosphere/energy. The Sustainable Built Environment Program includes creating processes, techniques, materials, and monitoring technologies for planning, design, construction and operation of environmentally sensitive, economically efficient, performance-based buildings and infrastructure, and managing associated risks from natural and man-made hazards. The Environmental and Water Studies Program includes creating plans, policies, science-based assessment models and engineered systems to manage water in ways that protect human health, promote human welfare, and provide freshwater and coastal ecosystem services. The Atmosphere/Energy Program includes studying fundamental energy and atmospheric engineering and science, assessing energy-use effects on atmospheric processes and air quality, and analyzing and designing energy-efficient generation and use systems with minimal environmental impact.

The department oversees undergraduate programs in Civil Engineering and in Environmental Systems Engineering. The department also hosts the School of Engineering undergraduate major in Architectural Design and the undergraduate major in Atmosphere/Energy; both of these programs lead to a B.S. in Engineering.

Mission of the Undergraduate Program in Civil Engineering

The mission of the undergraduate program in Civil Engineering is to provide students with the principles of engineering and the methodology needed for civil engineering practice. This pre-professional program balances the fundamentals common to many specialties in civil engineering and allows for concentration in structures and construction or environmental and water studies. Students in the major learn to apply knowledge of mathematics, science, and civil engineering to conduct experiments, design structures and systems to creatively solve engineering problems, and communicate their ideas effectively. The curriculum includes course work in structural, construction, and environmental engineering. The major prepares students for careers in consulting, industry and government, as well as for graduate school in Engineering.

Learning Outcomes

1. apply knowledge of mathematics, science, and engineering.
2. design and conduct experiments, as well as analyze and interpret data.
3. design a system, component, or process to meet desired needs.
4. function on multidisciplinary teams.
5. identify, formulate, and solve engineering problems.
6. understand professional and ethical responsibility.
7. communicate effectively.
8. obtain the broad education necessary to understand the impact of engineering solutions in a global and societal context.
9. recognize the need for and engage in life-long learning.
10. gain knowledge of contemporary issues.
11. apply the techniques, skills, and modern engineering tools necessary for engineering practice.
12. acquire the background for admission to engineering or other professional graduate programs.

Mission of the Undergraduate Program in Environmental Systems Engineering

The mission of the undergraduate program in Environmental Systems Engineering is to prepare students for incorporating environmentally sustainable design, strategies and practices into natural and built systems and infrastructure involving buildings, water supply, and coastal regions. Courses in the program are multidisciplinary in nature, combining math, science, and engineering fundamentals, and tools and skills considered essential for an engineer, along with a choice of one of three focus areas for more in-depth study: coastal environments, freshwater environments, or urban environments. This major offers the opportunity for a more focused curriculum than the Environmental and Water Studies concentration in the Civil Engineering degree program. The program of study, which includes a capstone experience, aims to equip engineering students to take on the complex challenges of the 21st century involving natural and built environments, in consulting and industry as well as in graduate school.

Learning Outcomes (Undergraduate)

Undergraduates in the Civil Engineering and the Environmental Systems Engineering programs are expected to achieve the following learning outcomes through their major. These learning outcomes are used both in evaluating students and the department’s undergraduate programs. Students are expected to demonstrate the ability to:

1. apply knowledge of mathematics, science, and engineering.
2. design and conduct experiments, as well as analyze and interpret data.
3. design a system, component, or process to meet desired needs.
4. function on multidisciplinary teams.
5. identify, formulate, and solve engineering problems.
6. understand professional and ethical responsibility.
7. communicate effectively.
8. obtain the broad education necessary to understand the impact of engineering solutions in a global and societal context.
9. recognize the need for and engage in life-long learning.
10. gain knowledge of contemporary issues.
11. apply the techniques, skills, and modern engineering tools necessary for engineering practice.
12. acquire the background for admission to engineering or other professional graduate programs.

Learning Outcomes (Graduate)

The purpose of the master’s program is to provide students with the knowledge and skills necessary for a professional career or doctoral studies. Students are prepared through course work with specialization within one of three broad areas including the built environment, atmosphere and energy, and environmental and water studies. All graduate students must master the analytical, quantitative, and interpretive skills necessary for successful leadership in their chosen field.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares students to make original contributions in Civil and Environmental Engineering and related fields.
Graduate Programs in Civil and Environmental Engineering

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

- The Atmosphere/Energy Program offers degrees with the designation of Atmosphere/Energy.
- The Sustainable Built Environment Program offers degrees with two designations:
  - Structural Engineering and Geomechanics
  - Sustainable Design and Construction
- The Environmental and Water Studies Program offers degrees with two designations:
  - Environmental Engineering and Science
  - Environmental Fluid Mechanics and Hydrology

For detailed information on these programs and degree designations, see the "Programs of Graduate Study in Civil and Environmental Engineering" section of this bulletin.

Admissions and Financial Aid

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 all courses taken at colleges and universities. See http://gradadmissions.stanford.edu. Policies for each of the department’s programs are available on the department website. See: http://cee.stanford.edu. Successful applicants are advised as to the degree and program for which they are admitted. If students wish to transfer 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.

The department maintains a continuing program of merit-based financial aid for graduate students. MS and ENG applications for financial aid and assistantships should be filed by December 2, 2014; it is important that Graduate Record Examination scores be available at that time. MS and ENG applicants not requesting financial assistance have until January 13, 2015 to submit their online application. PhD applicants for financial aid and assistantships should be filed January 13, 2015. Merit-based financial aid consists of teaching assistantships and research assistantships for up to half-time work. Engineer and Ph.D. candidates may be able to use research results as a basis for their thesis or dissertation. Fellowship and scholarship awards or loans may supplement assistantships and other basic support. 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 research projects.

Research Centers and Facilities

Research work and instruction in the three principal areas are carried out in these facilities: Building Energy Laboratory; Environmental Engineering and Science Laboratory (EESL); Environmental Fluid Mechanics Laboratory (EFML); Geotechnical Engineering Laboratory; Structural Engineering Laboratory.

The EESL conducts laboratory and field-based research on air quality and on water and wastewater quality and treatment and is home to the following centers: The National Science Foundation (NSF) supported Engineering Research Center for Re-inventing the Nation’s Urban Water Infrastructure (ReNUWIt): a four-university consortium that seeks more sustainable solutions to urban water challenges in the arid west; and The William and Cloy Codiga Resource Recovery Center (CR2C), a new facility for pilot-scale testing of resource recovery technology, will be operational in 2015. The EFML focuses on transport and mixing processes in the surface and sub-surface environment using computation, laboratory experimentation and a global network of field sites.

The John A. Blume Earthquake Engineering Center conducts research on earthquake engineering including advanced sensing and control, innovative materials, and risk hazard assessment.

Research and advanced global teamwork education is conducted in the Project Based Learning (PBL) Laboratory. In collaboration with the Department of Computer Science, the Center for Integrated Facility Engineering (CIFE) employs advanced CAD, artificial intelligence, communications concepts, and information management to integrate participants in the facility development process and to design construction automation. The Global Projects Center (GPC) is a multi-school, multi-university research program aimed at improving the performance of global engineering and construction projects, with a special focus on financing and governance of sustainable civil and social infrastructure projects. The Stanford Sustainable Systems Lab (S3L) aims to advance the state of the art in the design, monitoring and management of built environment systems, with a special focus on smart grid, smart buildings and smart infrastructures.

Programs of Graduate Study in Civil and Environmental Engineering

Atmosphere/Energy Program

The Atmosphere/Energy Program in Civil and Environmental Engineering combines atmospheric science with energy science and engineering. The main goals of the program are to educate students and the public, through courses, research, and public outreach, about the causes of climate, air pollution, and weather problems and methods of addressing these problems through renewable and efficient energy systems. In addition, students learn about feedback between the atmosphere and renewable energy systems and the effects of the current energy infrastructure on the atmosphere.

Major focus areas of energy research include examining the resource availability of renewable energies, such as wind, solar, and wave, and studying optimal methods of combining renewable energies together to match energy supply with instantaneous demand. This type of work is generally done through a combination of data analysis, three-dimensional atmospheric computer modeling of wind, solar, wave, and hydroelectric power resources, and transmission load flow computer modeling. Other energy research, performed through three-dimensional computer modeling, focuses on the effects, for example, of hydrogen fuel cell vehicles on air pollution and the ozone layer and the effects of ethanol and diesel vehicles on air quality and climate. Studies also examine the feedback of wind turbines to the atmosphere and the effects of climate change on wind and solar energy resources.

Atmospheric research in the program generally involves laboratory work, field measurements, or three-dimensional computer modeling of the combined atmosphere, ocean, and land surface. An example of laboratory
work includes measuring the properties of organic particulate matter that forms in the atmosphere. Examples of fieldwork include measuring exposures to secondhand smoke, allergens, and emissions from building materials.

Computer modeling is performed at a variety of spatial scales, from the globe down to the size of a building or smaller. Some examples of modeling studies include examining the effects of air pollution particles on clouds, rainfall, water supply, ultraviolet radiation, the stratospheric ozone layer, and climate, simulating the dispersion of toxic contaminants in an urban street canyon, studying the effects of aircraft exhaust and biomass burning on climate, studying the effects of carbon dioxide domes over cities on air pollution mortality, and studying the leading causes of global warming and their impacts.

Environmental and Water Studies Programs

Environmental and Water Studies include subprograms in Environmental Engineering and Science and Environmental Fluid Mechanics and Hydrology, which includes environmental planning. Course offerings permit study in a single area or interrelated study between areas. Programs are flexible to foster interaction among students and encourage the development of individual programs. The Stanford laboratories for water quality control and environmental fluid mechanics are well equipped for advanced research and instruction.

Courses from other programs and departments complement our programs’ course offerings. Examples include the Institute for Computational and Mathematical Engineering (applied math, numerical methods), Environmental Earth System Science (geostatistics, soil science, hydrogeology, oceanography), Mechanical Engineering (experimental methods, fluid mechanics, heat transfer), Energy Resources Engineering (reservoir engineering, well-test analysis), Statistics (probability and statistics), and the School of Law (natural resources law, environmental law).

Environmental Engineering and Science

The Environmental Engineering and Science (EES) subprogram emphasizes the chemical and biological processes involved in water quality engineering, pollution treatment, remediation, and environmental protection.

Course offerings include: the biological, chemical, and engineering aspects of water supply; the movement and fate of pollutants in surface and ground waters, soil, and the atmosphere; hazardous substance control; molecular environmental biotechnology; and water and air pollution. Companion courses in the Environmental Fluid Mechanics and Hydrology Program (EFMH) include environmental planning and impact assessment, and environmental fluid mechanics, hydros, and transport modeling.

Environmental Fluid Mechanics and Hydrology

The Environmental Fluid Mechanics and Hydrology (EFMH) subprogram focuses on understanding, characterizing, and modeling the physical and biochemical processes, and their interaction, controlling the movement of mass, energy, and momentum in the water environment and the atmosphere. It also considers the planning, design, and implementation of water resources projects and systems, including environmental and institutional issues.

Environmental fluid mechanics courses address: experimental methods in the field and in the laboratory; fluid transport and mixing processes; the fluid mechanics of geophysical and stratified flows; natural flows in coastal waters, estuaries, lakes, and open channels; and hydrodynamic modeling. Hydrology courses consider flow and transport in porous media, stochastic methods in both surface and subsurface hydrology, and watershed hydrology and modeling. Water resources courses address design principles and tools for systems incorporating urban and rural water supply, irrigation, hydropower, stormwater management, flood-damage mitigation, and hydrologic ecosystem services. Planning courses emphasize environmental policy implementation and sustainable water resources development.

The research of this group is focused in the Environmental Fluid Mechanics Laboratory, which includes the P. A. McCuen Environmental Computing Center, and a wide range of field sites.

Admission to Environmental Engineering and Science and Environmental Fluid Mechanics and Hydrology are handled separately; prospective students should indicate their preference on their application.

Sustainable Built Environment Program

The Sustainable Built Environment Program includes subprograms in Structural Engineering and Geomechanics, and Sustainable Design and Construction. These programs focus on educating practitioners and researchers to plan, design, build, and operate more sustainable buildings and infrastructure.

The Structural Engineering and Geomechanics (SEG) subprogram educates designers and researchers who want to progress beyond traditional life safety code-based design, to develop and disseminate performance-based structural and geotechnical engineering methods and tools that maximize the lifecycle economic value of facilities.

The Sustainable Design and Construction (SDC) program provides courses in sustainable, multi-stakeholder design methods and tools that incorporate lifecycle assessment, project planning and entitlement, green architectural design, lighting, and energy analysis, power systems, transportation, water supply and wastewater treatment to educate students interested in promoting more sustainable development of buildings and infrastructure.

Admission is managed separately for these two subprograms; prospective students should indicate their preference on their application.

Structural Engineering and Geomechanics

The Structural Engineering and Geomechanics (SEG) subprogram encompasses teaching and research in structural design and analysis, structural materials, earthquake engineering and structural dynamics, advanced sensing and structural health monitoring, risk and reliability analysis, computational science and engineering, solid mechanics, computational mechanics, and geomechanics. The SEG subprogram prepares students for industrial or academic careers.

Students can balance engineering fundamentals with modern computational and experimental methods to customize programs to launch careers as consultants on large and small projects, designers, and engineering analysts.

Structural design and analysis focuses on the conceptual design of structural systems and on computational methods for predicting the static and dynamic, linear and nonlinear responses of structures.

Structural materials research and teaching focuses on the design and analysis of high-performance as well as low-environmental impact materials.

Earthquake engineering and structural dynamics addresses earthquake phenomena, ground shaking, and the behavior, analysis, and design of structures under seismic and other dynamic forces.

Reliability and risk analysis focuses on assessing damage and losses to structures and lifeline systems under earthquakes, wind and other hazards;
insights from these assessments are used to engineer more sustainable structures and more resilient communities.

Computational science and engineering emphasizes the application of modern computing methods to structural engineering and geomechanics, and encompasses numerical, structural, and geotechnical analysis.

In the area of geomechanics, students focus on the application of the principles of computational and applied mechanics to problems involving geologic materials including soil and rock, as well as on the use of computational methods for analysis and design of foundations and earth structures.

**Sustainable Design and Construction**

The Sustainable Design and Construction (SDC-X) subprogram prepares students for careers in planning, designing, building, and operating sustainable buildings and infrastructure to maximize their lifecycle economic value, their net contribution to environmental functions and services, and their social equity.

The SDC-X subprogram offers courses in:

- Project finance
- Lifecycle assessment
- Sustainable multidisciplinary, multi-stakeholder planning and design processes
- Green architecture
- Performance-based structural design
- Building energy systems
- Renewable power generation and smart electrical grids
- Water supply
- Wastewater treatment
- Transportation development
- Sustainable construction materials and processes

Classes on cutting-edge information technology, sensor networks embedded in intelligent buildings and infrastructure, strategy, economics, entrepreneurship and organization design for new businesses, corporate or governmental initiatives aimed at enhancing the sustainability of buildings and infrastructure round out the subprogram.

This subprogram is intended for students with undergraduate degrees in architecture, engineering, science, construction management, economics or business who wish to pursue careers that enhance the sustainability of the built environment.

Employers of past SDC graduates include: architectural and engineering design firms, constructors, design-build firms and developers focused on delivering green buildings and infrastructure; energy and sustainability consultants; facility management or sustainability departments within large companies; clean-tech start ups, and clean-tech venture funds.

There are four tracks in the SDC subprogram. All four SDC tracks have a common overarching structure and core that includes courses in an integrated design and construction process. The subprogram extends beyond the SDC core to support a specific career direction.

**SDC Construction (SDC-C)**

The SDC-C track includes courses in construction engineering and management and introduces advanced modeling and visualization methods and tools known as virtual design and construction. This track prepares technically qualified students for responsible engineering and management roles in all phases of the development of major constructed facilities. It emphasizes management techniques useful in organizing, planning, and controlling the activities of diverse specialists working within the unique project environment of the construction industry, and it covers construction engineering aspects of heavy, industrial and building construction.

SDC-C offers courses in:

- Building systems
- Construction administration
- Construction law
- Project finance
- Accounting
- Real estate development
- Structural design
- Equipment and methods
- Estimating
- International construction
- Labor relations
- Managing human resources
- Planning and control techniques
- Productivity improvement
- 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.

SDC-C allows students substantial flexibility to tailor their program of study for careers with general contractors, specialty contractors, real estate or infrastructure developers or facility owners and operators.

**SDC-Energy (SDC-E)**

The SDC-Energy (SDC-E) track includes courses on design and construction of buildings and infrastructure systems to produce, distribute and consume energy sustainably. SDC-E prepares students for careers in design and construction of building energy systems, renewable power generating systems, and smart power grids connected to smart buildings and infrastructure, cleantech venture capital, sustainability-focused public policy, green real estate development, and sustainability management positions.

SDC-E includes courses from our department and several other departments at Stanford on sustainable HVAC design and construction of small scale and large structures, the planning, design and construction of renewable power systems, and sensing and control technologies to link integrated smart grids with intelligent buildings, data centers and infrastructure systems.

**SDC-Structures (SDC-S)**

The SDC-Structures (SDC-S) track includes courses from construction engineering and management and Structural Engineering and Geomechanics (SEG) to prepare students for careers in design and construction firms that provide integrated design-build project delivery, construction management, and pre-construction services.

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

The SDC-S track is intended for applicants with backgrounds in engineering and science. Applicants should also have a background in the planning, design, or construction of facilities by virtue of work experience and/or their undergraduate education. Knowledge in subjects from the traditional areas of civil engineering is necessary for students to receive the degree and to satisfy prerequisite requirements for some of the required graduate courses.
Students with an undergraduate degree in Civil Engineering, and who expect to pursue careers with design or construction firms that emphasize design-build, EPC, or turnkey projects should consider SDC-S.

**SDC-Water (SDC-W)**

The SDC-Water (SDC-W) track combines courses from our department’s subprograms in Environmental Engineering and Science and Environmental Fluid Mechanics with courses on sustainable design and construction methods and tools. The SDC-W track prepares students for careers in sustainable design, construction and operation of both centralized systems and emerging distributed systems for water supply and water and waste treatment that integrate the production of energy and a grown stream of valuable bio-engineered products recovered from the waste stream.

This track offers courses in physical and chemical treatment processes for water and wastewater treatment, environmental biotechnology for use in water resource management and bioremediation, watershed and wetland management, environmental engineering design, and sustainable water resource development. Additional related course work is available from other programs within the department, including the Environmental Engineering and Science (EES) and Environmental Fluid Mechanics and Hydrology (EFMH) programs.

This track is intended for students with a background and interest in environmental engineering and fluid mechanics who wish to pursue careers in the development of sustainable water and waste treatment facilities with large integrated design-building firms or progressive governmental agencies in this sector.

**Bachelor of Science in Civil Engineering**

The B.S. in Civil Engineering is an ABET accredited program, which integrates research with engineering education. The B.S. in Civil Engineering offers the opportunity to focus on structures and construction, or on environmental and water studies. No new majors are being accepted for the B.S. in Environmental Engineering. Current Environmental Engineering majors should refer to the 2013-14 Bulletin for details. Any current Environmental Engineering major wishing ABET accreditation must graduate by June 2015.

Three educational objectives structure the Civil Engineering degree program. Graduates of the program are expected within a few years of graduation to have the ability to:

1. Establish themselves as practicing professionals in civil or environmental engineering or a related field.
2. Pursue graduate study in civil or environmental engineering or other fields.
3. Work effectively as responsible professionals alone or in teams handling increasingly complex professional and societal expectations.

Students who major in Civil Engineering must complete the appropriate requirements for the B.S. degree listed. Each student has elective units, which may be used in any way the student desires, including additional studies in the department of Civil and Environmental Engineering or any other school or department in the University. Because the undergraduate engineering curriculum provides breadth of study, students who intend to enter professional practice in civil 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 Environmental and Water Studies track within the Civil Engineering major, students may consider related programs in the department such as Atmosphere/Energy and Environmental Systems Engineering, as well as programs offered in other departments and schools such as Earth Systems, Geological and Environmental Sciences, Urban Studies, and Human Biology.

**Civil Engineering (CE)**

Completion of the undergraduate program in Civil Engineering leads to the conferral of the Bachelor of Science in Civil Engineering.

**Mission of the Undergraduate Program in Civil Engineering**

The mission of the undergraduate program in Civil Engineering is to provide students with the principles of engineering and the methodologies necessary for civil engineering practice. This pre-professional program balances the fundamentals common to many specialties in civil engineering and allows for concentration in structures and construction or environmental and water studies. Students in the major learn to apply knowledge of mathematics, science, and civil engineering to conduct experiments, design structures and systems to creatively solve engineering problems, and communicate their ideas effectively. The curriculum includes course work in structural, construction, and environmental engineering. The major prepares students for careers in consulting, industry and government, as well as for graduate studies in engineering.

**Requirements**

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Units</th>
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<tbody>
<tr>
<td><strong>Mathematics and Science</strong></td>
<td>45</td>
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<tr>
<td>45 units minimum; see Basic Requirements 1 and 2</td>
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<tr>
<td><strong>Technology in Society</strong></td>
<td></td>
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<tr>
<td>One course; see Basic Requirement 4</td>
<td>3.5</td>
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<tr>
<td><strong>Engineering Fundamentals</strong></td>
<td></td>
</tr>
<tr>
<td>Three courses minimum, see Basic Requirement 3</td>
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<tr>
<td>ENGR 14 Intro to Solid Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 90/CEE 70 Environmental Science and Technology</td>
<td>3</td>
</tr>
<tr>
<td>Fundamentals Elective</td>
<td>3.5</td>
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<tr>
<td><strong>Engineering Depth</strong></td>
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<tr>
<td>Minimum of 68 Engineering Fundamentals plus Engineering Depth; see Basic Requirement 5</td>
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<tr>
<td>CEE 100 Managing Sustainable Building Projects</td>
<td>4</td>
</tr>
<tr>
<td>CEE 101A Mechanics of Materials</td>
<td>4</td>
</tr>
<tr>
<td>CEE 101B Mechanics of Fluids</td>
<td>4</td>
</tr>
<tr>
<td>CEE 101C Geotechnical Engineering</td>
<td>4</td>
</tr>
<tr>
<td>CEE 146A Engineering Economy</td>
<td>3</td>
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<tr>
<td>Specialty courses in either:</td>
<td></td>
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<tr>
<td>Environmental and Water Studies (see below)</td>
<td></td>
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<tr>
<td>Structures and Construction (see below)</td>
<td></td>
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<tr>
<td>Other School of Engineering Electives</td>
<td>3.0</td>
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<tr>
<td><strong>Total Units</strong></td>
<td>115-123</td>
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</tbody>
</table>
Mathematics must include CME 100 Vector Calculus for Engineers/ CME 102 Ordinary Differential Equations for Engineers (or Math 51 Linear Algebra and Differential Calculus of Several Variables/ MATH 53 Ordinary Differential Equations with Linear Algebra) and a Statistics course. Science must include Physics 41 Mechanics; either ENGR 31 Chemical Principles with Application to Nanoscale Science and Technology, CHEM31A Chemical Principles I or CHEM 31X Chemical Principles; two additional quarters in either chemistry or physics and GES 1A Introduction to Geology: The Physical Science of the Earth (or GES 1B or 1C); for students in the Environmental and Water Studies track, the additional chemistry or physics must include CHEM 33; for students in the Structures and Construction track, it must include PHYSICS 43 or 45.

Chosen TiS class must specifically include an ethics component, such as ENGR 130 Science, Technology, and Contemporary Society, ENGR 131 Ethical Issues in Engineering, and MS&E 197 Ethics and Public Policy.

CEE 100 meets the Writing in the Major (WIM) requirement.

**Environmental and Water Studies Focus**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>ENGR 30</td>
<td>Engineering Thermodynamics 1</td>
<td>3</td>
</tr>
<tr>
<td>CEE 101D</td>
<td>Computations in Civil and Environmental Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CEE 160</td>
<td>Mechanics of Fluids Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>CEE 161A</td>
<td>Rivers, Streams, and Canals</td>
<td>3-4</td>
</tr>
<tr>
<td>CEE 166A</td>
<td>Watersheds and Wetlands</td>
<td>3</td>
</tr>
<tr>
<td>CEE 166B</td>
<td>Floods and Droughts, Dams and Aqueducts</td>
<td>3</td>
</tr>
<tr>
<td>CEE 171</td>
<td>Environmental Planning Methods</td>
<td>3</td>
</tr>
<tr>
<td>CEE 172</td>
<td>Air Quality Management</td>
<td>3</td>
</tr>
<tr>
<td>CEE 177</td>
<td>Aquatic Chemistry and Biology</td>
<td>4</td>
</tr>
<tr>
<td>CEE 179A</td>
<td>Water Chemistry Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>CEE 179C</td>
<td>Environmental Engineering Design</td>
<td>5</td>
</tr>
<tr>
<td>(or CEE 169)</td>
<td>Capstone design experience course</td>
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Remaining specialty units from:

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>CEE 63</td>
<td>Weather and Storms 2</td>
<td>3</td>
</tr>
<tr>
<td>CEE 64</td>
<td>Air Pollution and Global Warming: History, Science, and Solutions</td>
<td>3</td>
</tr>
<tr>
<td>CEE 109</td>
<td>Creating a Green Student Workforce to Help Implement Stanford's Sustainability Vision</td>
<td>2</td>
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<tr>
<td>CEE 129</td>
<td>Climate Change Adaptation for Coastal Cities: Engineering and Policy for a Sustainable Future</td>
<td>3</td>
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<tr>
<td>CEE 155</td>
<td>Introduction to Sensing Networks for CEE</td>
<td>4</td>
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<tr>
<td>CEE 164</td>
<td>Introduction to Physical Oceanography</td>
<td>4</td>
</tr>
<tr>
<td>CEE 166D</td>
<td>Water Resources and Water Hazards Field Trips</td>
<td>2</td>
</tr>
<tr>
<td>CEE 172A</td>
<td>Indoor Air Quality</td>
<td>2-3</td>
</tr>
<tr>
<td>CEE 173A</td>
<td>Energy Resources</td>
<td>4-5</td>
</tr>
<tr>
<td>CEE 174A</td>
<td>Providing Safe Water for the Developing and Developed World</td>
<td>3</td>
</tr>
<tr>
<td>CEE 174B</td>
<td>Wastewater Treatment: From Disposal to Resource Recovery</td>
<td>3</td>
</tr>
<tr>
<td>CEE 176A</td>
<td>Energy Efficient Buildings</td>
<td>3-4</td>
</tr>
<tr>
<td>CEE 176B</td>
<td>Electric Power: Renewables and Efficiency</td>
<td>3-4</td>
</tr>
<tr>
<td>CEE 178</td>
<td>Introduction to Human Exposure Analysis</td>
<td>3</td>
</tr>
<tr>
<td>CEE 199</td>
<td>Undergraduate Research in Civil and Environmental Engineering</td>
<td>1-4</td>
</tr>
</tbody>
</table>

**Structures and Construction Focus**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE 102</td>
<td>Legal Principles in Design, Construction, and Project Delivery</td>
<td>3</td>
</tr>
<tr>
<td>CEE 156</td>
<td>Building Systems</td>
<td>4</td>
</tr>
<tr>
<td>CEE 181</td>
<td>Design of Steel Structures</td>
<td>4</td>
</tr>
<tr>
<td>CEE 180</td>
<td>Structural Analysis</td>
<td>4</td>
</tr>
<tr>
<td>CEE 182</td>
<td>Design of Reinforced Concrete Structures</td>
<td>4</td>
</tr>
<tr>
<td>CEE 183</td>
<td>Integrated Civil Engineering Design Project</td>
<td>4</td>
</tr>
<tr>
<td>CEE 199</td>
<td>Undergraduate Research in Civil and Environmental Engineering</td>
<td>1-4</td>
</tr>
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</table>

Select one of the following:

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>ENGR 50</td>
<td>Introduction to Materials Science, Nanotechnology Emphasis</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 50E</td>
<td>Introduction to Materials Science, Energy Emphasis</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 50M</td>
<td>Introduction to Materials Science, Biomaterials Emphasis</td>
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Remaining specialty units from:

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<tbody>
<tr>
<td>ENGR 15</td>
<td>Dynamics</td>
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<tr>
<td>CME 104</td>
<td>Linear Algebra and Partial Differential Equations for Engineers</td>
<td>5</td>
</tr>
<tr>
<td>CEE 101D</td>
<td>Computations in Civil and Environmental Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CEE 112A</td>
<td>Industry Applications of Virtual Design &amp; Construction</td>
<td>2-4</td>
</tr>
<tr>
<td>CEE 112B</td>
<td>Industry Applications of Virtual Design &amp; Construction</td>
<td>2-4</td>
</tr>
<tr>
<td>CEE 122A</td>
<td>Computer Integrated Architecture/Engineering/ Construction</td>
<td>2</td>
</tr>
<tr>
<td>CEE 122B</td>
<td>Computer Integrated A/E/C</td>
<td>2</td>
</tr>
<tr>
<td>CEE 129</td>
<td>Climate Change Adaptation for Coastal Cities: Engineering and Policy for a Sustainable Future</td>
<td>3</td>
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<tr>
<td>CEE 141A</td>
<td>Infrastructure Project Development</td>
<td>3</td>
</tr>
<tr>
<td>CEE 141B</td>
<td>Infrastructure Project Delivery</td>
<td>3</td>
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<tr>
<td>CEE 142A</td>
<td>Negotiating Sustainable Development</td>
<td>3</td>
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<tr>
<td>CEE 151</td>
<td>Negotiation</td>
<td>3</td>
</tr>
<tr>
<td>CEE 155</td>
<td>Introduction to Sensing Networks for CEE</td>
<td>4</td>
</tr>
<tr>
<td>CEE 160</td>
<td>Mechanics of Fluids Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>CEE 161A</td>
<td>Rivers, Streams, and Canals</td>
<td>3-4</td>
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<tr>
<td>CEE 171</td>
<td>Environmental Planning Methods</td>
<td>3</td>
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<tr>
<td>CEE 176A</td>
<td>Energy Efficient Buildings</td>
<td>3-4</td>
</tr>
<tr>
<td>CEE 176B</td>
<td>Electric Power: Renewables and Efficiency</td>
<td>3-4</td>
</tr>
<tr>
<td>CEE 195</td>
<td>Fundamentals of Structural Geology</td>
<td>3</td>
</tr>
<tr>
<td>CEE 196</td>
<td>Engineering Geology and Global Change</td>
<td>3</td>
</tr>
<tr>
<td>CEE 199</td>
<td>Undergraduate Research in Civil and Environmental Engineering</td>
<td>1-4</td>
</tr>
<tr>
<td>CEE 203</td>
<td>Probabilistic Models in Civil Engineering</td>
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<td></td>
<td>One of the following can also count as remaining specialty units.</td>
<td>3-4</td>
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<tr>
<td>CEE 120A</td>
<td>Building Information Modeling Workshop</td>
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<tr>
<td>or CEE 120B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 130</td>
<td>Architectural Design: 3-D Modeling, Methodology, and Process</td>
<td>2-4</td>
</tr>
<tr>
<td>CEE 131A</td>
<td>Professional Practice: Mixed-Use Design in an Urban Setting</td>
<td></td>
</tr>
<tr>
<td>CEE 134B</td>
<td>Intermediate Arch Studio</td>
<td></td>
</tr>
</tbody>
</table>

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).
Bachelor of Science in Environmental Systems Engineering

For undergraduate studies focusing on Environmental Engineering, two options are available. The undergraduate Civil Engineering major (which is ABET-accredited) offers an Environmental & Water Studies track, and the new Environmental Systems Engineering major (which is not ABET-accredited) offers a choice of focusing on coastal environments, freshwater environments, or urban environments.

Environmental Systems Engineering (EnvSE)

Completion of the undergraduate program in Environmental Systems Engineering leads to the conferral of the Bachelor of Science in Environmental Systems Engineering.

Environmental Engineering (ENV)

The program in Environmental Engineering has been discontinued. Students currently enrolled in this program should consult the previous year's Stanford Bulletin (http://exploredegrees.stanford.edu/archive/2012-13/schoolofengineering/civilandenvironmentalengineering/ #bachelorofsciencetext-enviengi) for program requirements (click on Environmental Engineering in the right hand menu). Any current Environmental Engineering major wishing ABET accreditation must graduate by June 2015.

Mission of the Undergraduate Program in Environmental Systems Engineering

The mission of the undergraduate program in Environmental Systems Engineering is to prepare students for incorporating environmentally sustainable design, strategies and practices into natural and built systems and infrastructure involving buildings, water supply, and coastal regions. Courses in the program are multidisciplinary in nature, combining math/science/engineering fundamentals, and tools and skills considered essential for an engineer, along with a choice of one of three focus areas for more in-depth study: coastal environments, freshwater environments, or urban environments. This major offers the opportunity for a more focused curriculum than the Environmental and Water Studies concentration in the Civil Engineering degree program. The program of study, which includes a capstone experience, aims to equip engineering students to take on the complex challenges of the 21st Century involving natural and built environments, in consulting and industry as well as in graduate school.

Requirements

Mathematics and Science

See Basic Requirement 1 and 2 1

36

Technology in Society (TIS)

One 3-5 unit course required, see Basic Requirement 4

3-5

Engineering Fundamentals

Three courses minimum (see Basic Requirement 3), including:

ENGR 70A Programming Methodology 5

(or ENGR 70X)

(req’d) plus one of the following courses:

ENGR 90 Environmental Science and Technology

Fundamentals Tools/Skills 2

in Visual, Oral/Written Communication, and Modeling/Analysis

Specialty Courses, in either

Coastal Environments (see Below)

36

or Freshwater Environments (see Below)

or Urban Environments (see Below)

Total Units

96-100

1 Math must include CME 100 Vector Calculus for Engineers (or MATH 51 Linear Algebra and Differential Calculus of Several Variables), and either a Probability/Statistics course or CME 102 Ordinary Differential Equations for Engineers (or MATH 53 Ordinary Differential Equations with Linear Algebra). Science must include PHYSICS 41 Mechanics; and either ENGR 31 Chemical Principles with Application to Nanoscale Science and Technology, CHEM 31B Chemical Principles II or CHEM 31X Chemical Principles Accelerated (or PHYSICS 43 Electricity and Magnetism, for Urban track only).

2 Fundamental Tools/Skills must include: (a) CEE 1 Introduction to Environmental Systems Engineering (offered AY 2015-16); (b) at least one Visual Communication class from CEE 31 Accessing Architecture Through Drawing / CEE 31Q Accessing Architecture Through Drawing, CEE 133F Principles of Freehand Drawing, ME 110 Design Sketching, ARTSTUDI 160 Design 1: Fundamental Visual Language, or OSPPARIS 44 EAP: Analytical Drawing and Graphic Art; (c) at least one Oral/Written Communication class from ENGR 103 Public Speaking (or ORALCOMM 122 "The TED Commandments": The Art and Heart of Effective Public Speaking), ENGR 202W Technical Writing, CEE 151 Negotiation, EARTHSYS 195 Natural Hazards and Risk Communication or ENVRES 200 Sustaining Action: Research, Analysis and Writing for the Public; and (d) at least one Modeling/Analysis class from CEE 155 Introduction to Sensing Networks for CEE, CEE 120A Building Information Modeling Workshop (or CEE 120B Building Information Modeling Workshop), CEE 226 Life Cycle Assessment for Complex Systems, EARTHSYS 144 Fundamentals of Geographic Information Science (GIS), ENERGY 160 Modeling Uncertainty in the Earth Sciences, CEE 101D Computations in Civil and Environmental Engineering (if not counted as Math), or CEE 211 Introduction to Programming for Scientists and Engineers (or EARTHSYS 211 Fundamentals of Modeling).

Urban Environments Focus Area (36 units)

Required

CEE 100 Managing Sustainable Building Projects 4

CEE 101B Mechanics of Fluids 4

CEE 176A Energy Efficient Buildings 3-4

Electives

Building Systems

CEE 102 Legal Principles in Design, Construction, and Project Delivery 3

CEE 130 Architectural Design: 3-D Modeling, Methodology, and Process 4

CEE 156 Building Systems 4

Energy Systems

CEE 173A Energy Resources 3-5

CEE 176B Electric Power: Renewables and Efficiency 3-4
### Freshwater Environments Focus Area (36 units)

**Required**
- CEE 171: Energy Infrastructure, Technology and Economics 3
- CEE 191: Optimization of Energy Systems 3-4

**Water Systems**
- CEE 166A: Watersheds and Wetlands 3
- CEE 166B: Floods and Droughts, Dams and Aqueducts 3
- CEE 174A: Providing Safe Water for the Developing and Developed World 3
- CEE 174B: Wastewater Treatment: From Disposal to Resource Recovery 3

**Urban Planning**
- CEE 171: Environmental Planning Methods 3
- CEE 177L: Smart Cities & Communities 2-3
- URBANST 113: Introduction to Urban Design: Contemporary Urban Design in Theory and Practice 5
- or
- URBANST 164: Sustainable Cities 4-5
- or
- URBANST 165: Sustainable Urban and Regional Transportation Planning 4-5

**Capstone**
- CEE 112A: Industry Applications of Virtual Design & Construction 2-4
- and
- CEE 112B: Industry Applications of Virtual Design & Construction 2-4
- CEE 141A: Infrastructure Project Development 3
- CEE 141B: Infrastructure Project Delivery 3
- CEE 221A: Planning Tools and Methods in the Power Sector 3-4

**Electives**
- (if not counted as a req’d course)
  - CEE 160: Mechanics of Fluids Laboratory 2
  - CEE 166A: Watersheds and Wetlands 3
  - CEE 174A: Providing Safe Water for the Developing and Developed World 3
  - CEE 199: Undergraduate Research in Civil and Environmental Engineering 3-4

**Freshwater Environments Focus Area (36 units)**

**Required**
- CEE 101B: Mechanics of Fluids 4
- CEE 164: Introduction to Physical Oceanography 4
- CEE 175A: California Coast: Science, Policy, and Law 3-4

**Electives**
- CEE 160: Mechanics of Fluids Laboratory 2
- CEE 166A: Watersheds and Wetlands 3
- CEE 171: Environmental Planning Methods 3
- CEE 174A: Providing Safe Water for the Developing and Developed World 3
- CEE 174B: Wastewater Treatment: From Disposal to Resource Recovery 3
- CEE 177: Aquatic Chemistry and Biology 4
- CEE 272: Coastal Contaminants 3-4
- BIO 30: Ecology for Everyone 4
- EARTHSYS 8: The Oceans: An Introduction to the Marine Environment 3
- or
- GES 8: Oceanography: An Introduction to the Marine Environment 3
- EARTHSYS 141: Remote Sensing of the Oceans 3-4
- EARTHSYS 146B: Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation 3
- EARTHSYS 151: Biological Oceanography 3-4
- to be taken concurrently with
- EARTHSYS 152: Marine Chemistry 3-4

**Capstone (1 class req’d)**
- CEE 141A: Infrastructure Project Development 3
- CEE 169: Environmental and Water Resources Engineering Design 5
- CEE 179C: Environmental Engineering Design 5
- CEE 199: Undergraduate Research in Civil and Environmental Engineering 3-4

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

### Honors Program

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

The program involves an in-depth research study in an area proposed to and agreed to by a Department of Civil and Environmental Engineering faculty adviser and completion of a thesis of high quality. A written proposal...
for the research to be undertaken must be submitted and approved by the faculty advisor in the fourth quarter prior to graduation. At the time of application, the student must have an overall grade point average (GPA) of at least 3.3 for course work at Stanford; this GPA must be maintained to graduation. The thesis is supervised by a CEE faculty adviser and must involve input from the School of Engineering writing program by means of ENGR 202S Writing: Special Projects or its equivalent. The written thesis must be approved by the thesis adviser. Students are encouraged to present their results in a seminar for faculty and students. Up to 10 units of CEE 199H Undergraduate Honors Thesis, May be taken to support the research and writing (not to duplicate ENGR 202S). These units are beyond the normal Civil Engineering or Environmental Systems Engineering major program requirements.

Minor in Civil Engineering or Environmental Systems Engineering

The department offers a minor in Civil Engineering and a minor in Environmental Systems 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.

Civil Engineering (CE) Minor

The civil engineering minor is intended to give students a focused introduction to one or more areas of civil engineering. Departmental expertise and undergraduate course offerings are available in the areas of Architectural Design, Construction Engineering and Management, and Structural and Geotechnical Engineering. Students interested in Environmental and Water Studies should refer to the Environmental Systems Engineering minor.

The minimum prerequisite for a civil engineering minor is MATH 42 Calculus (or MATH 21 Calculus); however, many courses of interest require PHYSICS 41 Mechanics and/or MATH 51 Linear Algebra and Differential Calculus of Several Variables as prerequisites. The minimum prerequisite for a Civil Engineering minor focusing on architectural design is MATH 41 Calculus (or MATH 19 Calculus) and a course in Statistics. Students should recognize that a minor in civil engineering is not an ABET-accredited degree program.

Since undergraduates having widely varying backgrounds may be interested in obtaining a civil engineering minor, and the field itself is so broad, no single set of course requirements will be appropriate for all students. Instead, interested students are encouraged to propose their own set of courses within the guidelines listed below. Additional information on preparing a minor program is available in the Undergraduate Engineering Handbook (http://ughb.stanford.edu) .

General guidelines are—

1. A civil engineering minor must contain at least 24 units of course work not taken for the major, and must consist of at least six classes of at least 3 units each of letter-graded work, except where letter grades are not offered.
2. The list of courses must represent a coherent body of knowledge in a focused area, and should include classes that build upon one another. Example programs are given on the CEE webpage.

Professor Anne Kiremidjian (kiremidjian@stanford.edu) is the CEE undergraduate minor adviser in Structural Engineering and Construction

Environmental Systems Engineering (EnvSE) Minor

The Environmental Systems Engineering minor is intended to give students a focused introduction to one or more areas of Environmental Systems Engineering. Departmental expertise and undergraduate course offerings are available in the areas of environmental engineering and science, environmental fluid mechanics and hydrology, and atmosphere/energy. The minimum prerequisite for an Environmental Systems Engineering minor is MATH 42 Calculus (or MATH 21 Calculus); however, many courses of interest require PHYSICS 41 Mechanics and/or MATH 51 Linear Algebra and Differential Calculus of Several Variables as prerequisites. Students should recognize that a minor in Environmental Systems Engineering is not an ABET-accredited degree program.

Since undergraduates having widely varying backgrounds may be interested in obtaining an environmental systems engineering minor, no single set of course requirements is appropriate for all students. Instead, interested students are encouraged to propose their own set of courses within the guidelines listed below. Additional information on preparing a minor program is available in the Undergraduate Engineering Handbook (http://ughb.stanford.edu) .

General guidelines are—

1. An Environmental Systems Engineering minor must contain at least 24 units of course work not taken for the major, and must consist of at least six classes of at least 3 units each of letter-graded work, except where letter grades are not offered.
2. The list of courses must represent a coherent body of knowledge in a focused area, and should include classes that build upon one another. Example programs are available on the CEE web site (http://cee.stanford.edu/prospective/undergrad/minor_overview.html) and in Chapter 6 of the Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu) .

Professor Lynn Hildemann (hildemann@stanford.edu) is the CEE undergraduate minor adviser in Environmental Systems Engineering. Students must consult with Professor Hildemann in developing their minor program, and obtain approval of the finalized study list from her.

Coterminal B.S./M.S. Program in Civil and Environmental Engineering

Stanford undergraduates who wish to continue their studies for the Master of Science degree in the coterminal program at Stanford must have earned a minimum of 120 units towards graduation. This includes allowable Advanced Placement (AP) and transfer credit. Applicants must submit their application no later than the quarter prior to the expected completion of their undergraduate degree and are expected to meet the Department of Civil and Environmental Engineering application deadlines for coterminal applicants for graduate study (January 16, 2015). Applications are considered once a year during Winter Quarter. An application must display evidence of potential for strong academic performance as a graduate student.

It is recommended that students who contemplate advanced study at Stanford discuss their plans with their advisers in the junior year.

University requirements for the coterminal M.S. are described in the "Coterminal Bachelor's and Master's Degrees (http://exploredegrees.stanford.edu/archive/2014-15/cotermdegrees) " section of
this bulletin. For University coterminal degree program rules and University application forms, see the Stanford Undergrad Coterm Guide (http://undergrad.stanford.edu/advising/student-guides/coterm).

Master of Science in Civil and Environmental Engineering

The following programs are available leading to the M.S. degree in Civil and Environmental Engineering:

- Atmosphere/Energy
- Environmental Engineering and Science
- Environmental Fluid Mechanics and Hydrology
- Geomechanics
- Structural Engineering
- Sustainable Design and Construction

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

The program of study must be approved by the faculty of the department and should include at least 45 units of courses in engineering, mathematics, science, and related fields unless it can be shown that other work is pertinent to the student’s objectives. Additional program area requirements are available on the department web site and from the department’s student services office (Y2E2 room 316).

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

Engineer in Civil and Environmental Engineering

A student with an M.S. in Civil Engineering may satisfy the requirements of the degree of Engineer in Civil and Environmental Engineering by completing 45 unduplicated course work and research units for a total of 90 units. Engineer candidates must submit an acceptable thesis (12-15 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. For students who will continue study toward a CEE Ph.D., the Engineer thesis topic must be significantly different from their doctoral research.

Graduate students who lack adequate background in their area of specialization (e.g. lack a prior degree in civil engineering, if required in their program) or who are not full-time students should expect to be enrolled for more than two years. Engineer degree candidates should develop individually tailored expected-progress timetables in consultation with their program advisers.

For graduate students not currently attending Stanford, admission to study for the Engineer degree in the Department of Civil and Environmental Engineering begins with the office of Graduate Admissions (http://www.stanford.edu/home/admission/index/html).

If you are currently pursuing a graduate degree at Stanford, and wish to apply for the Engineer degree program, submit an Application for Post-Masters Study (available in the department office, Y2E2 Room 314). This form is typically filed during your second quarter of graduate study, preferably before January 1, so that your application may be reviewed during the normal graduate admissions cycle. You may apply at a later date if your adviser feels that it is appropriate to do so.

A minimum of 90 quarter units of full-time graduate study (or equivalent part-time graduate study) is required for the Engineer degree. For most students, the master's degree supplies 45 of these units.

If your master's degree was obtained at another school, you can apply to transfer up to 45 quarter units of residency credit by completing an Application for Transfer Credit for Graduate Work Done Elsewhere. No units need to be transferred if you hold an M.S. degree from Stanford.

Doctor of Philosophy in Civil and Environmental Engineering

The Ph.D. is offered under the general regulations of the University as set forth in the “Graduate Degrees” section of this bulletin. This degree is recommended for those who expect to engage in a professional career in research, teaching, or technical work of an advanced nature. The Ph.D. program requires a total of 135 units of graduate study, at least 90 units of which must be at Stanford. Up to 45 units of graduate study can be represented by the M.S. program described above. Students must maintain a minimum GPA of 3.0 in post-M.S. course work. All candidates for the Ph.D. degree are required to complete CEE 200 in conjunction with a one-quarter teaching assistantship/course assistantship to gain training and instructional experience. Further information on Ph.D. requirements and regulations is found in the department Graduate Handbook.

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

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


Ph.D. Minor in Civil and Environmental Engineering

A Ph.D. minor is a program outside a major department. Requirements for a minor are established by the minor department. Acceptance of the minor as part of the total Ph.D. program is determined by the major department. Application for the Ph.D. minor must be approved by both the major and the minor department, and the minor department must be represented at the University oral examination.

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

The program must include at least 20 units of graduate-level course work (courses numbered 200 or above, excluding special studies and thesis) in CEE completed at Stanford University. Units taken for the minor cannot be counted as part of the 45 unduplicated units for the Ph.D. major. 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.


Chair: Stephen G. Monismith

Associate Chair: Sarah Billington


Associate Professors: Jack W. Baker, Alexandria B. Boehm, Jennifer Davis, David L. Freyberg, Oliver B. Fringer, Eduardo Miranda, William A. Mitchell

Assistant Professors: Michael D. Lepech, Christian Linder, Ram Rajagopal

Courtesy Professors: Peter M. Pinsky, David D. Pollard

Courtesy Associate Professor: Margot G. Gerritsen

Courtesy Assistant Professor: Karen L. Cassiotti


Consulting Associate Professors: Edward S. Gross, Gloria T. Lau, Karl Knapp, Colin Ong, Ryan J. Orr, Joel N. Swisher, Jie Wang

Shimizu Visiting Professor: Jennifer Whyte

UPS Visiting Associate Professor: Angela Lin

* Recalled to active duty.

Overseas Studies Courses in Civil and Environmental Engineering

The Bing Overseas Studies Program (http://bosp.stanford.edu) manages Stanford study abroad programs for Stanford undergraduates. Students should consult their department or program’s student services office for applicability of Overseas Studies courses to a major or minor program.

The Bing Overseas Studies course search site (https://undergrad.stanford.edu/programs/bosp/explore/search-courses) displays courses, locations, and quarters relevant to specific majors.

For course descriptions and additional offerings, see the listings in the Stanford Bulletin’s ExploreCourses (http://exploreCourses.stanford.edu) or Bing Overseas Studies (http://bosp.stanford.edu).

<table>
<thead>
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<th>Units</th>
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<tr>
<td>OSPAUSTL 10 Coral Reef Ecosystems</td>
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<tr>
<td>OSPAUSTL 25 Freshwater Systems</td>
</tr>
<tr>
<td>OSPAUSTL 30 Coastal Forest Ecosystems</td>
</tr>
<tr>
<td>OPSANTG 31 The Chilean Energy System: 30 Years of Market Reforms</td>
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Note: OSPAUSTL 10 may count towards the ENVEN-BS and the CE-BS with Specialty in Environmental & Water Studies, however it does not count towards the CE-BS with Specialty in Structures & Construction.

Courses

CEE 1. Introduction to Environmental Systems Engineering. 1 Unit.
Field trips visiting environmental systems installations in Northern California, including coastal, freshwater, and urban infrastructure. Requirements: Several campus meetings, and field trips. Enrollment limited; priority given to undergraduates who have declared Environmental Systems Engineering major. Contact hildemann@stanford.edu to request enrollment/permission code.

CEE 1A. Graphics Course. 1 Unit.
This course, intended for students taking a design studio, will focus on presentation theories, skills and design approaches. Through readings and exercises, and ultimately the student’s own work, students will develop skill and complexity in their graphic and verbal presentations.

CEE 10. Introduction to the Civil & Environmental Engineering Majors. 1 Unit.
Open to freshman and sophomores; limited enrollment. Overview of undergraduate majors and possible career paths in Civil Engineering, Environmental Engineering, Atmosphere/Energy, and Architectural Design. Panel discussions with current undergraduate majors, and with alums. Hands-on activities with faculty in CEE. For students with interest areas such as water resources, environmental biotechnologies, sustainability, architecture, infrastructure planning, global warming, green energy, structures, and construction.

CEE 10A. Introduction to Architecture. 2 Units.
This class introduces students to the discipline of architecture and to the fundamental question: What is an architect and how is architecture distinct from other arts and sciences? To answer this question, the class will focus on concepts important to the practice of architecture including: project conception, drawing, modeling, materials, structure, form, and professionalism. These terms will be investigated through short talks, site visits, historical precedent, in-class exercises, panel discussions and two on-campus case studies. No prior knowledge of architecture is required.
CEE 10AX. Chicago Architecture: History and Form. 2 Units.
Chicago is America's architectural hub. Rebuilt, phoenix-like, out of a devastating fire, but at a moment of great technological change, Chicago is the birthplace of grand American planning - the high-rise, construction technologies - and continues to this day to be a place of urban and architectural innovation. This course students will be introduced to the history of Chicago including the Burnham Plan, the technological developments of the iron structure, modern curtain wall, and elevator that allowed for the first high-rises, the subsequent development of innovative structural systems, and the modern high-rise. Further investigation will include the legacies of Louis Sullivan, Frank Lloyd Wright, Mies Van Der Rohe, SOM, and others. Based at a Chicago Architecture firm, the class will mix a short high-rise design exercise on a real site with discussions with local architects, field trips to landmark structures, and exploration of current development and planning issues. The course will include extensive walks and trips using local transit. This course is open to all students regardless of their experience in architecture.

CEE 10B. Presentation Skills. 0 Units.

CEE 11SC. People, Land, and Water in the Heart of the West. 2 Units.
Salmon River. Sun Valley. Pioneer Mountains. The names speak of powerful forces and ideas in the American West. Central Idaho - a landscape embracing snow-capped mountains, raging rivers, sagebrush deserts, farms, ranches, and resort communities - is this classroom for a field-based seminar led by David Freyberg, professor of Civil and Environmental Engineering, and David Kennedy, professor emeritus of History. This course focuses on the history and future of a broad range of natural resource management issues in the western United States. We will spend a week on campus preparing for a two-week field course in Idaho exploring working landscapes, private and public lands, water and fisheries, conservation, and the history and literature of the relationship between people and the land in the American West. After the first week spent on campus, we will drive to Idaho to begin the field portion of our seminar. In Idaho, we will spend time near Twin Falls, at Lava Lake Ranch near Craters of the Moon National Monument, in Custer County at the Upper Salmon River, and near Stanley in the Sawtooth National Forest. No prior camping experience is required, but students should be comfortable living outdoors in mobile base camps for periods of several days. Students will investigate specific issues in-depth and present their findings at the end of the course. Same as: EARTHSYS 13SC

CEE 12SC. Good Food, Fast Cars, Great Spaces: Connections Between Architecture, Cooking, Photography, Design. 2 Units.
Why is it that architects almost routinely share passions for cuisine, vehicles, photography, and sailing? Many chefs were trained as architects, most architects are excellent cooks and photographers, and a stunning number of architects own boats. This course will explore the key design ideas, notions of creativity, and interest in form that thread through each of these professions. The first half of the course will focus on readings and discussion about creativity and form; the second half will test a single conceptual idea through a series of projects in two or three fields. Possible field trips may include a visit to Tesla, America's Cup events in SF, Baune (2 Michelin Star restaurant in Palo Alto), IDEO, and architecture firms.

CEE 13SC. Energizing a Sustainable Future. 2 Units.
The economic advancement, social equity, and planet earth habitat of your and future generations depend in major part on preparing for sustainable supply and efficient use of energy. The objective of this course is to provide a foundation for your future scholarship and action to increase energy sustainability. We will explore three major energy activities: development of fossil and renewable resources; conversion to useful forms; and use in buildings, transportation, and industry. All are strongly influenced by the energy markets, technologies, and policies that we will also study. Our quest for a sustainable energy future will begin at Stanford's Bass Center in Washington D.C. and conclude back on the Farm. This will allow access to policy makers and major organizations along with plans for major improvements to Stanford's energy system and buildings. The course requires: query responses on the readings in advance of class sessions; participation in morning class discussions and afternoon activities with key energy players; in teams of two, analysis of a self-selected topic related to an energy market or technology; and a group course project to analyze an energy policy or proposal. It is offered for two units with Satisfactory/No Credit grading. Students cover their own travel to the Bass center and arrive by 5 p.m. on September 6. The program will cover your travel to campus on September 16. Students planning to observe religious holidays during September Studies should check with the instructor to work through potential conflicts.

CEE 13SI. Introduction to Architectural Modeling. 2 Units.
Architecture is half design, half communicating design. In this course, students will gain the skills necessary to communicate architectural concepts through 3D modeling. From foam core to basswood to less known materials, students will gain a tactile understanding of material qualities and present their study models in portfolio format. Special focus will also be placed on techniques incorporating both computer-aided drafting and physical modeling through the laser cutter machine. No prior experience is necessary, but students will be expected to work in the studio outside of class time. Unlimited enrollment. Please contact Derek Ouyang at derekouyang@gmail.com for more info. Class meets in PRL 36.

CEE 14SC. When Engineers Go Sailing: the Science and Technology of America's Cup Yachts and Matches. 2 Units.
Intense competition drives technological advancement in many sports; the America's Cup sailing competition stands out as a leading venue for innovation. The 34th AC competition will take place in San Francisco Bay during September 2013, providing close proximity, great timing, and the showcasing of major new technologies to create a special learning opportunity for Sophomore College students. This seminar will introduce students to engineering fundamentals, computer-based modeling and design, and advanced materials, using America's Cup technology as examples. The course will include guest speakers from America's Cup teams, visits to facilities, and field trips to matches. Students will complete readings and queries prior to the class sessions; class and laboratory exercises for sailing, modeling, and materials testing; group observation and analysis of America's Cup races; and group course projects analyzing a part of the technology for America's Cup yacht. The course will also explore how students can apply engineering fundamentals, modeling techniques, advanced materials, and processes of innovation to other activities and industries. The seminar is offered for 2 units with S/NC grading.
CEE 16SC. Energy in the Southwest. 2 Units.
We will examine the technical, social, and political issues surrounding energy management and use in the West, using California, Nevada, and Arizona as our field laboratory. Students will explore a number of energy narratives, such as: How does our energy and from what sources?; How is it transported?; Who distributes to users and how do they do it?; What is the role of water energy and water-energy nexus; Meeting carbon emission goals by 2020; Conflicts between desert ecosystems and renewable energy development. We will place particular emphasis on renewable energy sources and the water-energy nexus, a critically important issue for the arid and semi-arid southwest. Central to the course will be field exploration in northern and southern California, as well as neighboring areas in Arizona and Nevada, to tour sites such as wind and solar facilities, geothermal plants, hydropower pumped storage, desalination plants, water pumping stations, liquid fuels distribution operations centers, and California Independent System Operator. Students will have the opportunity to meet with community members and with national, state, and regional authorities to discuss Western energy challenges and viable solutions. We will also take advantage of Stanford's own energy systems with site visits to the new energy facilities. Throughout the seminar, we will be introduced to the basics of energy and energy politics through discussions, lectures, and conversations. Over the summer, students will be responsible for assigned readings, online interactive materials, and relevant recent news articles. Participants will return to Stanford by September 19. Travel expenses during the course will be provided (except incidentals) by the Bill Lane Center for the American West and Sophomore College.

Same as: ENERGY 11SC, POLISCI 25SC

CEE 20. Elementary Surveying. 0-60 Units.

CEE 29N. Managing Natural Disaster Risk. 3 Units.
Natural disasters arise from the interaction of natural processes, such as earthquakes or floods, with human development that suffers safety-related and economic losses. We cannot predict exactly when those disasters will occur, or prevent them entirely, but we have a number of engineering and policy options that can reduce the impacts of such events.

CEE 31. Accessing Architecture Through Drawing. 4 Units.
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.

CEE 31B. Architectural Drawing and Rendering. 4 Units.
Course will expand on basics taught in CEE 31. Refreshers on the basics of plans, sections, elevations, axonometrics, and perspectives. Students will be encouraged in conceptual thinking and translating concepts into Architecture. Introduction of computers for renderings and drafting as well as expanding on early model building. Field trip.

CEE 31Q. Accessing Architecture Through Drawing. 4 Units.
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.

CEE 32A. Psychology of Architecture. 3 Units.
This course argues that architecture often neglects the interdisciplinary investigation of our internal psychological experience and the way it impacts our creation of space. How does our inner life influence external design? How are we impacted emotionally, physically, psychologically by the spaces we inhabit day to day? How might we intentionally imbue personal and public spaces with specific emotions? This seminar serves as a call to action for students interested in approaching architecture with a holistic understanding of the emotional impact of space. Sample topics addressed will include: conscious vs. unconscious design; the ego of architecture; psycho-spatial perspectives; ideas of home; integral/holistic architecture; phenomenology of inner and outer spaces; exploring archetypal architecture; and translating emotion through environment.

CEE 32B. Design Theory. 4 Units.
This seminar focuses on the key themes, histories, and methods of architectural theory -- a form of architectural practice that establishes the aims and philosophies of architecture. Architectural theory is primarily written, but it also incorporates drawing, photography, film, and other media. One of the distinctive features of modern and contemporary architecture is its pronounced use of theory to articulate its aims. One might argue that modern architecture is modern because of its incorporation of theory. This course focuses on those early-modern, modern, and late-modern writings that have been and remain entangled with contemporary architectural thought and design practice. Rather than examine the development of modern architectural theory chronologically, it is explored through thematic topics. These themes enable the student to understand how certain architectural theoretical concepts endure, are transformed, and can be furthered through his/her own explorations.

CEE 32D. Construction: The Writing of Architecture. 4 Units.
This seminar focuses on the construction of architectural writing. The class will analyze this idea through four topics: formal analysis, manifesto, translation, and preservation. The seminar is divided into two-week modules with each of these four concepts functioning as organizing principles. The first week of each module will involve familiarizing the student with each of these four topics in the context of a specific example, case study, or recent event. The second week will involve further analysis in addition to each student writing a short paper (3-4 pages) discussing the example discussed and the student's own experiences in the discipline. The goal of the seminar is for each student to be able to analyze how an architectural writing is constructed and to develop his/her skills in the construction of his/her own writing.

CEE 32F. Light, Color, and Space. 3 Units.
This course explores color and light as a medium for spatial perception. Through the introduction of color theory, color mixing, and light analyses, students will learn to see and use light and color fields as a way to shape experience. We will examine the work of a range of artists and architects who use light and color to expand the field of perception (i.e. Rothko, Turrell, Eliasson, Holl, Aalto).

CEE 32G. Architecture Since 1900. 4 Units.
Art 142 is an introduction to the history of architecture since 1900 and how it has reshaped and been shaped by its cultural contexts. The class also investigates the essential relationship between built form and theory during this period.

Same as: ARTHIST 142
CEE 32H. Transparent Structures: Design-Build Seminar Proposal. 2 Units.
This design-build seminar investigates the use of glass as a structural system and spatial medium. We will examine the physical and visual properties of engineered high-strength glass, and develop structural systems and spatial configurations that will expand our understanding of what glass can do. The seminar will culminate in a full-scale installation of the developed design on campus. The experiential objectives of the seminar draw upon Colin Rowe’s definition of phenomenal transparency as a unique spatial order, in which the perception of space is fluctuating and in constant activity. The installation will act as a filter through which the surrounding context will be redefined, resulting in a complex spatial experience.

CEE 32Q. Place: Making Space Now. 3 Units.
This seminar argues that architects are ultimately “placemakers,” and questions what that means in the contemporary world. Part I investigates the meaning of the word “place.” Additional background for understanding contemporary place making will include a critique of the history of modern place-making through an examination of modern form. Part II examines two traditional notions of place by scale: from “home” to “the city.” What elements give these conceptions of space a sense of place? To answer this question, themes such as memory, mapping, and boundary, among others, will be investigated. Part III presents challenges to the traditional notions of place discussed in Part II. Topics addressed include: What does it mean to be “out of place”? What sense of place does a nomad have, and how is this represented? What are the “non-places” and how can architects design for these spaces? Part IV addresses the need to re-conceptualize contemporary space. The role of digital and cyber technologies, the construction of locality in a global world, and the in-between places that result from a global world in flux are topics discussed in this section of the seminar. Learning goals: Specific goals include close reading of texts, understanding of philosophical thinking and writing, argument under uncertainty, and developed concepts of place, space and architecture.

CEE 44Q. Critical Thinking and Career Skills. 3 Units.

CEE 46Q. Fail Your Way to Success. 3 Units.
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.

CEE 48N. Managing Complex, Global Projects. 3 Units.
This freshman seminar highlights the challenges the challenges associated with planning and executing complex and challenging global projects in private, governmental and nonprofit/NGO settings. Covers organization and project management theory, methods, and tools to optimize the design of work processes and organizations to enhance complex, global project outcomes. Student teams model and analyze the work process and organization of a real-world project team engaged in a challenging local or global project.

CEE 50N. Multi-Disciplinary Perspectives on a Large Urban Estuary: San Francisco Bay. 3 Units.
This course will be focused around San Francisco Bay, the largest estuary on the Pacific coasts of both North and South America as a model ecosystem for understanding the critical importance and complexity of estuaries. Despite its uniquely urban and industrial character, the Bay is of immense ecological value and encompasses over 90% of California’s remaining coastal wetlands. Students will be exposed to the basics of estuarine biogeochemistry, microbiology, ecology, hydrodynamics, pollution, and ecosystem management/restoration issues through lectures, interactive discussions, and field trips. Knowledge of introductory biology and chemistry is recommended. Same as: EARTH/SYS 49N, EESS 49N

CEE 63. Weather and Storms. 3 Units.
Daily and severe weather and global climate. Topics: structure and composition of the atmosphere, fog and cloud formation, rainfall, local winds, wind energy, global circulation, jet streams, high and low pressure systems, inversions, el Niño, La Niña, atmospheric/ ocean interactions, fronts, cyclones, thunderstorms, lightning, tornadoes, hurricanes, pollutant transport, global climate and atmospheric optics. Same as: CEE 263C

CEE 64. Air Pollution and Global Warming: History, Science, and Solutions. 3 Units.
Survey of sources of air pollution and global warming and their renewable energy solutions. Topics: evolution of the Earth’s atmosphere, history of discovery of chemicals in the air, bases and particles in urban smog, visibility, indoor air pollution, acid rain, stratospheric and Antarctic ozone layer loss, the historic climate record, causes and effects of global warming, impacts of energy systems on pollution and climate, renewable energy solutions to air pollution and global warming. UG Reqs: GER: DBNatSci. Same as: CEE 263D

CEE 70. Environmental Science and Technology. 3 Units.
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. Same as: ENGR 90

CEE 70N. Water, Public Health, and Engineering. 3 Units.
Preference to sophomores. Linkages between water, wastewater and public health, with an emphasis on engineering interventions. Topics include the history of water and wastewater infrastructure development in the U.S. and Europe; evolution of epidemiological approaches for water-related health challenges; biological and chemical contaminants in water and wastewater and their management; and current trends and challenges in access to water and sanitation around the world. Identifying ways in which freshwater contributes to human health; exposure routes for water-and sanitation-illness. Classifying illnesses by pathogen type and their geographic distribution. Identifying the health and economic consequences of water- and sanitation-related illnesses; costs and benefits of curative and preventative interventions. Interpreting data related to epidemiological and environmental concepts. No previous experience in engineering is required.

CEE 73. Foundations of Water Science and Engineering. 3 Units.
Water physics and chemistry shape our world. Without water there is no life, no biology. This class provides an introduction to these basic sciences as applied to water and considers how they interact to give water its critical role in the processes that sustain, and sometimes poison, our planet. We will explore both the natural world and the engineered systems critical to civilization.

CEE 100. Managing Sustainable Building Projects. 4 Units.
Managing the life cycle of buildings from the owner, designer, and contractor perspectives emphasizing sustainability goals; methods to define, communicate, coordinate, and manage multidisciplinary project objectives including scope, quality, life cycle cost and value, schedule, safety, energy, and social concerns; roles, responsibilities, and risks for project participants; virtual design and construction methods for product, organization, and process modeling; lifecycle assessment methods; individual writing assignment related to a real world project.

CEE 101A. Mechanics of Materials. 4 Units.
Introduction to beam and column theory. Normal stress and strain in beams under various loading conditions; shear stress and shear flow; deflections of determinate and indeterminate beams; analysis of column buckling; structural loads in design; strength and serviceability criteria. Lab experiments. Prerequisites: ENGR 14.
CEE 101B. Mechanics of Fluids. 4 Units.
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: E14, PHYSICS 41 (formerly 53), MATH 51.

CEE 101C. Geotechnical Engineering. 3-4 Units.
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.

CEE 101D. Computations in Civil and Environmental Engineering. 3 Units.
Computational and visualization methods in the design and analysis of civil and environmental engineering systems. Focus is on applications of MATLAB. How to develop a more lucid and better organized programming style.
Same as: CEE 201D

CEE 101S. Science & Engineering Problem-Solving with MatLab.. 3 Units.
Introduction to the application of MATLAB to an array of engineering systems. Emphasis on computational and visualization methods in the design, modeling and analysis of engineering problems.
Same as: CEE 201S

CEE 102. Legal Principles in Design, Construction, and Project Delivery. 3 Units.
Introduction to the key legal principles affecting design, construction and the delivery of infrastructure projects. The course begins with an introduction to the structure of law, including principles of contract, negligence, professional responsibility, intellectual property, land use and environmental law, then draws on these concepts to examine current and developing means of project delivery.

CEE 107S. Energy Resources: Fuels and Tools. 3 Units.
Energy is a vital part of our daily lives. This course examines where that energy comes from, and the advantages and disadvantages across different fuels. Contextual analysis of energy decisions for transportation and electricity generation around the world. Energy resources covered include oil, biomass, natural gas, nuclear, hydropower, wind, solar, geothermal, and emerging technologies. Prerequisites: Algebra. Note: may not be taken by students who have completed CEE 173A, CEE 207 or EARTHSYS 103.
Same as: CEE 207S

CEE 109. Creating a Green Student Workforce to Help Implement Stanford's Sustainability Vision. 2 Units.
Examination of program-based local actions that promote resource conservation and an educational environment for sustainability. Examination of building-level actions that contribute to conservation, lower utility costs, and generate understanding of sustainability consistent with Stanford's commitment to sustainability as a core value. Overview of operational sustainability including energy, water, buildings, waste, and food systems. Practical training to enable students to become sustainability coordinators for their dorms or academic units.
Same as: EARTHSYS 109, ENVRINST 109

CEE 110A. Building Information Modeling and Short Course. 2-4 Units.
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 /instructor consent required.
Same as: CEE 210A

CEE 110B. Industry Applications of Virtual Design & Construction. 2-4 Units.
Building upon the concept of VDC Scorecard, CEE 111A/211A investigates in the management of Virtual Design and Construction (VDC) programs and projects in the building industry. Interacting with experts and professionals in real estate, architecture, engineering, construction and technology providers, students will learn from the industry applications of Building Information Modeling and its relationship with Integrated Project Delivery, Sustainable Design and Construction. Students will conduct case studies to evaluate the maturity of VDC planning, adoption, technology and performance in practice. Students taking 3 or 4 units will be paired up with independent research or case study projects on the industry applications of VDC. No prerequisite. See CEE 112B/212B in the Winter Quarter and CEE 112C/212C in the Spring Quarter.

CEE 112B. Industry Applications of Virtual Design & Construction. 2-4 Units.
CEE 112B/212B is a practicum on the Industry Applications on Virtual Design and Construction (VDC). Students will gain insights and develop skills that are essential for academic research, internships or industry practice in VDC and Building Information Modeling (BIM). Students can choose between one of the two project topics: [1] Industrialized Construction with Virtual Parts (No Prerequisite) or [2] Industry Benchmarking & Applications of the VDC Management Scorecard (Suggested Prerequisite: CEE 112A/212A).
Same as: CEE 212B

CEE 112C. Industry Applications of Virtual Design & Construction. 2-4 Units.
Following the Autumn- and Winter-quarter course series, CEE 112C/212C is an industry-focused and project-based practicum that focuses on the industry applications of Virtual Design and Construction (VDC). Students will be paired up with industry-based VDC projects with public owners and private developers, such as GSA Public Buildings Service, the Hong Kong Mass Transit Railway, Optima, Walt Disney Imagineering, Microsoft facilities and/or other CIFE International members. Independently, students will conduct case studies and/or develop VDC and building information models (BIM) using off-the-shelf technologies for project analysis, collaboration, communication and optimization. Students will gain insights and develop skills that are essential for academic research, internships or industry practice in VDC. Prerequisite: CEE 112A/212A, CEE 112B/212B, CEE 159C/259C, CEE 159D/259D, or Instructor's Approval.
Same as: CEE 212C

CEE 112D. Industry Applications of Virtual Design and Construction. 2-4 Units.
A continuation of the CEE 112/212 series, CEE 112D/212D is an industry-focused and project-based practicum that focuses on the industry applications of Virtual Design and Construction (VDC). Students will be paired up with industry-based VDC research or application opportunities with public owners and private developers, professional associations, and/or other member organizations of the Center for Integrated Facility Engineering at Stanford. Independently, students will conduct case studies, research activities, and/or develop VDC and building information models (BIM) using off-the-shelf technologies for project analysis, collaboration, communication and optimization. Students will gain insights and develop skills that are essential for academic research, internships or industry practice in VDC. Prerequisite: CEE 110/210, CEE 112C/212C, CEE 122B/222B, or Instructor's Approval.
Same as: CEE 212D
CEE 113. Patterns of Sustainability. 1-4 Unit.
This seminar examines the interrelated sustainability of the natural, built and social environments of places in which we live. Several BOSP centers and the home Stanford campus will hold this 1-2 unit seminar simultaneously and collaborate with a shared curriculum, assignments, web conference and a Wiki. The goal of the collaborative arrangement is to expose, share, compare and contrast views of sustainability in different parts of the world. We will look at and assess aspects of sustainability of the places we are living from a theoretical perspective from the literature, from observations and interviews in the countries in which we study. 
Same as: CEE 213

CEE 115. Goals and Methods of Sustainable Building Projects. 3 Units. 
(Graduate students register for 215.) Goals related to sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and economic and social sustainability. Methods to integrate these goals and enhance the economic, ecological, and equitable value of building projects. Industry and academic rating systems, project case studies, guest lecturers, and group project. 
Same as: CEE 215

CEE 120A. Building Information Modeling Workshop. 2-4 Units. 
The foundational Building Information Modeling course introduces techniques for creating, managing, and applying of building information models in the building design and construction process. The course covers processes and tools for creating, organizing, and working with 2D and 3D computer representations of building components and geometries to produce models used in architectural design, construction planning and documentation, rendering and visualization, simulation and analysis. 
Same as: CEE 220A

CEE 120B. Building Information Modeling Workshop. 2-4 Units. 
This course builds upon the Building Information Model concepts introduced in 110A/220A and illustrates how BIM modeling tools are used to design, analyze, and model building systems including structural, mechanical, electrical, plumbing and fire protection. The course covers the essential physical principles, design criteria, and design strategies for each system and explores processes and tools for modeling those systems and analyzing their performance. 
Same as: CEE 220B

CEE 120C. Parametric Design and Optimization. 2-4 Units. 
This course explores tools and techniques for computational design and parametric modeling as a foundation for design optimization. Class sessions will introduce several parametric design modeling platforms and scripting environments that enable rapid generation of 3D models and enable rapid evaluation of parametrically-driven design alternatives. Topics to be featured include: principles of parametric design vs. direct modeling, using scripting platforms (Revit FormIt, Rhino) in visual scripting languages and environments (Dynamo, Grasshopper, DesignScript) in Single- and multi-dimensional optimization techniques and guidance strategies. 
Same as: CEE 220C

CEE 120S. Building Information Modeling Special Study. 2-4 Units. 
Special studies of Building Information Modeling strategies and techniques focused on creating, managing, and applying models in the building design and construction process. Processes and tools for creating, organizing, and working with 2D and 3D computer representations of building components to produce models used in design, construction planning, visualization, and analysis. 
Same as: CEE 220S

CEE 122A. Computer Integrated Architecture/Engineering/Construction. 2 Units.
Undergraduates serve as apprentices to graduate students in the AEC global project teams in CEE 222A. Apprentices participate in all activities of the AEC team, including the goals, objectives, constraints, tasks, and process of a crossdisciplinary global AEC teamwork in the concept development phase of a comprehensive building project. Prerequisite: consent of instructor. 
Same as: A/E/C

CEE 122B. Computer Integrated A/E/C. 2 Units. 
Undergraduates serve as apprentices to graduate students in the AEC global project teams in CEE 222B. Project activity focuses on modeling, simulation, life-cycle cost, and cost benefit analysis in the project development phase. Prerequisite: CEE 122A.

CEE 124. Sustainable Development Studio. 1-5 Unit. 
(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.

CEE 127A. Energy System Design in Eastern Europe. 2 Units. 
Field-based seminar to evaluate and design future energy systems for Eastern Europe, 14-day field trip during early September 2013. Site visits, fact-finding, stakeholder meetings, presentation to policy makers. One unit for field trip; one unit for project deliverable. Prerequisite: consent of instructor. 
Same as: CEE 227A

CEE 127E. Infrastructure, Disruptive Technologies and Entrepreneurship. 1 Unit. 
Silicon Valley provides a dynamic environment perfectly suited for developing the disruptive technologies that are changing the faces of today's mainstream infrastructure systems and essential service industries. This course will provide an overview of the most exciting technologies emerging from Silicon Valley right now and the potential that exists to disrupt mainstream transportation, electricity, intelligence gathering, and banking infrastructure systems that were dominant in the 20th Century. Guest speakers include prominent CEOs, visionaries, investors, and serial entrepreneurs who are building game changing companies. 
Same as: CEE 227E

CEE 129. Climate Change Adaptation for Coastal Cities: Engineering and Policy for a Sustainable Future. 3 Units. 
How will climate change affect cities and how will cities respond? Includes an exploration of the threat of climate change to coastal cities worldwide and the potential engineering and policy responses. Understanding of the nature of the challenge of city adaptation planning in terms of earth systems, infrastructure development, urban planning, and social systems. Consideration of economic, social, legal and environmental implications. Student projects will contribute to on-going research. Interdisciplinary. Guest speakers, case studies, and readings. 
Same as: CEE 229

CEE 129S. Climate Change Adaptation in the Coastal Built Environment. 1 Unit. 
How will climate change impact coastal ports and harbors around the world? Leading experts discuss the latest science, policy, and engineering research on this important issue, including the necessary response to protect ports and harbors from significant sea-level rise and storm surge. Focus is on the built environment. Guest speakers. CEE 229/129 for research option. See www.groupspaces.com/seaports/2100. 
Same as: CEE 229S
CEE 130. Architectural Design: 3-D Modeling, Methodology, and Process. 4 Units.
Preference to Architectural Design majors; others by consent of instructor. Projects investigate conceptual approaches to the design of key architectural elements, such as wall and roof. Functional and structural considerations. Focus is on constructing 3-D models in a range of materials; 3-D computer modeling. Students keep a graphic account of the evolution of their design process. Final project entails design of a simple structure. Limited enrollment. Pre- or corequisite: CEE 31 or 31Q.

CEE 131. Architectural Design Process. 4 Units.
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.

CEE 131A. Professional Practice: Mixed-Use Design in an Urban Setting. 4 Units.
The delivery of a successful building design program involves unique collaboration between architect and client. This course will endeavor to teach the skills necessary for a designer to identify, evaluate, conceptualize and fully document a complex mixed-use urban design. Students will complete the course with a detailed knowledge of the consultants, engineers and other professionals needed for a complete project. Course deliverables will include three short assignments and a final project consisting of basic schematic drawings for the selected project. Guest presenters will cover topics of interest. Lectures, discussions, in-class studio-work and an oral presentation. Pre-requisite: CEE 130.

CEE 131B. Financial Management of Sustainable Urban Systems. 3 Units.
Focus is on financial management of sustainable urban systems. The course will study different kinds of financial services available, the management of financial resources, and relationships to financial service providers. The course will also study how financial services and relationships to financial service providers can be used to accomplish construction management, energy, and architecture work in sustainable urban systems. The learning outcome is an understanding of how financial services can be used in development of sustainable urban systems. The course work is structured so that there are three modules: 1) general knowledge of financial management, 2) in-depth application in construction management, energy, or architecture, and 3) comparison of similarities and differences in-between the in-depth applications in a group work, and present the result of this application to students that make other applications. A key learning aspect is the understanding of how finance is used in construction management, energy, and architecture work. Students should be able to show the value, financial viability, and risk management of sustainable urban system development in construction management, energy, and architecture. Students should be able to finance construction management, energy, and architecture work. Readings include applications of finance and management to construction management, energy, or architecture. Guest speakers include developers, financial managers at construction firms, managers at energy firms, construction managers.

CEE 132. Interplay of Architecture and Engineering. 4 Units.
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.

CEE 132Q. Office of Metropolitan Architecture: Workshop of the New. 4-5 Units.
This seminar investigates all aspects of the work of the Office of Metropolitan Architecture (OMA) and its leader Rem Koolhaas. Topics for class research and inquiry include but are not be limited to: Koolhaas’s early work at the Architectural Association and the founding of OMA, the publications of OMA and their style of presentation and theoretical foundations, the importance of AMO, and the architects who have left OMA and founded their own practices and how these differ from OMA. Each student completes an in-depth research paper and an in-class presentation. Same as: ARTHIST 262

CEE 133. Advanced Rhinoceros Modeling and Workflows. 3 Units.
Rhinoceros is a powerful 3D modeling program that provides great control and accuracy, and also allows great flexibility and creativity in the design process. Rhinoceros is used by many top-level architecture firms because it can be customized, it can be integrated with many other design programs, and has the potential to create unique and detailed forms. The course will concentrate on introducing students to the Rhinoceros platform in great depth so that they may comfortably utilize the program for any type of design project. In addition to basic and advanced modeling skills in Rhinoceros, the course will explore an integrated workflow between design environments. Comprehension will be expanded from simple 3D modeling to a process that optimizes the strengths of different design platforms. Students will study and implement an integrated workflow that connects powerful conceptual modeling with building information models in order to produce a quality design product ready for documentation and presentation. Same as: CEE 233

CEE 133F. Principles of Freehand Drawing. 3 Units.
Traditional methods of depicting shape, form, and surface are applied to the discipline of architectural drawing. Students develop abilities to observe visual phenomenon analytically and transcribe subjects onto a twodimensional surface in a variety of media. Drawing techniques such as modeling form, shading, rendering materials, and articulating landscaping are explored. Linear perspective exercises provide a foundation for the construction of drawings to illustrate cohesive design proposals. Step-by-step constructions, quick freehand sketches from slides, and on-location studies.

CEE 134A. Site and Space. 4 Units.
Preference to Architectural Design and CEE majors; others by consent of instructor. An architectural design studio exploring the Stanford Green Dorm project. Initial sessions develop a working definition of sustainable design and strategies for greening the built environment in preparation for design studio work. Enrollment limited to 14. Prerequisites: 31 or 31Q, and 110 and 130.

CEE 134B. Intermediate Arch Studio. 4 Units.
This studio offers students experience in working with a real site and a real client program to develop a community facility. Students will develop site analysis, review a program for development and ultimately design their own solutions that meet client and community goals. Sustainability, historic preservation, community needs and materials will all play a part in the development of students final project. Students will also gain an understanding of graphic conventions, verbal and presentation techniques. Course may be repeated for credit. Same as: CEE 234B

CEE 135. Parametric Modeling and Optimization. 4 Units.
This course introduces and explores tools and techniques for computational design and parametric modeling as a foundation for design optimization. The course covers several parametric design modeling platforms and scripting environments that enable rapid generation and evaluation of parametrically-driven design alternatives. Topics include: Parametrical modeling platforms ((Revit/FormIt, Rhino, Digital Project); Scripting languages and environments (Dynamo, Grasshopper, DesignScript); Single-goal optimization; and Multi-dimensional optimization techniques and selection/guidance strategies.
CEE 135A. Parametric Modeling and Optimization. 4 Units.
This course introduces and explores tools and techniques for computational design and parametric modeling as a foundation for design optimization. The course covers several parametric design modeling platforms and scripting environments that enable rapid generation and evaluation of parametrically-driven design alternatives.

CEE 136. Green Architecture. 4 Units.
Preference to Architectural Design and CEE majors; others by consent of instructor. An architectural design studio exploring green design and green design processes. Initial sessions develop a working definition of sustainable design and strategies for greening the built environment in preparation for design studio work. Prerequisites: 31 or 31Q, and 110 and 130. Enrollment is limited to 14 (or possibly 16) students. Please do not enroll in the class until after attending the first class meeting. If the number of students interested in taking the class is greater than 14 (or possibly 16), space will be assigned based on requirements for graduation.
Same as: CEE 236

CEE 137A. Form and Structure. 4 Units.
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.

CEE 137B. Advanced Architecture Studio. 5 Units.
This course will focus on the topic of interdisciplinary collaboration and its role in the development of design concepts. Specifically, the integration of structural with architectural considerations to produce a unified urban, spatial, tectonic and structural proposition will be our field of investigation. This course is an architecture studio course where class time will be spent primarily in individual or group desk critiques and pin-up sessions. Additionally, there will be lectures, case study presentations and a field trip.
Prerequisites: required. CEE 31 (or 31Q) Drawing, CEE 110 BIM and CEE 130 Design.
Same as: CEE 237B

CEE 138A. Contemporary Architecture: Materials, Structures, and Innovations. 3 Units.
Structural and material bases for contemporary architecture; its roots in modern innovations. Recent technological developments; new materials and structural expressions. Sources include specific buildings and construction techniques. How to think critically about design strategies, material properties, and structural techniques.

CEE 139. Design Portfolio Methods. 2 Units.
Students present designs completed in other studio courses to communicate design intentions and other aspects of their work. Instruction in photography; preparation of a design portfolio; and short essays that characterize portfolio contents. Oral presentation workshops offered through the Center for Teaching and Learning. Limited enrollment.
Prerequisites: two Art or Architecture studio courses, or consent of instructor.

CEE 140. Field Surveying Laboratory. 3 Units.
Graduate students register for 225. Friday afternoon laboratory provides practical surveying experience. Additional morning classes to prepare for the afternoon sessions. Hands-on operation of common traditional field survey tools; introduction to the newest generation of digital measuring, positioning, and mapping tools. Emphasis is on the concept of using the data collected in the field as the basis for subsequent engineering and economic decisions.
Same as: CEE 225

CEE 141A. Infrastructure Project Development. 3 Units.
Infrastructure is critical to the economy, global competitiveness and quality of life. Topics include energy, transportation, water, public facilities, and communications sectors. Analysis of the condition of the nation’s infrastructure and how projects are planned and financed. Focus is on public works in the U.S. The role of public and private sectors through a step-by-step study of the project development process. Case studies of real infrastructure projects. Industry guest speakers. Student teams prepare project environmental impact statements.
Same as: CEE 241A

CEE 141B. Infrastructure Project Delivery. 3 Units.
Infrastructure is critical to the economy, global competitiveness and quality of life. Topics include energy, transportation, water, public facilities, and communications sectors. Analysis of how projects are designed, constructed, operated, and maintained. Focus is on public works projects in the U.S. Alternative project delivery approaches and organizational strategies. Case studies of real infrastructure projects. Industry guest speakers. Student teams prepare finance/design/build/operate/maintain project proposals.
Same as: CEE 241B

CEE 141C. Global Infrastructure Projects Seminar. 1-2 Unit.
Real infrastructure projects presented by industry guest speakers. Energy, transportation, water, public facilities and communications projects are featured. Course provides comparisons of project development and delivery approaches for mega-projects around the world. Alternative project delivery methods, the role of public and private sector, different project management strategies, and lessons learned. Field trips to local projects.
Same as: CEE 241C

CEE 142A. Negotiating Sustainable Development. 3 Units.
How to be effective at achieving sustainability by learning the skills required to negotiate differences between stakeholders who advocate for their own interests. How ecological, social, and economic interests can be effectively balanced and managed. How to be effective actors in the sustainability movement, and use frameworks to solve complex, multiparty processes. Case study analysis of domestic and international issues. Students negotiate on behalf of different interest groups in a variety of arenas including energy, climate, land use, and the built environment. One Saturday all day field trip. No prerequisites.
Same as: CEE 242A, EARTHSYS 142A, EARTHSYS 242A

CEE 144. Design and Innovation for the Circular Economy. 3 Units.
The last 150 years of our industrial evolution have been material and energy intensive. The linear model of production and consumption manufactures goods from raw materials, sells and uses them, and then discards the products as waste. Circular economy provides a framework for systems-level redesign. It builds on schools of thought including regenerative design, performance economy industrial ecology, blue economy, biomimicry, and cradle to cradle. This course introduces the concepts of the circular economy and applies them to case studies of consumer products, household goods, and fixed assets. Students will conduct independent projects on circular economy. Students may work alone or in small teams under the guidance of the teaching team and various collaborators worldwide. Class is limited to 14 students. All disciplines are welcome. This class fulfills the Writing & Rhetoric 2 requirement.
Prerequisite: PWR 1.

CEE 146A. Engineering Economy. 3 Units.
Same as: CEE 246A
CEE 147. Cases in Personality, Leadership, and Negotiation. 3 Units.
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.
Same as: CEE 247
CEE 151. Negotiation. 3 Units.
Students learn to prepare for and conduct negotiations in a variety of arenas including getting a job, managing workplace conflict, negotiating transactions, and managing personal relationships. Interactive class. The internationally travelled instructor who has mediated cases in over 75 countries will require students to negotiate real life case studies and discuss their results in class. Application required before first day of class; see Coursework.
Same as: CEE 251, EARTHSCI 251
CEE 154. Cases in Estimating Costs. 3 Units.
Students participate in bidding contests requiring cost determination in competitive markets. Monetary forces driving the construction industry as general principles applicable to any competitive business. Cases based on field trips and professor's experience as small business owner and construction engineer. Required full afternoon field trips to local sites. Limited enrollment; no auditors. Prerequisites: consent or instructor and application downloaded from CourseWork prior to start of class.
Same as: CEE 254
CEE 155. Introduction to Sensing Networks for CEE. 3-4 Units.
Introduce the design and implementation of sensor networks for monitoring the built and natural environment. Emphasis on the integration of modern sensor and communication technologies, signal processing and statistical models for network data analysis and interpretation to create practical deployments to enable sustainable systems, in areas such as energy, weather, transportation and buildings. Students will be involved in a practical project that may involve deploying a small sensor system, data models and analysis and signal processing. Limited enrollment.
Same as: CEE 255
CEE 156. Building Systems. 4 Units.
HVAC, lighting, and envelope systems for commercial and institutional buildings, with a focus on energy efficient design. Knowledge and skills required in the development of low-energy buildings that provide high quality environment for occupants.
Same as: CEE 256
CEE 160. Mechanics of Fluids Laboratory. 2 Units.
Lab experiments illustrate conservation principles and flows of real fluids, analysis of error and modeling of simple fluid systems. Corequisite: 101B.
CEE 161A. Rivers, Streams, and Canals. 3-4 Units.
Introduction to the movement of water through natural and engineered channels, streams, and rivers. Basic equations and theory (mass, momentum, and energy equations) for steady and unsteady descriptions of the flow. Application of theory to the 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. Limited enrollment in lab section. Prerequisite: CEE 101B.
Same as: CEE 264A
CEE 164. Introduction to Physical Oceanography. 4 Units.
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).
Same as: CEE 262D, EARTH SYS 164, EESS 148
CEE 165C. Water Resources Management. 3 Units.
Examination of the basic principles of surface and ground water resources management in the context of increasing water scarcity and uncertainty due to climate change and other factors. Specific topics include reservoir, river basin and aquifer management, conjunctive use of surface and ground water, and treated wastewater reuse. Special emphasis is placed on demand management through conservation, increased water use efficiency and economic measures. Besides the technical aspects of water management, an overview of its legal and institutional framework is provided.
Same as: CEE 265C
CEE 166A. Watersheds and Wetlands. 3 Units.
Introduction to the occurrence and movement of water in the natural environment and its role in creating and maintaining terrestrial, wetland, and aquatic habitat. Hydrologic processes, including precipitation, evaporation, transpiration, snowmelt, infiltration, subsurface flow, runoff, and streamflow. Rivers and lakes, springs and swamps. Emphasis is on observation and measurement, data analysis, modeling, and prediction. Prerequisite: 101B or equivalent. (Freyberg).
Same as: CEE 266A
CEE 166B. Floods and Droughts, Dams and Aqueducts. 3 Units.
Sociotechnical systems associated with human use of water as a resource and the hazards posed by too much or too little water. Potable and non-potable water use and conservation. Irrigation, hydroelectric power generation, rural and urban water supply systems, storm water management, flood damage mitigation, and water law and institutions. Emphasis is on engineering design. Prerequisite: 166A or equivalent. (Freyberg).
Same as: CEE 266B
CEE 166D. Water Resources and Water Hazards Field Trips. 2 Units.
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.
Same as: CEE 266D
CEE 169. Environmental and Water Resources Engineering Design. 5 Units.
Application of fluid mechanics, hydrology, water resources, environmental sciences, and engineering economy fundamentals to the design of a system addressing a complex problem of water in the natural and constructed environment. Problem changes each year, generally drawn from a challenge confronting the University or a local community. Student teams prepare proposals, progress reports, oral presentations, and a final design report. Prerequisite: senior in Civil Engineering or Environmental Engineering; 166B.
CEE 171. Environmental Planning Methods. 3 Units.
For juniors and seniors. Use of microeconomics and mathematical optimization theory in the design of environmental regulatory programs; tradeoffs between equity and efficiency in designing regulations; techniques for predicting adverse effects in environmental impact assessments; information disclosure requirements; and voluntary compliance of firms with international regulating norms. Prerequisites: MATH 51. Recommended: 70.
CEE 171E. Environmental Challenges and Policies in Europe. 3 Units.
Current and future environmental challenges in Europe and related public policies in the European Union (EU). State of the European environment and human development, European environmental policy-making (multi-level ecological governance), global ecological role of the EU. Specific challenges include climate change adaptation, mitigation (carbon taxes, carbon market), climate change and European cities, biodiversity and ecosystems preservation (economics of biodiversity), energy management. Specific policies include environmental justice (environmental inequalities), human development and environmental sustainability indicators (beyond GDP) and absolute and relative decoupling (carbon intensity and resource productivity improvement). Open to undergraduates (freshmen, sophomores, juniors and seniors) as CEE 171E.
Same as: CEE 271E

CEE 171F. New Indicators of Well-Being and Sustainability. 3 Units.
Explore new ways to better measure human development, comprehensive wealth and sustainability beyond standard economic indicators such as income and GDP. Examine how new indicators shape global, national and local policy worldwide. Well-being topics include health, happiness, trust, inequality and governance. Sustainability topics include sustainable development, environmental performance indicators, material flow analysis and decoupling, and inclusive wealth indicators. Students will build their own indicator of well-being and sustainability for a term paper.
Same as: CEE 271F

CEE 172. Air Quality Management. 3 Units.
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.

CEE 172A. Indoor Air Quality. 2-3 Units.
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.
Same as: CEE 278C

CEE 172B. Green House Gas Mitigation. 1-3 Unit.
This course will introduce the main concepts of greenhouse gas (GHG) emissions measurement and management, and it will explore the main mitigation options for reducing emissions or sequestering carbon dioxide. It will address technical aspects of GHG mitigation via energy efficiency and demand-side management, energy in high-technology industry, distributed power and co-generation, the role of renewable energy in GHG management, carbon sequestration in forestry, agriculture, and geological formations. The course explores policy options, carbon trading and business strategies for GHG mitigation.
Same as: CEE 272S

CEE 173A. Energy Resources. 3-5 Units.
Comprehensive overview of fossil and renewable energy resources and energy efficiency. Topics covered for each resource: resource abundance, location, recovery, conversion, consumption, end-uses, environmental impacts, economics, policy, and technology. Applied lectures in specific energy sectors: buildings, transportation, the electricity industry, and energy in the developing world. Required field trips to local energy facilities. Optional discussion section for extra unit. CEE 173 is offered for 4-5 units; ES 103 is offered for 4-5 units; CEE 207A is offered for 3-5 units: instructor approval required for 3-unit option.
Same as: CEE 207A, EARTHSYS 103

CEE 173C. Introduction to Membrane Technology for Water / Wastewater Treatment. 3 Units.
This course equips students with a basic understanding of membrane processes and their application in the water industry. Topics covered include: introduction to membrane separation, reverse osmosis, nanofiltration, membrane characterization techniques (XPS, TEM, ATR-FTIR, streaming potential), mass transport phenomena (concentration polarization, solution-diffusion, pore-flow) fouling processes (scaling, biofouling), rejection of salts and trace organics, brine disposal, system design, energy and cost considerations of membrane treatment, pre- and post-treatment, case studies. The course includes a field trip to a reverse osmosis pilot plant and evaluation of field data.
Same as: CEE 273C

CEE 174A. Providing Safe Water for the Developing and Developed World. 3 Units.
This course will cover basic hydraulics and the fundamental processes used to provide and control water, and will introduce the basics of engineering design. In addition to understanding the details behind the fundamental processes, students will learn to feel comfortable developing initial design criteria (30% designs) for fundamental processes. Students should also develop a feel for the typical values of water treatment parameters and the equipment involved. The course should enable students to work competently in environmental engineering firms or on non-profit projects in the developing world such as Engineers without Borders. Pre-requisite: Chem31B/X.

CEE 174B. Wastewater Treatment: From Disposal to Resource Recovery. 3 Units.
This course builds upon CEE 174A, covering basic hydraulics and the fundamental processes used to treat wastewater. In addition to understanding the details behind the fundamental processes, students will learn to feel comfortable developing initial design criteria (30% designs) for fundamental processes. Students should also develop a feel for the typical values of water treatment parameters and the equipment involved. After covering conventional processes, the class addresses newer processes used to meet emerging treatment objectives, including nutrient removal, composting of biosolids and recycling of wastewater for beneficial uses, including potable reuse. Pre-requisites: CEE 174A.

CEE 175A. California Coast: Science, Policy, and Law. 3-4 Units.
Same as LAW 514. Interdisciplinary. The legal, science, and policy dimensions of managing California's coastal resources. Coastal land use and marine resource decision making. The physics, chemistry, and biology of the coastal zone, tools for exploring data from the coastal ocean, and the institutional framework that shapes public and private decision making. Field work: how experts from different disciplines work to resolve coastal policy questions. Primarily for graduate students; upper-level undergraduates may enroll with permission of instructor. Students will be expected to participate in at least three mandatory field trips.
Same as: CEE 275A, EARTHSYS 175, EARTHSYS 275

CEE 175S. Environmental Entrepreneurship and Innovation. 2 Units.
Our current infrastructure for provision of critical services-clean water, energy, transportation, environmental protection; requires substantial upgrades. As a complement to the scientific and engineering innovations taking place in the environmental field, this course emphasizes the analysis of economic factors and value propositions that align value chain stakeholder interests.
Same as: CEE 275S

CEE 176A. Energy Efficient Buildings. 3-4 Units.
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.
CEE 176B. Electric Power: Renewables and Efficiency. 3-4 Units.
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.

CEE 176C. Energy Storage Integration - Vehicles, Renewables, and the Grid. 3-4 Units.
This course will describe the background on existing energy storage solutions being used on the electric grid and in vehicles with a primary focus on batteries and electrochemical storage. It will discuss the operating characteristics, cost and efficiency of these technologies and how tradeoff decisions can be made. The course will describe the system-level integration of new storage technologies, including chargers, inverters, battery management systems and controls, into the existing vehicle and grid infrastructure. Specific focus will be given to the integration of electric vehicle charging combined with demand-side management, scheduled renewable energy absorption and local grid balancing. This course may be taken for 3 units; or 4 units if taken with the optional laboratory session.

CEE 176D. Advanced Topics in Integrated Demand Side Management. 2 Units.
The American economy is highly inefficient: between 14-39% of the energy inputs into the US economy are ultimately used to create goods and services, while the remaining energy is lost in energy conversion and other inefficiencies. While this inefficiency results in a heavy social, environmental, and economic burden on both individuals and society as a whole, it also presents a tremendous opportunity to re-imagine how we use and manage our energy consumption. Recent technological advances, including the rise of information technology, sensors, controls, are dramatically re-shaping how energy is utilized, controlled, stored and integrated with traditional supply side resources. These emerging technologies and energy management techniques provide some of the greatest opportunities to improve the efficiency of our economy and address climate change. This course begins with an overview of demand side management (the application of efficiency, demand reduction, distributed generation, storage, and other resource to shape energy demand) practice to date and a detailed look at how energy is used throughout each sector of the economy. Based on this starting point, the course explores emerging technologies and optimization strategies that enable greater insight and control of energy use both at the device and aggregate level, including integration with renewables, storage, and electric vehicles. It then quantifies and monetizes these optimization strategies into revenue streams to both utility and end-user, and culminates in a discussion of how the intersection of these new technologies, optimization strategies, and revenue streams can help de-carbonize the American economy and shape energy use and the utility of the future. Prerequisites: This course is intended for students who wish to gain an understanding of how energy efficiency and demand management occurs in practice. While there are no formal prerequisites, it is expected that students will have familiarity with energy resources and building energy end uses, such as topics covered in CEE 176A/276A, CEE 173A/207A, CEE 156/256, and CEE 226E.
Same as: CEE 276C

Energy resources and policies in use and under development in China. 12-day field trip to China during Spring Break. One unit for seminar and readings; one unit for field trip. Tuesday section is required for all students. Thursday section is also required for students attending the field trip. Prerequisite: consent of instructor for field trip.
Same as: CEE 276F

CEE 176G. Instrumental Analysis of Emerging Contaminants in the Environment. 3 Units.
Introduction to the occurrence and behavior of trace organic compounds in the environment and focus on research approaches to investigate these compounds. Principles of analytical techniques and experimental approaches to detect and monitor trace organic contaminants in the environment will be examined. Students will critically review published original research and prepare and an original research project proposal. Same as: CEE 276G

CEE 176H. Aquatic Chemistry and Biology. 4 Units.
Introduction to 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 biogeochemistry 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.

CEE 177K. Environmental Information Engineering. 2-3 Units.
The role of information technology (IT) in enabling mankind to understand its impact on the planet and balance that with improving the quality of life of a rapidly growing population. After surveying the field, the course will examine the specific impacts that IT may have, by reference to case studies from energy, transportation, water and urban design fields. While some specific information technologies will be examined, this will be from a business perspective - detailed technical knowledge of IT not required. Same as: CEE 277K

CEE 177L. Smart Cities & Communities. 2-3 Units.
The role of information technology (IT) in enabling mankind to improve the operations and sustainability of cities and communities. Review of what a "smarter" city of community might be, the role of IT in enabling them to become "smarter" (including what IT cannot achieve). Case studies on water, energy, transportation urban design and resilience. Same as: CEE 277L

CEE 177S. Design for a Sustainable World. 1-3 Unit.
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. (Staff).
Same as: CEE 277S

CEE 177X. Current Topics in Sustainable Engineering. 1-3 Unit.
This course is the first half of a two quarter, project-based design course that addresses the cultural, political, organizational, technical, and business issues at the heart of implementing sustainable engineering projects in the developing world. Students will be placed into one of three project teams and tackle a real-world design challenge in partnership with social entrepreneurs and NGOs. In CEE 177X/277X, students will gain the background skills and context necessary to effectively design engineering projects in developing nations. Instructor consent required. Same as: CEE 277X

CEE 178. Introduction to Human Exposure Analysis. 3 Units.
(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. Apply at first class for admission. Same as: CEE 276

CEE 179A. Water Chemistry Laboratory. 3 Units.
(Graduate students register for 273A.) Laboratory application of techniques for the analysis of natural and contaminated waters, emphasizing instrumental techniques. Same as: CEE 273A
CEE 179C. Environmental Engineering Design. 5 Units.
Application of engineering fundamentals including environmental engineering, hydrology, and engineering economy to a design problem.
Enrollment limited; preference to seniors in Civil and Environmental Engineering.

CEE 179S. Seminar: Issues in Environmental Science, Technology and Sustainability. 1-2 Unit.
Invited faculty, researchers and professionals share their insights and perspectives on a broad range of environmental and sustainability issues.
Students critique seminar presentations and associated readings.
Same as: CEE 279S, EARTHSYS 179S, EESS 179S

CEE 179X. Sustainable Urban System Seminar. 1 Unit.
SYSTEM OF SYSTEMS: Cities are based on several different systems; infrastructures, networks and environments. The effectiveness and efficiency of these systems determine how cities work and how successful a city is at delivering critical services. These systems are not discrete and must be considered holistically as well as individually. These core systems are interconnected and must be treated as such. Understanding one system and making it work better means that cities must comprehend the larger context and how the various systems are interconnected. This seminar series will explore various aspects of these critical systems and how we can make them more resilient and robust, to meet future challenges. Guest speakers, discussion and critical readings.
Same as: CEE 279X

CEE 180. Structural Analysis. 4 Units.
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.

CEE 181. Design of Steel Structures. 4 Units.
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.

CEE 182. Design of Reinforced Concrete Structures. 3-4 Units.
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.

CEE 183. Integrated Civil Engineering Design Project. 4 Units.
Studio format. Design concepts for civil engineering facilities from schematic design through construction, taking into account sustainable engineering issues. Design exercises culminating in the design of a civil engineering facility, emphasizing structural systems and materials and integration with construction and other project requirements. Prerequisites: CEE 180, 181, 182; civil engineering major; architectural design major with instructor consent.

CEE 195. Fundamentals of Structural Geology. 3 Units.
Techniques for mapping using GPS and differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; measurement and analysis of stress; elastic deformation and properties of rock; brittle deformation including fracture and faulting; linear viscous flow including folding and magma dynamics; model development and methodology. Models of tectonic processes are constructed and solutions visualized using MATLAB. Prerequisites: GES 1, MATH 51.
Same as: GES 111

CEE 196. Engineering Geology and Global Change. 3 Units.
The application of geology and global change to the planning, design, and operation of engineering projects. Case histories taught in a seminar setting and field trips emphasize the impact of geology and global change on both individual engineering works and the built environment by considering Quaternary history and tectonics, anthropogenic sea level rise, active geologic processes, engineering properties of geologic deposits, site exploration, and professional ethics. Prerequisite: GES 1 or consent of instructor.
Same as: GES 115

CEE 198. Directed Reading or Special Studies in Civil Engineering. 1-4 Unit.
Written report or oral presentation required. Students must obtain a faculty sponsor.

CEE 199. Undergraduate Research in Civil and Environmental Engineering. 1-4 Unit.
Written report or oral presentation required. Students must obtain a faculty sponsor.

CEE 199A. Special Projects in Architecture. 1-4 Unit.
Faculty-directed study or internship. May be repeated for credit. Prerequisite: consent of instructor.

CEE 199B. Directed Studies in Architecture. 1-4 Unit.
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.

CEE 199E. Outreach and Mentoring Program Development in CEE. 1-2 Unit.
Open to undergraduates who are declared majors in Civil Engineering, Environmental Engineering, Atmosphere/Energy, and Architectural Design. Will brainstorm and develop an innovative curriculum and engaging activities for CEE 10 (Intro. to the Civil & Environmental Engineering Professions).

CEE 199H. Undergraduate Honors Thesis. 2-3 Units.
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. (Staff).

CEE 199L. Independent Project in Civil and Environmental Engineering. 1-4 Unit.
Prerequisite: Consent of Instructor.

CEE 200A. Teaching of Civil and Environmental Engineering. 1 Unit.
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.mn 200A. Aut, 200B. Win, 200C. Spr.

CEE 200B. Teaching of Civil and Environmental Engineering. 1 Unit.
Required of CEE Ph.D. students. Strategies for effective teaching and introduction to engineering pedagogy. Topics: problem solving techniques and learning styles, individual and group instruction, the role of TAs, balancing other demands, grading. Teaching exercises. Register for quarter of teaching assistantship. May be repeated for credit. 200A. Aut, 200B. Win, 200C. Spr.

CEE 200C. Teaching of Civil and Environmental Engineering. 1 Unit.
Required of CEE Ph.D. students. Strategies for effective teaching and introduction to engineering pedagogy. Topics: problem solving techniques and learning styles, individual and group instruction, the role of TAs, balancing other demands, grading. Teaching exercises. Register for quarter of teaching assistantship. May be repeated for credit. 200A. Aut, 200B. Win, 200C. Spr.
CEE 201D. Computations in Civil and Environmental Engineering. 3 Units.
Computational and visualization methods in the design and analysis of civil and environmental engineering systems. Focus is on applications of MATLAB. How to develop a more lucid and better organized programming style.
Same as: CEE 101D

CEE 201S. Science & Engineering Problem-Solving with MatLab.. 3 Units.
Introduction to the application of MATLAB to an array of engineering systems. Emphasis on computational and visualization methods in the design, modeling and analysis of engineering problems.
Same as: CEE 101S

CEE 202. Construction Law and Claims. 3 Units.
Concepts include the preparation and analysis of construction claims, cost overrun and schedule delay analysis, general legal principles, contracts, integrated project delivery, public private partnerships and the resolution of construction disputes through ADR and litigation. Requires attendance of the ten weeks of Monday classes (1/6/14 - 4/10/14) and the first five weeks of Tuesday classes (1/7/14 - 2/4/14).

CEE 203. Probabilistic Models in Civil Engineering. 3-4 Units.
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.

CEE 204. Structural Reliability. 3-4 Units.

CEE 205A. Structural Materials Testing and Simulation. 3-4 Units.
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 introduction to sustainable, bio-based composites. Prerequisites: basic course in reinforced concrete design CEE 182 or equivalent.

CEE 205B. Advanced Topics in Structural Concrete. 3 Units.
Concepts and application of strut and tie modeling including deep beams, design for torsion resistance, beam-column joints, bridge components, and post-tensioned anchor zones. Course project integrating computer simulation and physical experimentation of a structural concrete component. Prerequisites: CEE 285A or equivalent.

CEE 206. Decision Analysis for Civil and Environmental Engineers. 3 Units.
Current challenges in selecting an appropriate site, alternate design, or retrofit strategy based on environmental, economic, and social factors can be best addressed through applications of decision science. Basics of decision theory, including development of decision trees with discrete and continuous random variables, expected value decision making, utility theory value of information, and elementary multi-attribute decision making will be covered in the class. Examples will cover many areas of civil and environmental engineering problems. Prerequisite: CEE 203 or equivalent.

CEE 206A. Decision Models in Civil Engineering. 2 Units.
For advanced graduate students in CEE. Applications of decision science to address current challenges in selecting an appropriate site and appropriate design or retrofit strategy based on environmental, economic, and social factors. Examples from everyday civil and environmental engineering problems. Prerequisite: CEE 203 or equivalent.

CEE 207A. Energy Resources. 3-5 Units.
Comprehensive overview of fossil and renewable energy resources and energy efficiency. Topics covered for each resource: resource abundance, location, recovery, conversion, consumption, end-uses, environmental impacts, economics, policy, and technology. Applied lectures in specific energy sectors: buildings, transportation, the electricity industry, and energy in the developing world. Required field trips to local energy facilities.
Optional discussion section for extra unit. CEE 173 is offered for 4-5 units; ES 103 is offered for 4-5 units; CEE 207A is offered for 3-5 units: instructor approval required for 3-unit option.
Same as: CEE 173A, EARTHSYS 103

CEE 207B. Energy Resources: Fuels and Tools. 3 Units.
Energy is a vital part of our daily lives. This course examines where that energy comes from, and the advantages and disadvantages across different fuels. Contextual analysis of energy decisions for transportation and electricity generation around the world. Energy resources covered include oil, biomass, natural gas, nuclear, hydropower, wind, solar, geothermal, and emerging technologies. Prerequisites: Algebra. Note: may not be taken by students who have completed CEE 173A, CEE 207 or EARTHSYS 103. Same as: CEE 107S

Structural health monitoring systems, which enables us to automatically diagnose structural damage, are important to ensure safe and functional built environment. This course provides theoretical background on damage diagnosis algorithms using model-based and signal-based methods for civil structures with an emphasis on the underlying physical interpretations and their practical usage.

CEE 209. Risk Quantification and Insurance. 2 Units.
Principles of risk management along with concepts of frequency and severity and various risk measures such as probabilities of exceeding given loss level, probabilities of insolvency, and expected value of shortfall will be introduced. Various risk handling techniques will be discussed with particular emphasis on insurance. Ability to express preferences between random future gains or losses, will be presented in the context of stochastic ordering of risks. Credibility theory and generalized linear models will be used for claims predictions. Prerequisites: CEE 203 or equivalent.

CEE 210A. Building Information Modeling and Short Course. 2-4 Units.
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 /instructor consent required.
Same as: CEE 110A

CEE 212A. Industry Applications of Virtual Design & Construction. 2-4 Units.
Building upon the concept of the VDC Scorecard, CEE 112A/212A investigates in the management of Virtual Design and Construction (VDC) programs and projects in the building industry. Interacting with experts and professionals in real estate, architecture, engineering, construction and technology providers, students will learn from the industry applications of Building Information Modeling and its relationship with Integrated Project Delivery, Sustainable Design and Construction, and Virtual Design and Construction. Students will conduct case studies to evaluate the maturity of VDC planning, adoption, technology and performance in practice. Students taking 3 or 4 units will be paired up with independent research or case study projects on the industry applications of VDC. No prerequisite. See CEE 112B/212B in the Winter Quarter and CEE 112C/212C in the Spring Quarter.
CEE 212B. Industry Applications of Virtual Design & Construction. 2-4 Units.
CEE 112B/212B is a practicum on the Industry Applications on Virtual Design and Construction (VDC). Students will gain insights and develop skills that are essential for academic research, internships or industry practice in VDC and Building Information Modeling (BIM). Students can choose between one of the two project topics: [1] Industrialized Construction with Virtual Parts (No Prerequisite) or [2] Industry Benchmarking & Applications of the VDC Management Scorecard (Suggested Prerequisite: CEE 112A/212A).
Same as: CEE 112B

CEE 212C. Industry Applications of Virtual Design & Construction. 2-4 Units.
Following the Autumn- and Winter-quarter course series, CEE 112C/212C is an industry-focused and project-based practicum that focuses on the industry applications of Virtual Design and Construction (VDC). Students will be paired up with industry-based VDC projects with public owners and private developers, such as GSA Public Buildings Service, the Hong Kong Mass Transit Railway, Optima, Walt Disney Imagineering, Microsoft facilities and/or other CIFE International Members. Independently, students will conduct case studies and/or develop VDC and building information models (BIM) using off-the-shelf technologies for project analysis, collaboration, communication and optimization. Students will gain insights and develop skills that are essential for academic research, internships or industry practice in VDC. Prerequisite: CEE 112A/212A, CEE 112B/212B, CEE 159C/259C, CEE 159D/259D, or Instructor's Approval.
Same as: CEE 112C

CEE 212D. Industry Applications of Virtual Design and Construction. 2-4 Units.
A continuation of the CEE 112/212 series, CEE 112D/212D is an industry-focused and project-based practicum that focuses on the industry applications of Virtual Design and Construction (VDC). Students will be paired up with industry-based VDC projects with public owners and private developers, professional associations, and/or other member organizations of the Center for Integrated Facility Engineering at Stanford. Independently, students will conduct case studies, research activities, and/or develop VDC and building information models (BIM) using off-the-shelf technologies for project analysis, collaboration, communication and optimization. Students will gain insights and develop skills that are essential for academic research, internships or industry practice in VDC. Prerequisite: CEE110/210, CEE 112C/212C, CEE 122B/222B, or Instructor's Approval.
Same as: CEE 112D

CEE 213. Patterns of Sustainability. 1-4 Unit.
This seminar examines the interrelated sustainability of the natural, built and social environments of places in which we live. Several BOSP centers and the home Stanford campus will hold this 1-2 unit seminar simultaneously and collaborate with a shared curriculum, assignments, web conference and a Wiki. The goal of the collaborative arrangement is to expose, share, compare and contrast views of sustainability in different parts of the world. We will look at and assess aspects of sustainability of the places we are living from a theoretical perspective from the literature, from observations and interviews in the countries in which we study.
Same as: CEE 113

CEE 214. Introduction to Modeling and Analysis in CEE. 3 Units.
Introduces students to modeling of products, processes and organizations in the AEC industry. Modeling and analysis purposes include support of technical, social, psychological and ethical decision making for different stakeholders. Different purposes and levels of detail for different models. CEM/DCI integrated approach to building using physical, mathematical, graphical and computer models of products, organizations and processes.

CEE 215. Goals and Methods of Sustainable Building Projects. 3 Units.
(Graduate students register for 215.) Goals related to sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and economic and social sustainability. Methods to integrate these goals and enhance the economic, ecological, and equitable value of building projects. Industry and academic rating systems, project case studies, guest lecturers, and group project.
Same as: CEE 115

CEE 217. Renewable Energy Infrastructure. 3 Units.
Construction of renewable energy infrastructure: geothermal, solar thermal, solar photovoltaic, wind, biomass. Construction and engineering challenges and related issues and drivers for performance, cost, and environmental impact. Context of renewable energy infrastructure development including comparison of the types of renewable energy, key economic, environmental, and social contextual factors, applicability of a type of renewable energy given a context, related barriers and opportunities. Class project to plan a start-up for developing a type of energy infrastructure based on an engineering innovation.

CEE 220A. Building Information Modeling Workshop. 2-4 Units.
The foundational Building Information Modeling course introduces techniques for creating, managing, and applying of building information models in the building design and construction process. The course covers processes and tools for creating, organizing, and working with 2D and 3D computer representations of building components and geometries to produce models used in architectural design, construction planning and documentation, rendering and visualization, simulation and analysis.
Same as: CEE 120A

CEE 220B. Building Information Modeling Workshop. 2-4 Units.
This course builds upon the Building Information Model concepts introduced in 110A/220A and illustrates how BIM modeling tools are used to design, analyze, and model building systems including structural, mechanical, electrical, plumbing and fire protection. The course covers the essential physical principles, design criteria, and design strategies for each system and explores processes and tools for modeling those systems and analyzing their performance.
Same as: CEE 120B

CEE 220C. Parametric Design and Optimization. 2-4 Units.
This course explores tools and techniques for computational design and parametric modeling as a foundation for design optimization. Class sessions will introduce several parametric design modeling platforms and scripting environments that enable rapid generation of 3D models and enable rapid evaluation of parametrically-driven design alternatives. Topics to be featured include: [a] Principles of parametric design vs. direct modeling [b] Design exploration using parametric modeling platforms (Revit/FormIt, Rhino) [c] Visual scripting languages and environments (Dynamo, Grasshopper, DesignScript) [d] Single- and multi-dimensional optimization techniques and guidance strategies.
Same as: CEE 120C

CEE 220S. Building Information Modeling Special Study. 2-4 Units.
Special studies of Building Information Modeling strategies and techniques focused on creating, managing, and applying models in the building design and construction process. Processes and tools for creating, organizing, and working with 2D and 3D computer representations of building components to produce models used in design, construction planning, visualization, and analysis.
Same as: CEE 120S
CEE 221A. Planning Tools and Methods in the Power Sector. 3-4 Units.
This course covers the planning methods most commonly used in the power sector today. It covers both the fundamental methods used and their applications to electricity generation, transmission and distribution planning, integrated resource planning using both energy efficiency and renewable resources as well as utility finance and ratemaking. The methods covered will include forecasting (time series, regression and the use of markets), resource assessment (including energy efficiency and demand-side management) optimization (in power markets operation and in expansion planning) and the processes used in decision-making.

CEE 222A. Computer Integrated Architecture/Engineering/Construction (AEC) Global Teamwork. 3 Units.
AEC students engage in a crossdisciplinary, collaborative, geographically distributed, and multicultural project-based teamwork. AEC teams exercise their domain knowledge and information technologies in a multidisciplinary context focusing on the design and construction concept development phase of a comprehensive building project. Prerequisite: interview with Instructor in Autumn Quarter.

CEE 222B. Computer Integrated Architecture/Engineering/Construction (AEC) Global Teamwork. 2 Units.
Global AEC student teams continue their project activity focusing on the most challenging concept developed in 222A and chosen jointly with their client. Comprehensive team project focusing on design and construction, including: project development and documentation; detailing, 3D and 4D modeling, simulation, sustainable concepts, cost benefit analysis, and life-cycle cost analysis; and final project presentation of product and process. Prerequisite: CEE 222A.

CEE 223. Materials for Sustainable Urban Systems. 3 Units.
Students will learn to evaluate alternate materials and make a case for materials selection for given urban infrastructure projects considering the material's performance over time, life cycle impacts, and effect on humans. Limited enrollment. Pre-requisites: CEE 226, CEE 101A or equivalent.

CEE 223A. Based Materials, Properties and Durability. 2 Units.
Students will develop an understanding of the chemical and physical processes of cement and concrete hydration, strength development, mechanical performance and durability. Students will learn how the properties of materials and admixture combine to create a wide range of cement-based materials used in the built environment. The course will address sustainable construction, including the use of alternative cements, admixtures, and aggregates. Students will apply the principles in this course to various aspects of civil and structural engineering, including innovative mix design specification and review, structural investigations and failure analysis, and cementitious materials research.

CEE 224A. Sustainable Development Studio. 1-5 Unit.
(Undergraduates, see 124.) Project-based. Sustainable design, development, use and evolution of buildings; connections of building systems to broader resource systems. Areas include architecture, structure, materials, energy, water, air, landscape, and food. Projects use a cradle-to-cradle approach focusing on technical and biological nutrient cycles and information and knowledge generation and organization. May be repeated for credit.

CEE 225. Field Surveying Laboratory. 3 Units.
Graduate students register for 225. Friday afternoon laboratory provides practical surveying experience. Additional morning classes to prepare for the afternoon sessions. Hands-on operation of common traditional field survey tools; introduction to the newest generation of digital measuring, positioning, and mapping tools. Emphasis is on the concept of using the data collected in the field as the basis for subsequent engineering and economic decisions.

CEE 226. Life Cycle Assessment for Complex Systems. 3-4 Units.
Life cycle modeling of products, industrial processes, and infrastructure/building systems; material and energy balances for large interdependent systems; environmental accounting; and life cycle costing. These methods, based on ISO 14000 standards, are used to examine emerging technologies, such as bio-based products, building materials, building integrated photovoltaics, and alternative design strategies, such as remanufacturing, dematerialization, LEED, and Design for Environment: DfE. Student teams complete a life cycle assessment of a product or system chosen from industry.

CEE 226E. Advanced Topics in Integrated, Energy-Efficient Building Design. 2-3 Units.
Innovative methods and systems for the integrated design and evaluation of energy efficient buildings. Guest practitioners and researchers in energy efficient buildings. Student initiated final project. Prerequisites: CEE 156 or CEE 256. All students are expected to participate in the group project assignments. Students taking the course for two units will not be required to complete in-class assignments or individual homework assignments.

CEE 227. Global Project Finance. 3-5 Units.
Private and public 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. Limited enrollment.

CEE 227A. Energy System Design in Eastern Europe. 2 Units.
Field-based seminar to evaluate and design future energy systems for Eastern Europe. 14-day field trip during early September 2013. Site visits, fact-finding, stakeholder meetings, presentation to policy makers. One unit for field trip; one unit for project deliverable. Prerequisite: consent of instructor. Same as: CEE 127A

CEE 227E. Infrastructure, Disruptive Technologies and Entrepreneurship. 1 Unit.
Silicon Valley provides a dynamic environment perfectly suited for developing the disruptive technologies that are changing the faces of today's mainstream infrastructure systems and essential service industries. This course will provide an overview of the most exciting technologies emerging from Silicon Valley right now and the potential that exists to disrupt mainstream transportation, electricity, intelligence gathering, and banking infrastructure systems that were dominant in the 20th Century. Guest speakers include prominent CEOs, visionaries, investors, and serial entrepreneurs who are building game changing companies. Same as: CEE 127E

CEE 228. Innovative Global Construction Technology. 2 Units.
(Formerly 245T.) Five-week class. How innovative companies invent new construction processes based on relative local labor, and materials and equipment cost, availability, and capabilities, and developed from experience and knowledge of construction technology in bridge, tunnel, and high-rise building. The process of generating new ideas. Industry guest speakers address the link between product/process innovation and construction technology.

CEE 228C. Design and Construction for Sustainability in Extreme Environments. 2 Units.
Course focuses on multi-disciplinary conceptual design of self-sustaining facilities in remote, extreme environments. Through this learn-by-doing course, students will apply an integrated sustainable design methodology for facility planning and operations. Research into environmental design criteria, opportunities, and constraints to logically guide facility form, shape, systems, and operational requirements. Additional independent study unit available for participation in process experiment. Guest lectures, discussion section, class project. Graduate only.
CEE 229. Climate Change Adaptation for Coastal Cities: Engineering and Policy for a Sustainable Future. 3 Units.
How will climate change affect cities and how will cities respond? Includes an exploration of the threat of climate change to coastal cities worldwide and the potential engineering and policy responses. Understanding of the nature of the challenge of city adaptation planning in terms of earth systems, infrastructure development, urban planning, and social systems. Consideration of economic, social, legal and environmental implications. Student projects will contribute to on-going research. Interdisciplinary. Guest speakers, case studies, and readings. Same as: CEE 129

CEE 229S. Climate Change Adaptation in the Coastal Built Environment. 1 Unit.
How will climate change impact coastal ports and harbors around the world? Leading experts discuss the latest science, policy, and engineering research on this important issue, including the necessary response to protect ports and harbors from significant sea-level rise and storm surge. Focus is on the built environment. Guest speakers. CEE 229/129 for research option. See www.groupspaces.com/seaports2100. Same as: CEE 129S

CEE 232. Interplay of Architecture and Engineering. 4 Units.
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. Same as: CEE 132

CEE 233. Advanced Rhinoceros Modeling and Workflows. 3 Units.
Rhinoceros is a powerful 3D modeling program that provides great control and accuracy, and also allows great flexibility and creativity in the design process. Rhinoceros is used by many top-level architecture firms because it can be customized, it can be integrated with many other design programs, and has the potential to create unique and detailed forms. The course will concentrate on introducing students to the Rhinoceros platform in great depth so that they may comfortably utilize the program for any type of design project. In addition to basic and advanced modeling skills in Rhinoceros, the course will explore an integrated workflow between design environments. Comprehension will be expanded from simple 3D modeling to a process that optimizes the strengths of different design platforms. Students will study and implement an integrated workflow that connects powerful conceptual modeling with building information models in order to produce a quality design product ready for documentation and presentation. Same as: CEE 133

CEE 234B. Intermediate Arch Studio. 4 Units.
This studio offers students experience in working with a real site and a real client program to develop a community facility. Students will develop site analysis, review a program for development and ultimately design their own solutions that meet client and community goals. Sustainability, historic preservation, community needs and materials will all play a part in the development of students final project. Students will also gain an understanding of graphic conventions, verbal and presentation techniques. Course may be repeated for credit. Same as: CEE 134B

CEE 236. Green Architecture. 4 Units.
Preference to Architectural Design and CEE majors; others by consent of instructor. An architectural design studio exploring green design and green design processes. Initial sessions develop a working definition of sustainable design and strategies for greening the built environment in preparation for design studio work. Prerequisites: 31 or 31Q, and 110 and 130. Enrollment is limited to 14 (or possibly 16) students. Please do not enroll in the class until after attending the first class meeting. If the number of students interested in taking the class is greater than 14 (or possibly 16), space will be assigned based on requirements for graduation. Same as: CEE 136

CEE 237B. Advanced Architecture Studio. 5 Units.
This course will focus on the topic of interdisciplinary collaboration and its role in the development of design concepts. Specifically, the integration of structural with architectural considerations to produce a unified urban, spatial, tectonic and structural proposition will be our field of investigation. This course is an architecture studio course where class time will be spent primarily in individual or group desk critiques and pin-up sessions. Additionally, there will be lectures, case study presentations and a field trip. Prerequisites: required: CEE 31 (or 31Q) Drawing, CEE 110 BIM and CEE 130 Design. Same as: CEE 137B

CEE 241. Managing Fabrication and Construction. 4 Units.
Methods to manage the physical production of construction projects; design, analysis, and optimization of the fabricate-assemble process including performance metrics. Project management techniques and production system design including: push versus pull methods; master scheduling and look-ahead scheduling; scope, cost, and schedule control; earned value analysis; critical path method; location-based scheduling; 4D modeling; workflow; trade coordination; methods to understand uncertainty and reduce process variability; and supply chain systems including made-to-stock, engineered-to-order, and made-to-order. Prerequisite: 100 or consent of instructor. Recommended corequisite: 240.

CEE 241A. Infrastructure Project Development. 3 Units.
Infrastructure is critical to the economy, global competitiveness and quality of life. Topics include energy, transportation, water, public facilities, and communications sectors. Analysis of the condition of the nation's infrastructure and how projects are planned and financed. Focus is on public works in the U.S. The role of public and private sectors through a step-by-step study of the project development process. Case studies of real infrastructure projects. Industry guest speakers. Student teams prepare project environmental impact statements. Same as: CEE 141A

CEE 241B. Infrastructure Project Delivery. 3 Units.
Infrastructure is critical to the economy, global competitiveness and quality of life. Topics include energy, transportation, water, public facilities and communications sectors. Analysis of how projects are designed, constructed, operated, and maintained. Focus is on public works projects in the U.S. Alternative project delivery approaches and organizational strategies. Case studies of real infrastructure projects. Industry guest speakers. Student teams prepare finance/design/build/operate/maintain project proposals. Same as: CEE 141B

CEE 241C. Global Infrastructure Projects Seminar. 1-2 Unit.
Real infrastructure projects presented by industry guest speakers. Energy, transportation, water, public facilities and communications projects are featured. Course provides comparisons of project development and delivery approaches for mega-projects around the world. Alternative project delivery methods, the role of public and private sector, different project management strategies, and lessons learned. Field trips to local projects. Same as: CEE 141C

CEE 241P. Integrated Management of Fabrication and Construction. 3-4 Units.
Application of the fundamental fabrication and construction management concepts covered in CEE 241T to an actual project; integrated software environments; integration of scope, schedule, and cost information for scheduling, estimating, and progress control; design workflow in BIM; off-site fabrication vs. on-site construction and supply chain coordination; group project; project permitting, potential for a joint project with CEE 242P. Prerequisites: CEE 210, CEE 241T.
CEE 241T. Fundamentals of Managing Fabrication and Construction. 2 Units.
Schedule representations including Gantt chart, critical path method (CPM),
4D modeling, and location-based schedules (LBS); activity definition; 
Product Breakdown Structure (PBS) and Work Breakdown Structure 
(WBS); consideration of resources constraints, variability, and types of 
materials in schedule definition; production systems including push, pull, 
and collaborative systems; project control including earned value analysis 
(EVA) and plan percent complete (PPC); schedule performance metrics. 
Class will be held during the first five weeks of Autumn Quarter only.

CEE 242A. Negotiating Sustainable Development. 3 Units. 
How to be effective at achieving sustainability by learning the skills 
required to negotiate differences between stakeholders who advocate 
for their own interests. How ecological, social, and economic interests 
can be effectively balanced and managed. How to be effective actors 
in the sustainability movement, and use frameworks to solve complex, 
multiparty processes. Case study analysis of domestic and international 
issues. Students negotiate on behalf of different interest groups in a variety 
of arenas including energy, climate, land use, and the built environment. 
One Saturday all day field trip. No prerequisites. 
Same as: CEE 142A, EARTHSYS 142A, EARTHSYS 242A

CEE 242P. Designing Project Organizations. 2 Units. 
Sequel to CEE 242T. Course develops information-processing approach 
for designing project and project-based company organizations to deliver 
sustainable construction projects; includes design of organizations 
and work processes for integrated project delivery and public-private 
partnership concession project delivery. Term project applies computer-
based organization simulation to optimize design of project organization for 
a participating company.

CEE 242T. Organizational Behavior and Design for Construction. 2 Units. 
Introduction to organizational behavior and organizational design for 
Architecture, Engineering and Construction projects and companies. 
Class incorporates readings, individual and group case study assignments. 
Students use computer simulation to analyze project organizations and 
predict schedule, cost and quality risks. This class is a prerequisite for CEE 242P.

CEE 244. Fundamentals of Construction Accounting and Finance. 2 Units. 
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.

CEE 244A. Sustainable Banking Seminar. 1 Unit. 
This seminar explores ideas for redesigning banks and the banking sector 
to achieve three goals: (1) keep the bank and its depositors safe; (2) keep 
the borrowers, communities, and societies affected by the bank's lending 
decisions safe, and (3) use bank transactions to improve the sustainability of 
natural ecosystems. Weekly speakers include bankers, bank regulators, and 
financial technology (fintech) innovators focused on sustainable banking.

CEE 245A. Global Project Seminar. 3 Units. 
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.

CEE 246. Entrepreneurship in Civil & Environmental Engineering. 3-4 Units. 
CEE 246 is a team project-based course geared toward developing 
entrepreneurial businesses related to civil and environmental engineering. 

With support of industry mentors, students are guided through the process of 
identifying opportunities, developing business plans, and determining 
funding sources. The class culminates with presentations to industry experts 
and venture capitalists (VC) to mimic typical investor pitches. The goal is to 
provide students with the knowledge and network to realize their business 
idea.

CEE 246A. Engineering Economy. 3 Units. 
For CEE 146A: enrollment is limited to juniors and seniors. Attendance to 
the first class is mandatory (for both CEE 146A and CEE 246A). 
Same as: CEE 146A

CEE 246B. Real Estate Finance Seminar. 1 Unit. 
Real estate principles and process. Financial modeling. Feasibility analysis. 
Sources and uses of funds. Cash flow projections. Profit and loss reports. 
Financing issues for different types of real estate projects. Redevelopment 
projects. Financing green projects and technologies. Current challenges in 
financial markets. Group project and presentation. Limited enrollment 
with priority to CEM, DCI, and SDC students not enrolled in CEE 248. 
Prerequisites: CEE 246A or equivalent, ENGR 60. Recommended: 
knowledge of spreadsheets.

CEE 247. Cases in Personality, Leadership, and Negotiation. 3 Units. 
Case studies target personality issues, risk willingness, and life skills 
esential 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. 
Same as: CEE 147

CEE 247A. Network Governance. 3-4 Units. 
This course aims at providing students with insights, concepts and skills 
needed to understand the dynamics of multi-actor interaction processes 
in uncertain and often highly politicized contexts and to be able to 
cope with technological and strategic uncertainties and risks including 
the unpredictable behavior of actors. They will develop knowledge, 
skills and competences about how to manage divergent and conflicting 
interests of different actors including principles of integrative negotiation, 
communication and mediation.

CEE 248. Real Estate Development. 3 Units. 
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.

CEE 248G. Certifying Green Buildings. 1 Unit. 
Open to all disciplines. Goal is prepare students for the United States Green 
Building Council's professional accreditation exam. Basic metrics for 
project certification via USGBC's LEED rating system. Recommended: 
familiarity with design and construction terminology.
CEE 248S. Introduction to Real Estate Development Seminar. 1 Unit. This seminar will offer students an introduction to Real Estate Development. Senior Principals from Sares Regis, a regional commercial and residential real estate development company, will cover topics on all aspects of the development process. Guest speakers from the fields of architecture and engineering, finance and marketing will participate in some of the classes. They will offer the students a window into the world of how houses, apartments, office buildings and public facilities are conceived of, brought through the design and approval process, financed, marketeted and then sold and/or rented. There will be five one-and-a-half-hour lectures (robust class discussion encouraged). Classes commence on April 9th and complete on May 7th. There will be one written project assignment due prior to class on April 23rd. No prior knowledge of real estate is required.

CEE 249. Labor and Industrial Relations: Negotiations, Strikes, and Dispute Resolution. 2 Units. 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.

CEE 251. Negotiation. 3 Units. Students learn to prepare for and conduct negotiations in a variety of arenas including getting a job, managing workplace conflict, negotiating transactions, and managing personal relationships. Interactive class. The internationally travelled instructor who has mediated cases in over 75 countries will require students to negotiate real life case studies and discuss their results in class. Application required before first day of class; see Coursework.

Same as: CEE 151, EARTHSCI 251


CEE 252P. Construction Engineering Practicum. 3 Units. Construction engineering is a series of technical activities to meet project objectives related to cost and schedule, safety, quality, and sustainability. These activities include: 1) designing temporary works and construction work processes; 2) providing the required temporary and permanent resources; and 3) integrating activities to consider construction during all project phases and between projects. The objectives of CEE 252P are to learn about the technical fundamentals, resources, and field operations required to complete construction engineering activities and to develop a foundation for continued related learning. The course requires reviewing recorded presentations and other online resources, completing queries, participating in class sessions with guest speakers and in field trips, and completing group exercises and projects. The exercises, completed by all of the student groups, include construction engineering activities for earthwork, concrete construction, and steel erection. Each group will also complete a project to analyze one of the following types of systems or facilities: building electrical systems, lighting systems, HVAC systems, control systems, solar photovoltaic power plant, and wind turbine power plant.


CEE 254. Cases in Estimating Costs. 3 Units. Students participate in bidding contests requiring cost determination in competitive markets. Monetary forces driving the construction industry as general principles applicable to any competitive business. Cases based on field trips and professor's experience as small business owner and construction engineer. Required full afternoon field trips to local sites. Limited enrollment; no auditors. Prerequisites: consent or instructor and application downloaded from CourseWork prior to start of class.

Same as: CEE 154

CEE 255. Introduction to Sensing Networks for CEE. 3-4 Units. Introduce the design and implementation of sensor networks for monitoring the built and natural environment. Emphasis on the integration of modern sensor and communication technologies, signal processing and statistical models for network data analysis and interpretation to create practical deployments to enable sustainable systems, in areas such as energy, weather, transportation and buildings. Students will be involved in a practical project that may involve deploying a small sensor system, data models and analysis and signal processing. Limited enrollment. Same as: CEE 155

CEE 256. Building Systems. 4 Units. HVAC, lighting, and envelope systems for commercial and institutional buildings, with a focus on energy efficient design. Knowledge and skills required in the development of low-energy buildings that provide high quality environment for occupants.

Same as: CEE 156

CEE 258. Donald R. Watson Seminar in Construction Engineering and Management. 1 Unit. Presentations from construction industry leaders. Discussions with speakers from various segments of industry regarding career options. Student groups interact with industry representatives after class.

CEE 258B. Donald R. Watson Seminar in Construction Engineering and Management. 1 Unit. Weekly seminars and field trips focusing on technical aspects of concrete and steel construction. Submission of abstract and paper required.

CEE 259A. Construction Problems. 1-3 Units. 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.
CEE 259B. Construction Problems. 1-3 Units.
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.

CEE 260A. Physical Hydrogeology. 4 Units.
(Formerly GES 230.) Theory of underground water occurrence and flow, analysis of field data and aquifer tests, geologic groundwater environments, solution of field problems, and groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.
Same as: EESS 220

CEE 260B. Surface and Near-Surface Hydrologic Response. 3 Units.
Same as: EESS 237

CEE 260C. Contaminant Hydrogeology and Reactive Transport. 4 Units.
For earth scientists and engineers. Environmental, geologic, and water resource problems involving migration of contaminated groundwater through porous media and associated biogeochemical and fluid-rock reactions. 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 reactive transport modeling using geochemical transport software. Some Matlab programming / program modification required. Prerequisite: Physical Hydrogeology EESS 220 / CEE 260A (Gorelick) or equivalent. Recommended: course work in environmental chemistry or geochemistry (e.g., one or more of the following: EESS 155, EESS 156/256 GES 90, GES 170/279, GES 171, CEE 177 or CEE 270).
Same as: EESS 221, GES 225

CEE 262A. Hydrodynamics. 3-4 Units.
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.

CEE 262B. Transport and Mixing in Surface Water Flows. 3-4 Units.

CEE 262C. Modeling Environmental Flows. 3 Units.
Introduction to numerical methods for modeling surface water flows in rivers, lakes, estuaries and the coastal ocean. Topics include stability and accuracy analysis, curvilinear and unstructured grids, implicit/explicit methods, transport and diffusion, shallow water equations, nonhydrostatic equations, Navier-Stokes solvers, turbulence modeling. Prerequisites: CEE262A, CME206, or equivalent.

CEE 262D. Introduction to Physical Oceanography. 4 Units.
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).
Same as: CEE 164, EARTHSYS 164, EESS 148

CEE 262E. Lakes and Reservoirs. 2-3 Units.
Physics and water quality dynamics in lakes and reservoirs. Implementation of physical and biogeochemical processes in 1-D models. Recommended: 262B.

CEE 262F. Ocean Waves. 3 Units.
The fluid mechanics of surface gravity waves in the ocean of relevance to engineers and oceanographers. Topics include irrotational waves, wave dispersion, wave spectra, effects of bathymetry (shoaling), mass transport, effects of viscosity, and mean currents driven by radiation stresses. Prerequisite: CEE 262A or a graduate class in fluid mechanics.

CEE 262G. Oceanography. 3-4 Units.
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).
Same as: CEE 164, EARTHSYS 164, EESS 148

CEE 263B. Numerical Weather Prediction. 3-4 Units.
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 chemical ordinary differential equation solver. Prerequisite: CS 106A or equivalent.

CEE 263C. Weather and Storms. 3 Units.
Daily and severe weather and global climate. Topics: structure and composition of the atmosphere, fog and cloud formation, rainfall, local winds, wind energy, global circulation, jet streams, high and low pressure systems, inversions, el Nintilde;ido, la Nintilde;ide, a, atmosphere/ ocean interactions, fronts, cyclones, thunderstorms, lightning, tornadoes, hurricanes, pollutant transport, global climate and atmospheric optics. Same as: CEE 63

CEE 263D. Air Pollution and Global Warming: History, Science, and Solutions. 3 Units.
Survey of air pollution and global warming and their renewable energy solutions. Topics: evolution of the Earth’s atmosphere, history of discovery of chemicals in the air, bases and particles in urban smog, visibility, indoor air pollution, acid rain, stratospheric and Antarctic ozone loss, the historic climate record, causes and effects of global warming, impacts of energy systems on pollution and climate, renewable energy solutions to air pollution and global warming. UG Req: GER: DBNAtSci. Same as: CEE 64

CEE 263S. Atmosphere/Energy Seminar. 1 Unit.
Interdisciplinary seminar with talks by researchers and practitioners in the fields of atmospheric science and renewable energy engineering. Addresses the causes of climate, air pollution, and weather problems and methods of addressing these problems through renewable and efficient energy systems. May be repeated for credit.
CEE 264. Sediment Transport Modeling. 3 Units.
Mechanics of sediment transport in rivers, estuaries and coastal oceans, with an emphasis on development of models and application of three-dimensional software tools. Topics include bottom boundary layers in steady and wave-driven flows, bedform dynamics, suspended and bedload transport, cohesive sediments. Prerequisites: CEE262A or consent of instructor.

CEE 264A. Rivers, Streams, and Canals. 3-4 Units.
Introduction to the movement of water through natural and engineered channels, streams, and rivers. Basic equations and theory (mass, momentum, and energy equations) for steady and unsteady descriptions of the flow. Application of theory to the 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. Limited enrollment in lab section. Prerequisite: CEE 101B.
Same as: CEE 161A

CEE 265A. Sustainable Water Resources Development. 3 Units.
Alternative criteria for judging the sustainability of projects. Application of criteria to evaluate sustainability of water resources projects in several countries. Case studies illustrate the role of political, social, economic, and environmental factors in decision making. Influence of international aid agencies and NGOs on water projects. Evaluation of benefit-cost analysis and environmental impact assessment as techniques for enhancing the sustainability of future projects. Limited enrollment. Prerequisite: graduate standing in Environmental and Water Studies, or consent of instructor.

CEE 265C. Water Resources Management. 3 Units.
Examination of the basic principles of surface and ground water resources management in the context of increasing water scarcity and uncertainty due to climate change and other factors. Specific topics include reservoir, river basin and aquifer management, conjunctive use of surface and ground water, and treated wastewater reuse. Special emphasis is placed on demand management through conservation, increased water use efficiency and economic measures. Besides the technical aspects of water management, an overview of its legal and institutional framework is provided.
Same as: CEE 165C

CEE 265D. Water and Sanitation in Developing Countries. 1-3 Unit.
Economic, social, political, and technical aspects of sustainable water supply and sanitation service provision in developing countries. 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, see jennadavis.stanford.edu for application.

CEE 266A. Watersheds and Wetlands. 3 Units.
Introduction to the occurrence and movement of water in the natural environment and its role in creating and maintaining terrestrial, wetland, and aquatic habitat. Hydrologic processes, including precipitation, evaporation, transpiration, snowmelt, infiltration, subsurface flow, runoff, and streamflow. Rivers and lakes, springs and swamps. Emphasis is on observation and measurement, data analysis, modeling, and prediction. Prerequisite: 101B or equivalent. (Freyberg).
Same as: CEE 166A

CEE 266B. Floods and Droughts, Dams and Aqueducts. 3 Units.
Sociotechnical systems associated with human use of water as a resource and the hazards posed by too much or too little water. Potable and non-potable water use and conservation. Irrigation, hydroelectric power generation, rural and urban water supply systems, storm water management, flood damage mitigation, and water law and institutions. Emphasis is on engineering design. Prerequisite: 166A or equivalent. (Freyberg).
Same as: CEE 166B

CEE 266C. Advanced Topics in Hydrology and Water Resources. 3 Units.
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.

CEE 266D. Water Resources and Water Hazards Field Trips. 2 Units.
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.
Same as: CEE 166D

CEE 268. Groundwater Flow. 3-4 Units.
Flow and mass transport in porous media. Applications of potential flow theory and numerical modeling methods to practical groundwater problems: flow to and from wells, rivers, lakes, drainage ditches; flow through and under dams; streamline tracing; capture zones of wells; and mixing schemes for in-situ remediation. Prerequisites: calculus and introductory fluid mechanics.

CEE 269A. Environmental Fluid Mechanics and Hydrology Seminar. 1 Unit.
Problems in all branches of water resources. Talks by visitors, faculty, and students. May be repeated two times for credit.

CEE 269B. Environmental Fluid Mechanics and Hydrology Seminar. 1 Unit.
Problems in all branches of water resources. Talks by visitors, faculty, and students. May be repeated two times for credit.

CEE 269C. Environmental Fluid Mechanics and Hydrology. 1 Unit.
Problems in all branches of water resources. Talks by visitors, faculty, and students. May be repeated two times for credit.

CEE 270. Movement and Fate of Organic Contaminants in Waters. 3 Units.
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.

CEE 270B. Environmental Organic Reaction Chemistry. 2-3 Units.
With over 70,000 chemicals now in production worldwide, predicting their fate in the environment is a difficult task. The course focuses on developing two key skills. First, students should develop the ability to derive mass balance equations used to quantify the fate of chemicals in the environment. With so many chemicals having been introduced in the past ~60 years, many of the key parameters needed for mass balance models have not been measured experimentally. The class builds on CEE 270, which developed methods of predicting equilibrium partitioning coefficients. For many situations involving reactions of target contaminants, equilibrium is not attained. The course develops methods of predicting the reactivity of chemicals based upon their chemical structures both qualitatively and quantitatively. Natural reaction processes covered include acid-base speciation, nucleophilic substitution, oxidation/reduction reactions, and photochemical reactions. Key treatment ractions (ozone, UV treatment and advanced oxidation) are also covered. Prerequisites: CEE 270, Chem 31B/ X.
CEE 271A. Physical and Chemical Treatment Processes. 3 Units.

CEE 271B. Environmental Biotechnology. 4 Units.
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.

CEE 271D. Introduction to Wastewater Treatment Process Modeling. 2 Units.
The course will present a structured protocol for simulator application comprising project definition, data collection and reconciliation, model set-up, calibration and validation, and simulation and result interpretation. This course will include a series of guided simulation exercises evaluating resource consumption (e.g., electrical energy, natural gas, chemicals) and resource recovery (e.g., biogas, struvite, biosolids, recycled water) from a variety of treatment plant configurations. Coursework for all students will comprise guided simulation exercises begun in class. Students may elect to take the course for 2 units by completing a group project evaluating an assigned plant configuration and presenting the results before the class.

CEE 271E. Environmental Challenges and Policies in Europe. 3 Units.
Current and future environmental challenges in Europe and related public policies in the European Union (EU). State of the European environment and human development, European environmental policy-making (multi-level ecological governance), global ecological role of the EU. Specific challenges include climate change adaptation, mitigation (carbon taxes, carbon market), climate change and European cities, biodiversity and ecosystems preservation (ecologies of biodiversity), energy management. Specific policies include environmental justice (environmental inequalities), human development and environmental sustainability indicators (beyond GDP) and absolute and relative decoupling (carbon intensity and resource productivity improvement). Open to undergraduates (freshmen, sophomores, juniors and seniors) as CEE 171E. Same as: CEE 171E

CEE 271F. New Indicators of Well-Being and Sustainability. 3 Units.
Explore new ways to better measure human development, comprehensive wealth and sustainability beyond standard economic indicators such as income and GDP. Examine how new indicators shape global, national and local policy worldwide. Well-being topics include health, happiness, trust, inequality and governance. Sustainability topics include sustainable development, environmental performance indicators, material flow analysis and decoupling, and inclusive wealth indicators. Students will build their own indicator of well-being and sustainability for a term paper. Same as: CEE 171F

CEE 271M. Transport Phenomena: Momentum, heat and mass transport. 3 Units.
Heat, mass and momentum transfer theory from the viewpoint of basic transport equations. Steady and unsteady state; laminar and turbulent flow; boundary layer theory. Prerequisites: fluid mechanics, ordinary differential equations. Same as: CEE 371M

CEE 272. Coastal Contaminants. 3-4 Units.
Coastal pollution and its effects on ecosystems and human health. The sources, fate, and transport of human pathogens and nutrients. Background on coastal ecosystems and coastal transport phenomena including tides, waves, and cross shelf transport. Introduction to time series analysis with MATLAB. Undergraduates require consent of instructor.

CEE 272R. Modern Power Systems Engineering. 3 Units.
Focus is on Power Engineering from a systems point of view. Topics covered may include modeling of generation, transmission and distribution systems, load flow analysis, transient and steady-state stability analysis. Special emphasis given to modern market operations and dispatch, modeling intermittent controllable power sources, storage technologies, mechanisms for demand response, sensing the grid and the role of market mechanisms for deep integration. Course content may vary year to year.

CEE 272S. Green House Gas Mitigation. 1-3 Unit.
This course will introduce the main concepts of greenhouse gas (GHG) emissions measurement and management, and it will explore the main mitigation options for reducing emissions or sequestering carbon dioxide. It will address technical aspects of GHG mitigation via energy efficiency and demand-side management, energy in high-technology industry, distributed power and co-generation, the role of renewable energy in GHG management, carbon sequestration in forestry, agriculture, and geological formations. The course explores policy options, carbon trading and business strategies for GHG mitigation. Same as: CEE 172S

CEE 272T. SmartGrids and Advanced Power Systems Seminar. 1-2 Unit.
A series of seminar and lectures focused on power engineering. Renowned researchers from universities and national labs will deliver bi-weekly seminars on the state of the art of power system engineering. Seminar topics may include: power system analysis and simulation, control and stability, new market mechanisms, computation challenges and solutions, detection and estimation, and the role of communications in the grid. The instructors will cover relevant background materials in the in-between weeks. The seminars are planned to continue throughout the next academic year, so the course may be repeated for credit. Same as: EE 292T

CEE 272W. Wind Power project Development. 1 Unit.
Introduction to wind power resource assessment and project development. Topics include the dynamics of large-scale and small-scale wind systems, vertical scaling of winds in the boundary layer, measurement instruments used for resource assessments, wind turbine technology, and wind farm siting, planning and economics. Analysis methods of wind data, use of industry-standard software for optimizing turbine siting and project feasibility studies. Project work using existing resource assessment from local areas. Prerequisite: Math41/42 or equivalent. Limited enrollment.

CEE 273. Aquatic Chemistry. 3 Units.
Chemical principles and their application to the analysis and solution of problems in aqueous geochemistry (temperatures near 25deg; 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.

CEE 273A. Water Chemistry Laboratory. 3 Units.
(Graduate students register for 273A.) Laboratory application of techniques for the analysis of natural and contaminated waters, emphasizing instrumental techniques. Same as: CEE 179A

CEE 273C. Introduction to Membrane Technology for Water/ Wastewater Treatment. 1 Unit.
Membrane separation processes focusing on their use for water and wastewater purification. Topics will include membrane types and materials; transport across and rejection by membranes; membrane fouling, cleaning and degradation; and design and operation of membrane systems.
CEE 273D. Wastewater Treatment Process Simulators and Their Use for Emerging Technologies. 2 Units.
Process simulators are used widely for analysis and design of municipal and industrial wastewater treatment facilities. The current generation of simulators integrates biological, chemical, and physical process models that enable steady-state and dynamic "whole plant" simulation of liquid and solids treatment process performance. This course reinforces the concepts presented in CEE 271A, CEE 271B, and CEE 273 and shows how these concepts are applied to analyze and design treatment systems for BOD removal, energy recovery, phosphorus removal and recovery, and nitrogen removal using BioWin TM 4, a commercially-available software package. A process-specific model for anaerobic treatment of domestic wastewater will also be developed for the new Staged Anaerobic Fluidized Membrane Bioreactor (SAF-MBR) based on the International Water Association (IWA) Anaerobic Digester Model No. 1 (ADM1) and implemented using the simulation software Aquasim.

CEE 273S. Chemical Transformation of Environmental Organic Compounds. 3 Units.
This course provides an introduction to the chemistry of organic compounds focusing on chemical transformation and the application of this knowledge to understand and predict the fate of environmentally relevant organic chemicals. The course will cover fundamental rules that govern chemical transformations of organic compounds and will familiarize students with the major physical/chemical factors influencing the kinetics of organic reactions in nature. Prerequisites: CEE 270.

CEE 274A. Environmental Microbiology I. 3 Units.

CEE 274B. Microbial Bioenergy Systems. 3 Units.
Introduction to microbial metabolic pathways and to the pathway logic with a special focus on microbial bioenergy systems. The first part of the course emphasizes the metabolic and biochemical principles of pathways, whereas the second part is more specifically directed toward using this knowledge to understand existing systems and to design innovative microbial bioenergy systems for biofuel, biorefinery, and environmental applications. There also is an emphasis on the implications of rerouting of energy and reducing equivalents for the fitness and ecology of the organism. Prerequisites: CHEMENG 174 or 181 and organic chemistry, or equivalents. Same as: CHEMENG 456

CEE 274D. Pathogens and Disinfection. 3 Units.
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.

CEE 274E. Pathogens in the Environment. 3 Units.
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.

CEE 274P. Environmental Health Microbiology Lab. 3-4 Units.
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. An application form must be filed and approved before admission to the class.

CEE 274S. Hopkins Microbiology Course. 3-12 Units.
(Formerly GES 274S.) Four-week, intensive. The interplay between molecular, physiological, ecological, evolutionary, and geochemical processes that constitute, cause, and maintain microbial diversity. How to isolate key microorganisms driving marine biological and geochemical diversity, interpret culture-independent molecular characterization of microbial species, and predict causes and consequences. Laboratory component: what constitutes physiological and metabolic microbial diversity; how evolutionary and ecological processes diversify individual cells into physiologically heterogeneous populations; and the principles of interactions between individuals, their population, and other biological entities in a dynamically changing microbial ecosystem. Prerequisites: CEE 274A, B, or equivalents. Same as: BIO 274S, BIOHOPK 274, EESS 253S

CEE 275A. California Coast: Science, Policy, and Law. 3-4 Units.
Same as LAW 514. Interdisciplinary. The legal, science, and policy dimensions of managing California’s coastal resources. Coastal land use and marine resource decision making. The physics, chemistry, and biology of the coastal zone, tools for exploring data from the coastal ocean, and the institutional framework that shapes public and private decision making. Field work: how experts from different disciplines work to resolve coastal policy questions. Primarily for graduate students; upper-level undergraduates may enroll with permission of instructor. Students will be expected to participate in at least three mandatory field trips. Same as: CEE 175A, EARTHSYS 175, EARTHSYS 275

CEE 275B. Process Design for Environmental Biotechnology. 3 Units.
Use of microbial bioreactors for degradation of contaminants and recovery of clean water, clean energy and/or green materials. Student teams design, operate, and analyze bioreactors and learn to write consulting style reports. Limited enrollment. Prerequisites: 271B.

CEE 275C. Water, Sanitation and Health. 1-4 Unit.
Students acquire basic knowledge to participate in a dialogue on water, sanitation and health issues in developing and developed countries. The focus is on enteric pathogenic pollutants. Material includes: Important pathogens, their modes of transmission and the diseases they cause, their fate and transport in the environment, and the means by which they are measured; statistical methods for processing and interpreting waterborne pollutant concentrations, and interpreting data from epidemiology studies; microbial source tracking; epidemiology and quantitative microbial risk assessment; reduction of pathogens in water and sludge; and non-experimental water, sanitation, and hygiene research. Several laboratory sessions will allow students to measure indicator bacteria and viruses using culture-based techniques and expose students to molecular methods for measuring health-relevant targets in water.

CEE 275K. The Practice of Environmental Consulting. 2 Units.
Class consists of eight interactive two-hour seminars with discussions, and will cover the evolution of the environmental consulting business, strategic choices and alternative business models for private and public firms, a review of the key operational issues in managing firm, organizational strategies, knowledge management and innovation, and ethical issues in providing professional services. Case studies will be used to illustrate key concepts. Selected reading materials drawn from the technical and business literature on the consulting business. Student groups will prepare and present an abbreviated business plan for an environmental based business. Enrollment limited to CEE MS and PHD students.
CEE 276S. Instrumental Analysis of Emerging Contaminants in the Environment. 3 Units.
Introduction to the occurrence and behavior of trace organic compounds in the environment and focus on research approaches to investigate these compounds. Principles of analytical techniques and experimental approaches to detect and monitor trace organic contaminants in the environment will be examined. Students will critically review published original research and prepare and an original research project proposal.
Same as: CEE 176S

CEE 277C. Environmental Governance. 3 Units.
This interdisciplinary course presents an overview of environmental governance through an examination of how and why societies manage the relationships between human beings and the natural world. By comparing regulatory, community-based, and incentive-based environmental management systems, we address why certain environmental problems are managed as they are, and what approaches to environmental management are more (or less) successful. Designed for graduate students and upper-level undergraduates with some exposure to both the natural sciences (ecology/environmental chemistry), and the social sciences (anthropology, economics, political science, or sociology). A pre-course incoming survey is required.
Same as: ENVRES 250

CEE 277D. Water, Health & Development in Africa. 1 Unit.
Graduate seminar focused on emerging research in the areas of water supply, sanitation, hygiene and health in developing countries. Limited enrollment; instructor permission required.

CEE 277F. Advanced Field Methods in Water, Health and Development. 1-10 Unit.
Field methods for assessing household stored water quality, hand contamination, behaviors, and knowledge related to water, sanitation and health. Limited enrollment. Instructor consent required.

CEE 277K. Environmental Information Engineering. 2-3 Units.
The role of information technology (IT) in enabling mankind to understand its impact on the planet and balance that with improving the quality of life of a rapidly growing population. After surveying the field, the course will examine the specific impacts that IT may have, by reference to case studies from energy, transportation, water and urban design fields. While some specific information technologies will be examined, this will be from a business perspective - detailed technical knowledge of IT not required.
Same as: CEE 177K

CEE 277L. Smart Cities & Communities. 2-3 Units.
The role of information technology (IT) in enabling mankind to improve the operations and sustainability of cities and communities. Review of what a "smarter" city of community might be, the role of IT in enabling them to become "smarter" (including what IT cannot achieve). Case studies on water, energy, transportation urban design and resilience.
Same as: CEE 177L

CEE 277S. Design for a Sustainable World. 1-5 Unit.
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. (Staff)
Same as: CEE 177S

CEE 276. Introduction to Human Exposure Analysis. 3 Units.
(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. Apply at first class for admission.
Same as: CEE 178

CEE 276C. Advanced Topics in Integrated Demand Side Management. 2 Units.
The American economy is highly inefficient: between 14-39% of the energy inputs into the US economy are ultimately used to create goods and services, while the remaining energy is lost in energy conversion and other inefficiencies. While this inefficiency results in a heavy social, environmental, and economic burden on both individuals and society as a whole, it also presents an tremendous opportunity to re-imagine how we use and manage our energy consumption. Recent technological advances, including the rise of information technology, sensors, controls, are dramatically re-shaping how energy is utilized, controlled, stored and integrated with traditional supply side resources. These emerging technologies and energy management techniques provide some of the greatest opportunities to improve the efficiency of our economy and address climate change. This course begins with an overview of demand side management (the application of efficiency, demand reduction, distributed generation, storage, and other resource to shape energy demand) practice to date and a detailed look at how energy is used throughout each sector of the economy. Based on this starting point, the course explores emerging technologies and optimization strategies that enable greater insight and control of energy use both at the device and aggregate level, including integration with renewables, storage, and electric vehicles. It then quantifies and monetizes these optimization strategies into revenue streams to both utility and end-user, and culminates in a discussion of how the intersection of these new technologies, optimization strategies, and revenue streams can help de-carbonize the American economy and shape energy use and the utility of the future. Prerequisites: This course is intended for students who wish to gain an understanding of how energy efficiency and demand management occurs in practice. While there are no formal prerequisites, it is expected that students will have familiarity with energy resources and building energy end uses, such as topics covered in CEE 176A/276A. CEE 173A/207A, CEE 156/256, and CEE 226E.
Same as: CEE 176D

CEE 276E. Environmental Toxicants. 2-3 Units.
Chemicals in the environment that pose toxicity risk. Introduction to environmental toxicology principles for identifying and characterizing toxicants based on sources, properties, pathways, and toxic action. Past and present environmental toxicant issues.

Energy resources and policies in use and under development in China. 12-day field trip to China during Spring Break. One unit for seminar and analysis of economic factors and value propositions that align value chain stakeholder interests. Thursday section is also required for students attending the field trip. Prerequisite: consent of instructor for field trip.
Same as: CEE 176F

CEE 277S. Environmental Entrepreneurship and Innovation. 2 Units.
Our current infrastructure for provision of critical services—clean water, energy, transportation, environmental protection; requires substantial upgrades. As a complement to the scientific and engineering innovations taking place in the environmental field, this course emphasizes the analysis of economic factors and value propositions that align value chain stakeholder interests.
Same as: CEE 175S

CEE 276. Introduction to Human Exposure Analysis. 3 Units.
(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. Apply at first class for admission.
Same as: CEE 178

CEE 276C. Advanced Topics in Integrated Demand Side Management. 2 Units.
The American economy is highly inefficient: between 14-39% of the energy inputs into the US economy are ultimately used to create goods and services, while the remaining energy is lost in energy conversion and other inefficiencies. While this inefficiency results in a heavy social, environmental, and economic burden on both individuals and society as a whole, it also presents an tremendous opportunity to re-imagine how we use and manage our energy consumption. Recent technological advances, including the rise of information technology, sensors, controls, are dramatically re-shaping how energy is utilized, controlled, stored and integrated with traditional supply side resources. These emerging technologies and energy management techniques provide some of the greatest opportunities to improve the efficiency of our economy and address climate change. This course begins with an overview of demand side management (the application of efficiency, demand reduction, distributed generation, storage, and other resource to shape energy demand) practice to date and a detailed look at how energy is used throughout each sector of the economy. Based on this starting point, the course explores emerging technologies and optimization strategies that enable greater insight and control of energy use both at the device and aggregate level, including integration with renewables, storage, and electric vehicles. It then quantifies and monetizes these optimization strategies into revenue streams to both utility and end-user, and culminates in a discussion of how the intersection of these new technologies, optimization strategies, and revenue streams can help de-carbonize the American economy and shape energy use and the utility of the future. Prerequisites: This course is intended for students who wish to gain an understanding of how energy efficiency and demand management occurs in practice. While there are no formal prerequisites, it is expected that students will have familiarity with energy resources and building energy end uses, such as topics covered in CEE 176A/276A. CEE 173A/207A, CEE 156/256, and CEE 226E.
Same as: CEE 176D

CEE 276E. Environmental Toxicants. 2-3 Units.
Chemicals in the environment that pose toxicity risk. Introduction to environmental toxicology principles for identifying and characterizing toxicants based on sources, properties, pathways, and toxic action. Past and present environmental toxicant issues.

Energy resources and policies in use and under development in China. 12-day field trip to China during Spring Break. One unit for seminar and analysis of economic factors and value propositions that align value chain stakeholder interests. Thursday section is also required for students attending the field trip. Prerequisite: consent of instructor for field trip.
Same as: CEE 176F
CEE 277X. Current Topics in Sustainable Engineering. 1-3 Unit.
This course is the first half of a two quarter, project-based design course that addresses the cultural, political, organizational, technical, and business issues at the heart of implementing sustainable engineering projects in the developing world. Students will be placed into one of three project teams and tackle a real-world design challenge in partnership with social entrepreneurs and NGOs. In CEE 177X/277X, students will gain the background skills and context necessary to effectively design engineering projects in developing nations. Instructor consent required.
Same as: CEE 177X

CEE 278A. Air Pollution Fundamentals. 3-4 Units.

CEE 278B. Atmospheric Aerosols. 3 Units.

CEE 278D. Indoor Air Quality. 2-3 Units.
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.
Same as: CEE 172A

CEE 279. Environmental Engineering Seminar. 1 Unit.
Current research, practice, and thinking in environmental engineering and science. Attendance at seminars is self-directed, the 20 hours of required seminar attendance may be accrued throughout the year. Must prepare a publication synopsis, and maintain log of seminar attendance. See Aut Qu CEE 279 syllabus for details on course requirements. Contact hildebrand@stanford.edu to be added to Coursework website.

CEE 279A. Seminar: Issues in Environmental Science, Technology and Sustainability. 1-2 Unit.
Invited faculty, researchers and professionals share their insights and perspectives on a broad range of environmental and sustainability issues. Students critique seminar presentations and associated readings.
Same as: CEE 179S, EARTSYS 179S, EESS 179S

CEE 279W. Innovation in Water Sector. 1 Unit.
A project class on the diffusion of ReNUWIt technologies into practice (David Sedlak is the overall course lead at UC Berkeley, Chris Higgins is the lead at Colorado School of Mines, and Dick Luthy is the lead at Stanford). Specifically, the class will examine the pathway through which ReNUWIt@quest's engineered wetland technologies will be adopted by utilities and consultants beyond our current group of industrial partners. We will work together to prepare background information that will be used in a 2-day workshop involving ReNUWIt researchers, utility leaders and technical experts in early 2015.

CEE 279X. Sustainable Urban System Seminar. 1 Unit.
SYSTEM OF SYSTEMS: Cities are based on several different systems; infrastructures, networks and environments. The effectiveness and efficiency of these systems determine how cities work and how successful a city is at delivering critical services. These systems are not discrete and must be considered holistically as well as individually. These core systems are interconnected and must be treated as such. Understanding one system and making it work better means that cities must comprehend the larger context and how the various systems are interconnected. This seminar series will explore various aspects of these critical systems and how we can make them more resilient and robust, to meet future challenges. Guest speakers, discussion and critical readings.
Same as: CEE 179X

CEE 280. Advanced Structural Analysis. 3-4 Units.
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.

CEE 281. Mechanics and Finite Elements. 3 Units.
Fluid conduction and solid deformation; conservation laws: balance of mass and balance of momentum; generalized Darcy’s law and Hooke’s law in 3D; the use of tensors in mechanics; finite element formulation of boundary-value problems; variational equations and Galerkin approximations; basic shape functions, numerical integration, and assembly operations.

CEE 282. Nonlinear Structural Analysis. 3-4 Units.
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 and an advanced course in structural behavior (e.g., 285A, 285B or equivalent).

CEE 283. Structural Dynamics. 3-4 Units.
Vibrations and dynamic response of simple structures under time dependent loads; dynamic analysis of simple and multiple degrees of freedom systems; support motion; response spectra.

CEE 284. Finite Element Methods in Structural Dynamics. 3-4 Units.
Computational methods for structural dynamics analysis of discrete and continuous systems in free and forced vibration; finite element formulation; modal analysis; numerical methods; introduction to nonlinear dynamics; advanced topics. Prerequisites: 280, 283.

CEE 285A. Advanced Structural Concrete Behavior and Design. 3-4 Units.
Behavior and design of reinforced and prestressed concrete for building and bridge design. Emphasis on flexural behavior, prestressed concrete design, slender columns, and two-way slab design & analysis.

CEE 285B. Advanced Structural Steel Behavior and Design. 3-4 Units.
Advanced topics in structural steel design. Topics include composite floor systems; bolted and welded connections; beam-column connections; innovative lateral load resisting systems. As part of this course students design a 15-story steel building. Prerequisite: basic course in structural steel design CEE181 or equivalent.
CEE 287. Earthquake Resistant Design and Construction. 3–4 Units.
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, force-based and displacement-based design methods, capacity design, detailing and construction of steel and reinforced concrete structures, introduction to performance-based design, seismic isolation, and energy dissipation. Prerequisites: 283 and either 285A or 285B.

CEE 288. Introduction to Performance Based Earthquake Engineering. 3–4 Units.
Earthquake phenomena, faulting, ground motion, earthquake hazard formulation, effects of earthquakes on manmade structures, response spectra, Fourier spectra, soil effects on ground motion and structural damage, methods for structural damage evaluation, and formulation of the performance-based earthquake engineering problems. Prerequisites: 203, 283.

CEE 289. Random Vibrations. 3–4 Units.
Introduction to random processes. Correlation and power spectral density functions. Stochastic dynamic analysis of multi-degree-of-freedom structures subjected to stationary and non-stationary random excitations. Crossing rates, first-excitation probability, and distributions of peaks and extremes. Applications in earthquake, wind, and ocean engineering. Prerequisite: 203 or equivalent.

CEE 290. Structural Performance and Failures. 2 Units.
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.

CEE 291. Solid Mechanics. 3 Units.
Introduction to vectors and tensors; kinematics, deformation, forces, and stress concept of continua and structures; balance principles; aspects of objectivity; hyperelastic materials; thermodynamics of materials; variational principles; applications to structural engineering.

CEE 292. Computational Micromechanics. 3 Units.
Thermodynamics of general internal variable formulations of inelasticity; 1D and 3D material models at small strains (nonlinear elasticity, viscoelasticity, plasticity, damage); development of efficient algorithms and finite element implementations; micromechanical based crystal plasticity models; review of nonlinear continuum mechanics; micromechanical based finite deformation rubber elasticity models; introduction to homogenization methods and micro-macro transitions. Prerequisite: CEE 281 or equivalent.

CEE 293. Foundations and Earth Structures. 3 Units.
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. Prerequisite: 101C or equivalent.

CEE 294. Computational Poromechanics. 3 Units.
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: CEE 281 or equivalent.

CEE 295. Plasticity Modeling and Computation. 3 Units.
Rate-independent elastoplasticity; classical plasticity models for metals and cohesive-frictional materials; cap plasticity models for porous materials; return-mapping algorithm; shear bands, faults, and other discontinuities; Lagrange multipliers, penalty and augmented Lagrangian methods for frictional contact; multiscale techniques: extended finite element and strong discontinuity methods; fault rupture dynamics with bulk plasticity. Prerequisite: CEE 281 or equivalent.

CEE 296. Special Topics in Fluid-Solid Interactions. 2 Units.
Civil, mechanical, and biomedical engineering. Topics include surge and wave impact on structures, tsunami induced sediment transport and scour, wave-soil interactions, dam-reservoir–foundation interactions, shock and blast loads on composite structures, hydroelastic tailoring of composite structures, and blood-vessel interactions. Term project.

CEE 297. Issues in Geotechnical and Environmental Failures. 3 Units.
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.

CEE 297M. Managing Critical Infrastructure. 2 Units.
Safe and effective performance of infrastructure systems is critical to our economy, quality of life and safety. This course will present topics associated with risk analysis and management of critical civil infrastructure systems, tolerable risk and community resilience. Methods of risk analysis including systems analysis, reliability analysis, expert elicitation and systems analysis for spatially distributed infrastructure systems will be presented. Aspects of seismic and flood risk analysis will also be discussed. Case histories and lessons learned from Hurricane Katrina, Tohoku earthquake, among others will be presented. The evolution of change in the risk management of civil infrastructure systems; how they are analyzed, designed and operated is discussed. Guest speakers. Student presentations. (Prerequisite: CEE 203 or equivalent).

CEE 297Q. Large Deformation Computational Inelasticity. 3 Units.
Covers kinematics, thermodynamics, constitutive modeling, numerical time integration, and finite element implementation of large deformation inelasticity. Kinematics of multiplicative decomposition and resulting objective stress rates in the current configuration. Linearization for formulation and finite element implementation of algorithm (consistent) tangent moduli, and local Newton–Raphson iteration for solution of nonlinear constitutive models. Emphasis is on being able to formulate, and numerically implement within a nonlinear finite element program, a wide range of finite strain inelastic constitutive models for solid materials of interest.

CEE 297R. Structural Geology and Rock Mechanics. 4 Units.
Structural Geology and Rock Mechanics. 4 Units. Case histories and lessons learned from Hurricane Katrina, Tohoku earthquake, among others will be presented. The evolution of change in the risk management of civil infrastructure systems; how they are analyzed, designed and operated is discussed. Guest speakers. Student presentations. (Prerequisite: CEE 203 or equivalent).

CEE 298. Structural Geology and Rock Mechanics. 4 Units.
Introduction to the definition of satisfactory 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. Student observation, participation in active lawsuits where possible.
CEE 299. Independent Study in Civil Engineering for CEE-MS Students. 1-5 Unit.
Directed study for CEE-MS students on subjects of mutual interest to students and faculty. Student must obtain faculty sponsor.

CEE 299L. Independent Project in Civil and Environmental Engineering. 1-4 Unit.
Prerequisite: Consent of Instructor.

CEE 299S. Independent Project in Civil and Environmental Engineering. 1-4 Unit.
Prerequisite: consent of instructor.

CEE 300. Thesis. 1-15 Unit.
Research by Engineer candidates. Same as: Engineer Degree

CEE 301. The Energy Seminar. 1 Unit.
Interdisciplinary exploration of current energy challenges and opportunities, with talks by faculty, visitors, and students. May be repeated for credit. Same as: ENERGY 301

CEE 305. Damage and Failure Mechanics of Structural Systems. 3-4 Units.
Examine the mechanics and failure mechanisms of structural deterioration mechanisms and hazards. Overview of fracture mechanics concepts as a general basis for analyzing brittle failure modes in steel and concrete structures. Analysis and design theory for corrosion, fatigue, fire and other damage mechanisms in steel and concrete structures. New methods for mitigation of these failure modes and hazards will be introduced, including new construction materials, structural designs and protection methods.

CEE 306. Computational Fracture Mechanics. 3 Units.
Brief review continuum mechanics; energy principles of mechanics; introduction to fracture mechanics; constrained problems; advanced finite element concepts like mixed, assumed, and enhanced strain methods; computational fracture strategies like cohesive finite elements, embedded and extended finite element methods. Prerequisite: CEE 281 or equivalent.

CEE 316. Sustainable Built Environment Research. 3 Units.
Intended for early stage Ph.D. students in Sustainable Design and Construction (SDC). Covers dominant methodological approaches at the intersection of engineering, social management science and computer science. Overviews an array of methods available for research, focusing on methods commonly used in SDC. Publications using various methods will be analyzed, and journal review processes will be discussed. Major deliverable is research proposal using one or more of the methods discussed. Students will gain familiarity with the array of methods available for SDC research, know how to apply the methods in their own research area, and receive guidance on publishing their research in scientific journals.

CEE 320. Integrated Facility Engineering. 1 Unit.
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.

CEE 321. Formal Models for Design. 3 Units.
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.

CEE 322. Data Analytics for Urban Systems. 3 Units.
TBA.

CEE 323A. Infrastructure Finance and Governance. 1 Unit.
Presentation and discussion of early stage or more mature research on a variety of topics related to financing, governance and sustainability of civil infrastructure projects by researchers associated with the Global Projects Center and visiting speakers. To obtain one unit of credit, students must attend and participate in all seminars, with up to two excused absences. Seminar meets weekly during Autumn, Winter and Spring Quarters.

CEE 323B. Infrastructure Finance and Governance. 1 Unit.
Presentation and discussion of early stage or more mature research on a variety of topics related to financing, governance and sustainability of civil infrastructure projects by researchers associated with the Global Projects Center and visiting speakers. To obtain one unit of credit, students must attend and participate in all seminars, with up to two excused absences. Seminar meets weekly during Autumn, Winter and Spring Quarters.

CEE 323C. Infrastructure Finance and Governance. 1 Unit.
Presentation and discussion of early stage or more mature research on a variety of topics related to financing, governance and sustainability of civil infrastructure projects by researchers associated with the Global Projects Center and visiting speakers. To obtain one unit of credit, students must attend and participate in all seminars, with up to two excused absences. Seminar meets weekly during Autumn, Winter and Spring Quarters.

CEE 328A. Multidisciplinary Design and Simulation of Building Envelopes. 3 Units.
Curtain walls are a manufactured product ubiquitous in the world of architecture and engineering that must meet structural, thermal, acoustic, environmental, and economic performance requirements. This course focuses on design strategies for building envelopes and explores new design approaches including parametric 3D modeling, simulation, and Multidisicplinary Design Optimization (MDO) methods that leverage computation to augment human abilities to identify novel, high performing solutions. Prerequisite: CEE 220A or equivalent. Limited to 16 students.

CEE 336. Turbulence Modeling for Environmental Fluid Mechanics. 2-4 Units.
An introduction to turbulence and its modeling, including Reynolds-average and large-eddy simulation models. Derivation of closure approximations and models. Impact of numerical code truncation error on turbulence model value and accuracy. Discussion of typical models and their applications to turbulent flows in rivers, estuaries, the coastal ocean and the atmospheric boundary layer (e.g., wind turbines and weather models). Prerequisites: knowledge of hydrodynamics or atmosphere dynamics and the basics of transport and mixing in the environment; consent of instructor.
CEE 362. Numerical Modeling of Subsurface Processes. 3-4 Units.
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.

CEE 362G. Stochastic Inverse Modeling and Data Assimilation Methods, 3-4 Units.
Stochastic methods for the solution of inverse problems that are algebraically underdetermined or have solutions that are sensitive to data. Emphasis is on geostatistical methods that, in addition to using data, incorporate information about structure such as spatial continuity and smoothness. Methods for real-time processing of new data. Prerequisite: consent of instructor.

CEE 362H. Heterogeneity and Scale in Groundwater, 3-4 Units.
Geologic materials are complex and composite media, in the microscale, but modeled as continua at the macroscale. We examine how our understanding of processes and heterogeneity at the microscale support laws that describe fluxes and change of state variables at the macroscale. We study Darcy's law for porous media, Fickian dispersion, non-Fickian dispersion, dilution of solutes, and mixing of reactants under mass transfer (diffusional) limitations. We use mathematical tools such as homogenization theories and stochastic analysis to find relations among macroscopic quantities. To be taught in Winter, alternate years starting 2011-2012.

CEE 363A. Mechanics of Stratified Flows. 3 Units.
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.

CEE 363C. Ocean and Estuarine Modeling, 3 Units.
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.

CEE 363F. Oceanic Fluid Dynamics. 3 Units.
Dynamics of rotating stratified fluids with application to oceanic flows. Topics include: inertia-gravity waves; geostrophic and cyclostrophic balance; vorticity and potential vorticity dynamics; quasi-geostrophic motions; planetary and topographic Rossby waves; inertial, symmetric, barotropic and baroclinic instability; Ekman layers; and the frictional spin-down of geostrophic flows. Prerequisite: CEE 262A or a graduate class in fluid mechanics.
Same as: EESS 363F

CEE 363G. Field Techniques in Coastal Oceanography. 3 Units.
This course focuses on the design and implementation of coastal oceanographic field studies from implementation through analysis. A wide range of field instrumentation and techniques, including AUVs and scientific diving is covered. Field studies. Data collection and analysis under instructor guidance.

CEE 364F. Advanced Topics in Geophysical Fluid Dynamics. 2-3 Units.
A seminar-style class covering the classic papers on the theory of the large-scale ocean circulation. Topics include: wind-driven gyres, mesoscale eddies and geostrophic turbulence, eddy-driven recirculation gyres, homogenization of potential vorticity, the ventilated thermocline, subduction, and the abyssal circulation. Prerequisite: EESS 363F or CEE 363F. Recommended: EESS 246B.
Same as: EESS 364F

CEE 364Y. Advanced Topics in Coastal Oceanography. 1-2 Unit.
The dynamics and transport implications of features in estuaries and coastal oceans characterized by sharp gradients: fronts, interfaces, and layers. Analytic framework to describe the formation, maintenance, and dissipation of such features. Examples include tidal mixing fronts, buoyant plume fronts and tidal intrusions, biological thin layers, and axial convergent fronts. Second unit for students who give a presentation.

CEE 365A. Advanced Topics in Environmental Fluid Mechanics and Hydrology. 2-6 Units.
Students must obtain a faculty sponsor.

CEE 365B. Advanced Topics in Environmental Fluid Mechanics and Hydrology. 2-6 Units.
Students must obtain a faculty sponsor.

CEE 365C. Advanced Topics in Environmental Fluid Mechanics and Hydrology. 2-6 Units.
Students must obtain a faculty sponsor.

CEE 365D. Advanced Topics in Environmental Fluid Mechanics and Hydrology. 2-6 Units.
Students must obtain a faculty sponsor.

CEE 370A. Environmental Research. 5-6 Units.
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.

CEE 370B. Environmental Research. 5-6 Units.
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.

CEE 370C. Environmental Research. 5-6 Units.
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.

CEE 370D. Environmental Research. 3-6 Units.
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.

CEE 371. Frontiers in Environmental Research. 1-2 Unit.
How to evaluate environmental research.
CEE 371L. Helminthic Disease Monitoring and Control. 5 Units.
Assessment will be based upon weekly written and/or oral reports, with a
final written critical review due at the end of the quarter.

CEE 371M. Transport Phenomena: Momentum, heat and mass
transport. 3 Units.
Heat, mass and momentum transfer theory from the viewpoint of basic
transport equations. Steady and unsteady state; laminar and turbulent flow;
boundary layer theory. Prerequisites: fluid mechanics, ordinary differential
equations.
Same as: CEE 271M

CEE 374A. Introduction to Physiology of Microbes in Biofilms. 1-6
Unit.
Diversification of biofilm populations, control of gene expression in biofilm
environments, and evolution of novel genetic traits in biofilms.
CEE 374B. Introduction to Physiology of Microbes in Biofilms. 1-6
Unit.
Diversification of biofilm populations, control of gene expression in biofilm
environments, and evolution of novel genetic traits in biofilms.
CEE 374C. Introduction to Physiology of Microbes in Biofilms. 1-6
Unit.
Diversification of biofilm populations, control of gene expression in biofilm
environments, and evolution of novel genetic traits in biofilms.
CEE 374D. Introduction to Physiology of Microbes in Biofilms. 1-6
Unit.
Diversification of biofilm populations, control of gene expression in biofilm
environments, and evolution of novel genetic traits in biofilms.
CEE 374S. Advanced Topics in Microbial Pollution. 1-5 Unit.
May be repeated for credit. Prerequisite: consent of instructor.
CEE 374T. Advanced Topics in Coastal Pollution. 1-5 Unit.
May be repeated for credit. Prerequisite: consent of instructor.
CEE 374U. Advanced Topics in Submarine Groundwater Discharge.
1-5 Unit.
May be repeated for credit. Prerequisite: consent of instructor.
CEE 374V. Advanced Topics in Microbial Source Tracking. 1-5 Unit.
May be repeated for credit. Prerequisite: consent of instructor.
CEE 374W. Advanced Topics in Water, Health and Development. 1-12
Unit.
Advanced topics in water, health and development. Emphasis on low-and
middle-income countries. Class content varies according to interests of
students. Instructor consent required.
CEE 374X. Advanced Topics in Multivariate Statistical Analysis. 1-6
Unit.
Analysis of experimental and non-experimental data using multivariate
modeling approaches. May be repeated for credit. Permission of instructor
required for enrollment.

CEE 375. Advanced Methods in Pathogen Detection. 2 Units.
Molecular and culture-based techniques for pathogen detection in water.

CEE 377. Research Proposal Writing in Environmental Engineering
and Science. 1-3 Unit.
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.

CEE 378. Statistical Analysis of Environmental Data: Tools and
Applications. 2-3 Units.
Preference to Environmental Engineering and Science Ph.D. students.
Practical data analysis techniques applicable to environmental engineering.
The role of statistics in data collection, experimental design, data
exploration, and effective communication of results. Use of statistical
packages such as Excel, Matlab, and R. Discussions partially based on
student interest and available datasets. Topics may include summarizing
data, hypothesis testing, nonparametric statistics, regression analysis,
classification and regression trees, cluster analysis, and computationally
intensive methods. Limited enrollment.

CEE 378D. Seminar of Statistical Analysis of Multidisciplinary
Primary Data. 1-3 Unit.
Practical management and analysis techniques for primary data collected
in multidisciplinary projects. Selection of appropriate statistical tests,
interpretation of results, and effective communication of findings
to lay audiences. Univariate, bivariate and multivariate techniques,
including hypothesis testing, nonparametric statistics, regression analysis
and matching. Use of SPSS statistical package. Limited enrollment.
Prerequisite: consent of instructor.

CEE 381. Advanced Engineering Informatics. 1-4 Unit.

CEE 385. Performance-Based Earthquake Engineering. 3-4 Units.
Synthesis and application of approaches to performance-based design and
assessment that recently have been developed or are under development.
Emphasis is on quantitative decision making based on life-cycle
considerations that incorporate direct losses, downtime losses, and collapse,
and the associated uncertainties. Hazard analysis, response simulation,
damage and loss estimation, collapse prediction. Case studies. Prerequisites:
282, 287, and 288.

CEE 386. Fundamentals and Applications of Wind Engineering, 3
Units.
This course provides a basic understanding of how winds interact with
the built environment. Knowledge of wind flow and the wind/structure
interaction is introduced to understand the risks associated with extreme
wind events (e.g., hurricanes, tornadoes, thunderstorm downbursts, etc.)
and its application for design, damage mitigation, and risk management.
In addition to providing an introduction to catastrophe risk modeling,
this course will show how the principles of wind engineering are used to
estimate the risk of the built environment subjected to catastrophic wind
events. Prerequisites: undergraduate fluid mechanics, structural dynamics
(CEE 283 or equiv), probability CEE 203.

CEE 398. Report on Civil Engineering Training. 1 Unit.
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.

CEE 399. Advanced Engineering Problems. 1-10 Unit.
Individual graduate work under the direction of a faculty member on a
subject of mutual interest. For Engineer Degree students and Pre-quals
Doctoral students. Student must have faculty sponsor. May be repeated for
credit.

CEE 400. Thesis. 1-15 Unit.
For students who have successfully completed the department general
qualifying examination. Research and dissertation for the Ph.D. degree.
Same as: Ph.D. Degree

CEE 801. TGR Project. 0 Units.
Same as: Engineer Degree

CEE 802. TGR Dissertation. 0 Units.
Same as: PhD degree