CIVIL AND ENVIRONMENTAL ENGINEERING

Courses offered by the Department of Civil and Environmental Engineering are listed under the subject code CEE (https://explorecourses.stanford.edu/search?/search?view=catalog&academicYear=&q=CEE&filter-departmentcode-CEE=on&filter-coursestatus-Active=on&filter-term-Autumn=on&filter-term-Winter=on&filter-term-Spring=on&filter-term-Summer=on&page=0) on the *Stanford Bulletin's* ExploreCourses (https://explorecourses.stanford.edu) web site.

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. In the area of sustainable built environments it focuses on 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. In the area of environmental and water studies the department focuses on 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. In the atmosphere/energy area it studies fundamental energy and atmospheric engineering and science, assess energy-use effects on atmospheric processes and air quality, and analyze and design 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 methodologies 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.

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 21^{st} 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 areas of study.

- 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 principal areas are carried out in research centers and facilities in these areas: Environmental Engineering and Science Laboratory (EESL); Environmental Fluid Mechanics Laboratory (EFML); and Sustainable Built Environment.

The EESL conducts laboratory and field-based research on air quality and on water and wastewater quality and treatment, on bioenergy and resource recovery, 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 2016. The Center for Sustainable Development and Global Competitiveness (CSDGC) engages in research and educational programs that integrate business development strategies with leadership practices that will ensure enterprise growth and success within a healthy and sustainable natural environment. EESL faculty are also active in the Stanford Program on Water, Health and Development, which his focused on improving the scientific basis for decision-making around water supply and sanitation services in the global South.

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

Several research centers focus on improving the sustainability of the built environment. 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 information and communication technologies and concepts to integrate the facility development process and enhance the usability, buildability, operability, and sustainability of facilities. The Global Projects Center (GPC) is a multi-discipline, 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 includes programs 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) Program emphasizes the chemical and biological processes involved in water quality engineering, pollution treatment, remediation, and environmental protection.

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

Environmental Fluid Mechanics and Hydrology

The Environmental Fluid Mechanics and Hydrology (EFMH) Program focuses on understanding, 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.

EFMH research is focused in the Bob and Norma Street Environmental Fluid Mechanics Laboratory, which includes numerous experimental facilities and a wide range of field equipment.

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) subprogram 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) 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. To give students the breadth and depth necessary to become leaders in practice or research in sustainable design and construction, the SDC program offers four tracks of study: construction, energy, structures, and water. In addition to providing critical skills and the necessary industry context, each track offers courses in the following areas of competency: Building and infrastructure development; structural performance, design, and analysis; water infrastructure systems; energy systems, energy efficiency, and atmosphere; and construction engineering and management.

Classes address advanced topics like cutting-edge information technology, metrics and tools to enhance lifecycle sustainability of the sustainable built environment, sensor networks embedded in intelligent buildings and infrastructure, strategy, economics, entrepreneurship and organization design for new businesses, and corporate or governmental initiatives aimed at enhancing the sustainability of buildings and infrastructure.

The SDC 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.

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. 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 the CEE 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. 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

		Units
Mathematics and Science		45
45 units minimum; see Basic Requirements 1 and 2 [1]		
Technology in Society		
One course; course chosen must be on the SoE Approved Courses list at <ughb.stanford.edu> the year taken; see Basic Requirement 4 [2]		3-5
Engineering Fundamentals		
Three courses minimum, see Basic Requirement 3		
ENGR 14	Intro to Solid Mechanics	4
ENGR 90/CEE 70	Environmental Science and Technology	3
Fundamentals Elective		3-5
Engineering Depth		
Minimum of 68 Engineering Fundamentals plus Engineering Depth; see Basic Requirement 5		
CEE 100	Managing Sustainable Building Projects [3]	4
CEE 101A	Mechanics of Materials	4
CEE 101B	Mechanics of Fluids (or CEE 101N)	4
CEE 101C	Geotechnical Engineering	4
CEE 146A	Engineering Economy	3
Specialty courses in either:		36-39
Environmental and Water Studies (see below)		
Structures and Construction (see below)		
Other School of Engineering Electives		3-0
Total Units		116-120

1 Mathematics must include CME 100 Vector Calculus for Engineers and CME 102 Ordinary Differential Equations for Engineers (or Math 51 Linear Algebra and Differential Calculus of Several Variables and 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 GS 1A Introduction to Geology: The Physical Science of the Earth (or GS 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. Please note that the only quarter GS 1A is offered for AY 2015-16 is Spring Quarter.

2 Chosen TiS class must specifically include an ethics component, as indicated in Figure 3-3 in the Engineering Undergraduate Handbook (http://web.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Handbooks)

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

Environmental and Water Studies Focus

		Units
ENGR 30	Engineering Thermodynamics [1]	3
CEE 101D	Computations in Civil and Environmental Engineering (or CEE 101S) [2]	3
CEE 162E	Rivers, Streams, and Canals	3
CEE 166A	Watersheds and Wetlands	4
CEE 166B	Floods and Droughts, Dams and Aqueducts	4
CEE 171	Environmental Planning Methods	3
CEE 172	Air Quality Management	3
CEE 177	Aquatic Chemistry and Biology	4
CEE 179A	Water Chemistry Laboratory	3
CEE 179C	Environmental Engineering Design	5
(or CEE 169) Capstone design experience course		
Remaining specialty units from:		
CEE 63	Weather and Storms [2]	3
CEE 64	Air Pollution and Global Warming: History, Science, and Solutions [2]	3
CEE 107A	Understanding Energy	3-5
CEE 107F	Understanding Energy -- Field Trips	1
CEE 155	Introduction to Sensing Networks for CEE	4
CEE 161C	Natural Ventilation of Buildings	3
CEE 161I	Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation	3
CEE 162D	Introduction to Physical Oceanography	4
CEE 162F	Coastal Engineering	4

CEE 162I	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation	3
CEE 165C	Water Resources Management	3
CEE 166D	Water Resources and Water Hazards Field Trips	2
CEE 174A	Providing Safe Water for the Developing and Developed World	3
CEE 174B	Wastewater Treatment: From Disposal to Resource Recovery	3
CEE 176A	Energy Efficient Buildings	3-4
CEE 176B	Electric Power: Renewables and Efficiency	3-4
CEE 178	Introduction to Human Exposure Analysis	3
CEE 199	Undergraduate Research in Civil and Environmental Engineering	1-4

Structures and Construction Focus

		Units
CEE 102	Legal Principles in Design, Construction, and Project Delivery	3
CEE 120A	Building Information Modeling Workshop (or CEE 120S)	3-4
CEE 156	Building Systems	4
CEE 180	Structural Analysis	4
CEE 181	Design of Steel Structures	4
CEE 182	Design of Reinforced Concrete Structures	4
CEE 183	Integrated Civil Engineering Design Project	4
Select one of the following:		4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	
ENGR 50E	Introduction to Materials Science, Energy Emphasis	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
Remaining specialty units from:		
ENGR 15	Dynamics	4
CME 104	Linear Algebra and Partial Differential Equations for Engineers	5
CEE 101D	Computations in Civil and Environmental Engineering (or CEE 101S)	3
CEE 112A	Industry Applications of Virtual Design & Construction	2-4
CEE 112B	Industry Applications of Virtual Design & Construction	2-4
CEE 122A	Computer Integrated Architecture/Engineering/Construction	2
CEE 122B	Computer Integrated A/E/C	2
CEE 131A Professional Practice: Mixed Use Design in an Urban Setting (not given AY 2015-16)		
CEE 131B	Financial Management of Sustainable Urban Systems	3
CEE 141A	Infrastructure Project Development	3
CEE 141B	Infrastructure Project Delivery	3
CEE 151	Negotiation	3
CEE 155	Introduction to Sensing Networks for CEE	4
CEE 161C	Natural Ventilation of Buildings	3
CEE 162E	Rivers, Streams, and Canals	3-4
CEE 171	Environmental Planning Methods	3
CEE 176A	Energy Efficient Buildings	3-4
CEE 176B	Electric Power: Renewables and Efficiency	3-4
CEE 195	Fundamentals of Structural Geology	3
CEE 196	Engineering Geology and Global Change	3
CEE 199	Undergraduate Research in Civil and Environmental Engineering	1-4
CEE 203	Probabilistic Models in Civil Engineering	3-4
One of the following can also count as remaining specialty units.		3-4
CEE 120B	Building Information Modeling Workshop	2-4
CEE 130	Architectural Design: 3-D Modeling, Methodology, and Process	
CEE 131A	Professional Practice: Mixed-Use Design in an Urban Setting	
CEE 134B	Intermediate Arch Studio	

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.

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 twenty-first 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, course chosen must be on the SoE Approved Courses list at <ughb.stanford.edu> the year taken; see Basic Requirement 4		3-5
Engineering Fundamentals		
Three courses minimum (see Basic Requirement 3), including:		
ENGR 70A	Programming Methodology	5
(or ENGR 70X)		
plus one Engineering fundamentals elective		3-5
Fundamental Tools/Skills [2]		9

in visual, oral/written communication, and modeling/analysis		
Specialty Courses, in either		37
Coastal environments (see below)		
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 focus area only).
2. Fundamental tools/skills must include:
    1. CEE 1 Introduction to Environmental Systems Engineering ;
    2. 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 101 Visual Thinking, ME 110 Design Sketching, ARTSTUDI 160 Intro to Digital / Physical Design, or OSPPARIS 44 EAP: Analytical Drawing and Graphic Art;
    3. at least one oral/written communication class from ENGR 103 Public Speaking, ENGR 102W Writing for Engineers, ENGR 202W Technical Writing, CEE 151 Negotiation, EARTHSYS 195 , or EARTHSYS 200 Environmental Communication in Action: The SAGE Project;
    4. at least one modeling/analysis class from CEE 155 Introduction to Sensing Networks for CEE, CEE 120A Building Information Modeling Workshop (or CEE 120S Building Information Modeling Special Study), CEE 146A Engineering Economy, CEE 226 Life Cycle Assessment for Complex Systems, EARTHSYS 144 Fundamentals of Geographic Information Science (GIS), CEE 101D Computations in Civil and Environmental Engineering (if not counted as Math), or CME 211 Software Development for Scientists and Engineers (or EARTHSYS 211 Fundamentals of Modeling).

Urban Environments Focus Area (37 units)

Required		
CEE 100	Managing Sustainable Building Projects	4
CEE 101B	Mechanics of Fluids	4
CEE 146A	Engineering Economy	3
(if not counted as 3rd Engineering fundamental)		
CEE 176A	Energy Efficient Buildings	3-4
Electives (at least two of the 4 areas below must be included, with at least 3 units from 2nd area)		
Building Systems		
CEE 102	Legal Principles in Design, Construction, and Project Delivery	3
CEE 130	Architectural Design: 3-D Modeling, Methodology, and Process	5
CEE 156	Building Systems	4
CEE 161C	Natural Ventilation of Buildings	3
Energy Systems		
CEE 107A	Understanding Energy	3-5
CEE 107F	Understanding Energy -- Field Trips	1
CEE 176B	Electric Power: Renewables and Efficiency	3-4
EE 151	Sustainable Energy Systems	3
ENERGY 171	Energy Infrastructure, Technology and Economics	3
or		
ENERGY 191	Optimization of Energy Systems	3-4
Water Systems		
CEE 165C	Water Resources Management	3
CEE 166A	Watersheds and Wetlands	4
CEE 166B	Floods and Droughts, Dams and Aqueducts	4
CEE 174A	Providing Safe Water for the Developing and Developed World	3
CEE 174B	Wastewater Treatment: From Disposal to Resource Recovery	3
Urban Planning, Design, Analysis		
CEE 6	Physics of Cities	3
CEE 171	Environmental Planning Methods	3
or		
URBANST 163	Land Use Control	4
CEE 177L	Smart Cities & Communities	2
CEE 177M		2
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 (one class required)		
CEE 112A	Industry Applications of Virtual Design & Construction	3-4
CEE 122A	Computer Integrated Architecture/Engineering/ Construction	2
and		
CEE 112B	Industry Applications of Virtual Design & Construction	2
CEE 126	International Urbanization Seminar: Cross-Cultural Collaboration for Sustainable Urban Development	4-5
CEE 131D	Urban Design Studio	5
CEE 141A	Infrastructure Project Development	3
CEE 141B	Infrastructure Project Delivery	3
CEE 224Y	Sustainable Urban Systems Project	3-5
CEE 224Z	Sustainable Urban Systems Project	3-5
CEE 226E	Advanced Topics in Integrated, Energy-Efficient Building Design	3
CEE 199	Undergraduate Research in Civil and Environmental Engineering	3-4

Freshwater Environments Focus Area (37 units)

Required		
CEE 70	Environmental Science and Technology	3
(if not counted as 3rd Engineering fundamental)		
CEE 101B	Mechanics of Fluids	4
CEE 177	Aquatic Chemistry and Biology	4
CEE 166A	Watersheds and Wetlands	4
or		
CEE 174A	Providing Safe Water for the Developing and Developed World	3
Electives		
CEE 162E	Rivers, Streams, and Canals	3
CEE 165C	Water Resources Management	3
CEE 166A	Watersheds and Wetlands (if not counted as a req'd course)	4
(if not counted as required course)		
CEE 166B	Floods and Droughts, Dams and Aqueducts	4
CEE 166D	Water Resources and Water Hazards Field Trips	2
CEE 171	Environmental Planning Methods	3
or		

URBANST 163	Land Use Control	4
CEE 174A	Providing Safe Water for the Developing and Developed World	3
(if not counted as a required course)		
CEE 174B	Wastewater Treatment: From Disposal to Resource Recovery	3
CEE 179A	Water Chemistry Laboratory	3
CEE 265A	Sustainable Water Resources Development	3
CEE 265D	Water and Sanitation in Developing Countries	3
BIOHOPK 150H	Ecological Mechanics	3
EARTHSYS 156	Soil and Water Chemistry	1-4
GEOPHYS 191	Observing Freshwater	3
GS 130	Soil Physics and Hydrology	3
OSPAUSTL 25	Freshwater Systems	3
Capstone (1 class required)		
CEE 126	International Urbanization Seminar: Cross-Cultural Collaboration for Sustainable Urban Development	4-5
CEE 141A	Infrastructure Project Development	3
CEE 169	Environmental and Water Resources Engineering Design	5
CEE 179C	Environmental Engineering Design	5
CEE 224Y	Sustainable Urban Systems Project	3-5
CEE 224Z	Sustainable Urban Systems Project	3-5
CEE 199	Undergraduate Research in Civil and Environmental Engineering	3-4

Coastal Environments Focus Area (37 units)

Required		
CEE 70	Environmental Science and Technology	3
(if not counted as 3rd Engineering fundamental)		
CEE 101B	Mechanics of Fluids	4
CEE 162D	Introduction to Physical Oceanography	4
CEE 162F	Coastal Engineering	4
or		
CEE 175A	California Coast: Science, Policy, and Law	3-4
Electives		
CEE 162D	Introduction to Physical Oceanography	4
CEE 166A	Watersheds and Wetlands	4
CEE 166B	Floods and Droughts, Dams and Aqueducts	4
CEE 171	Environmental Planning Methods	3
or		
URBANST 163	Land Use Control	4
CEE 174A	Providing Safe Water for the Developing and Developed World	3
CEE 174B	Wastewater Treatment: From Disposal to Resource Recovery	3
CEE 175A	California Coast: Science, Policy, and Law (if not counted as req'd course)	3-4
CEE 177	Aquatic Chemistry and Biology	4
CEE 272	Coastal Contaminants	3-4
BIO 30	Ecology for Everyone	4
or		
BIO 43	Plant Biology, Evolution, and Ecology (or BIOHOPK 43)	5
or		
BIOHOPK 172H	Marine Ecology: From Organisms to Ecosystems	5
or		
EARTHSYS 116	Ecology of the Hawaiian Islands	4
or		
OSPAUSTL 10	Coral Reef Ecosystems	3
or		
OSPSANTG 85		5
or		
BIOHOPK 182H	Stanford at Sea	16
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 required)		
CEE 126	International Urbanization Seminar: Cross-Cultural Collaboration for Sustainable Urban Development	4-5
CEE 141A	Infrastructure Project Development	3
CEE 169	Environmental and Water Resources Engineering Design	5
CEE 179C	Environmental Engineering Design	5
CEE 224Y	Sustainable Urban Systems Project	2-5
CEE 224Z	Sustainable Urban Systems Project	2-5
BIOHOPK 168H	Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations	3
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, including example minor programs, are provided 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).

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 Engineering and Management. John Barton (jhbarton@stanford.edu (http://www.stanford.edu/dept/registrar/bulletin/jhbarton@stanford.edu)), Program Director for Architectural Design, is the undergraduate minor adviser in Architectural Design. Students must consult the appropriate adviser when developing their minor program, and obtain approval of the finalized study list from them.

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—

- 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.
- 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).

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

Coterminal 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 20, 2017). 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 Coterminal Requirements

Coterminal master’s degree candidates are expected to complete all master’s degree requirements as described in this bulletin. University requirements for the coterminal master’s degree are described in the “Coterminal Master’s Program (http://exploredegrees.stanford.edu/cotermdegrees)” section. University requirements for the master’s degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master’s degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master’s degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master’s program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master’s degree requirements.

Course transfers are not possible after the bachelor’s degree has been conferred.

The University requires that the graduate adviser be assigned in the student’s first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master’s Degree Program Proposal be completed by the student and approved by the department by the end of the student’s first graduate quarter.

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. Additionally, up to 45 units of graduate study can be represented by the Engineer (ENG) program as described above if both the M.S. and ENG units were all completed at Stanford. 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 both a CEE faculty member and a member of the Academic Council. The faculty member must be in the program of the designated minor subfield of CEE. 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 PhD 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.

Emeriti: (Professors) Gilbert M. Masters*, Perry L. McCarty*, Henry W. Parker, Martin Reinhard*, Haresh C. Shah, Robert L. Street*, Clyde B. Tatum*, Paul M. Teicholz

Chair: Lynn M. Hildemann

Associate Chairs: Ronaldo I. Borja, Raymond E. Levitt

Professors: Sarah L. Billington, Alexandria B. Boehm, Ronaldo I. Borja, Craig S. Criddle, John O. Dabiri, Gregory G. Deierlein, Martin A. Fischer, Lynn M. Hildemann (on leave Aut), Mark Z. Jacobson, Anne S. Kiremidjian, Peter K. Kitanidis, Jeffrey R. Koseff, Kincho H. Law, James O. Leckie, Raymond E. Levitt, Richard G. Luthy, Stephen G. Monismith, Leonard Ortolano (on leave Autumn), Alfred M. Spormann

Associate Professors: Jack W. Baker, Jennifer Davis, David L. Freyberg, Oliver B. Fringer, Michael D. Lepech, Nicholas T. Ouellette, Eduardo Miranda, William A. Mitch

Assistant Professors: Catherine Gorlé, Rishee Jain, Christian Linder, Ram Rajagopal

Courtesy Professor: Peter M. Pinsky

Courtesy Associate Professor: Margot G. Gerritsen

Lecturers: Michael Azgour, Deborah Ballati, John Barton, Thomas Beischer, Michael Bennon, Beverly Choe Harris, Stanley Christensen, Charles Debbas, Kyle Douglas, Derek Fong, Renate Fruchter, Diana Ginnebaugh, Robert Groves, James Hawk, Kenneth Hayes, Glenn Katz, David Kleiman, Karl Knapp, Nelson Koen Cohen, John Koester, Royal Kopperud, David Lallemant, Amy Larimer, Eloi Laurent, Sophie Maisnier-Patin, Pedram Mokrian, Derek Ouyang, Jose, Luis Moscovich, Brian O'Kelly, Allison Pieja, Alexander (Sandy) Robertson, Peter Rumsey, Bill Shelander, Brian Shiles, Charlotte Stanton, J.B. Straubel, Hattie Stroud, Isabella Tomanek, Allison Williams, Peter Williams, Ethen J. Wood, Jon R. Wren

Adjunct Lecturer: Leo Chow, Erik Kolderup, Peter Rumsey, Mark Sarkisian, Robert Soden, Kristen Stasio, Christopher Wasney

Adjunct Professors: Howard Ashcraft, Vladimir Bazjanac, Terry Beaubois, Bruce Cahan, James Cloern, Angelos Findikakis, Robert Hickey, Thomas Holzer, Calvin Kam, Michael Kavanaugh, Karl Knapp, Martin McCann, William McDonough, Paul Meyer, Piotr Moncarz, Jose Luis Moscovitch, Wayne Ott, Benedict Schwegler, Brian Sedar, Patrick Shiel, Avram Tucker, Antonio Vives, Michael Walton, Jie Wang, Christopher Wasney, Jane Woodward

Adjunct Associate Professors: Jordan Brandt, Gloria T. Lau, Colin Ong

Adjunct Assistant Professor: Patrick Shiel

Shimizu Visiting Professors: Mette Geiker, Jennifer Luce, Eckart Meiburg, Glaucio H. Paulino

UPS Visiting Professor: Brendon Bradley

Visiting Professor: Ronita Bardhan, Leslie Norford

* 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).

		Units
OSPAUSTL 10	Coral Reef Ecosystems	3
OSPAUSTL 25	Freshwater Systems	3
OSPAUSTL 30	Coastal Forest Ecosystems	3

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. 2 Units.
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 6. Physics of Cities. 3 Units.
An introduction to the modern study of complex systems with cities as an organizing focus. Topics will include: cities as interacting systems; cities as networks; flows of resources and information through cities; principles of organization, self-organization, and complexity; how the properties of cities scale with size; and human movement patterns. No particular scientific background is required, but comfort with basic mathematics will be assumed. Prerequisites: MATH 19 and 20, or the equivalent.

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 10B. Presentation Skills. 0 Units.
TBD.

CEE 17SC. Water and Power in the Pacific Northwest: The Columbia River. 2 Units.
This seminar will explore the nature of and coupling between water and energy resources in the Pacific Northwest, using the Columbia River as our case study. We will explore the hydrologic, meteorologic, and geologic basis of water and energy resources, and the practical, social, environmental, economic, and political issues surrounding their development in the West. The Columbia River and its watershed provide a revealing prototype for examining these issues. A transnational, multi-state river with the largest residual populations of anadromous salmonids in the continental US, it provides a substantial fraction of the electrical energy produced in the Northwest (the Grand Coulee dam powerhouse on the Columbia is the largest-capacity hydropower facility in the US), it is a major bulk commodity transportation link to the interior West via its barge navigation system, it provides the water diversions supporting a large area of irrigated agriculture in Washington and Idaho, and its watershed is home to significant sources of solar and wind energy. We will use the Columbia to study water and energy resources, and especially their coupling, in the context of rapid climate change, ecosystem impacts, economics, and public policy.

We will begin with a week of classroom study and discussion on campus, preparing for the field portion of the seminar. We will then travel to the Columbia basin, spending approximately 10 days visiting a number of water and energy facilities across the watershed, e.g., solar, wind, and natural gas power plants; dams and reservoirs with their powerhouses, fish passage facilities, navigation locks, and flood-mitigation systems; an irrigation project; operation centers; and offices of regulatory agencies. We will meet with relevant policy experts and public officials, along with some of the stakeholders in the basin.

Over the summer students will be responsible for assigned readings from several sources, including monographs, online materials, and recent news articles. During the trip, students will work in small groups to analyze and assess one aspect of the coupling between water and energy resources in the Northwest. The seminar will culminate in presentations on these analyses.

Travel expenses during the seminar will be provided (except incidentals) by the Bill Lane Center for the American West and Sophomore College.
Same as: EARTHSYS 16SC, ENERGY 12SC, POLISCI 14SC

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. 5 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 31Q. Accessing Architecture Through Drawing. 5 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. nnOne 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. nnRather than examine the development of modern architectural theory chronologically, it is explored architectural 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. nnThe first week of each module will involve familiarizing the seminar with both the terms and rhetorical tactics of the given theme by reading and analyzing specific texts and completing a short written analysis (1-2 pages). The second week will expand upon this foundation and involve further analysis in addition to each student writing a short paper (3-4 pages) drawing on the examples discussed and their 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 architects and artist 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 shaped 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. Responsive Structures. 2 Units.
This Design Build seminar investigates the use of metal as a structural, spatial and organizational medium. We will examine the physical properties of post-formable plywood, and develop a structural system and design which respond to site and programmatic conditions. The process includes model building, prototyping, development of joinery, and culminates in the full scale installation of the developed design on campus. This course may be repeated for credit (up to three times).
Same as: CEE 132H

CEE 32Q. Place: Making Space Now. 3 Units.
This seminar argues that architeccts 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 world in flux are topics discussed in this section of the seminar. nLearning goals: Specific goals include clsoe reading of texts, understanding of philosophical thinking and writing, argument under uncertainty, and developed concepts of place, space and architecture.

CEE 32R. American Architecture. 4 Units.
A historically based understanding of what defines American architecture. What makes American architecture American, beginning with indigenous structures of pre-Columbian America. Materials, structure, and form in the changing American context. How these ideas are being transformed in today's globalized world.
Same as: AMSTUD 143A, ARTHIST 143A, ARTHIST 343A

CEE 32S. The Situated Workplace and Public Life. 4 Units.
The modern workplace has undergone fundamental change and continues to evolve. The context of work in many industries is today being shaped substantially by changing workforce demographics, the pervasiveness of mobile and embedded information technologies, hyper-connected work models on a global scale, evolving notions of health and well being, etc. nnOur public realm is changing too. People are moving to cities in greater numbers than ever before posing both challenges and opportunities related to new levels of density, sustainable resource management, resilient infrastructures, as well as new forms of civic engagement at neighborhood levels, to name but a few. These changes at an urban scale impact how and where public life happens and how it interacts with new modalities at work.nnThis course will combine research, conceptual explorations, studio design work, seminars and guest lectures to explore the impact of the changing workplace on the morphology of the city by examining these bi-coastal seats of innovation. As the creative workplace continues to evolve, how will it engage the public realm within both well-established urban frameworks such as San Francisco and Boston, and emerging suburban contexts, such as Silicon Valley?nnThe course will join graduate students from the Northeastern University School of Architecture with students from the Stanford University Architectural Design program. Students will reside primarily at their prospective universities and will travel selectively for site research, team charettes and project reviews. Project sites on both coasts will be utilized for research and studio work. This is an opportunity for students from two top universities, both situated in the epicenters of workplace change, to explore and conduct valuable research on an issue that is changing their urban environments.

CEE 32T. Making and Remaking the Architect: Edward Durell Stone and Stanford. 4 Units.
How does an architect establish a career? How is an architect remembered? What makes a building significant and how should it be preserved, if at all? Fundamental questions about the practice and production of architecture will be examined in this seminar that focuses on the work of Edward Durell Stone (1902-78) and specifically on his work at Stanford and in Palo Alto. By 1955, Stone was so well established that he founded an office in Palo Alto to design the Stanford Medical Center (currently slated for destruction) and several other significant local public buildings, such as the Palo Alto Civic Center. Through site visits to his buildings, research in the Stanford archives, and interviews with architects who worked in his office (among other strategies), students will question how architecture produced in the immediate post-WWII period is thought about historically and how and when it should be preserved.

CEE 32U. California Modernism: The Web of Apprenticeship. 4 Units.
This course will study at the development of Modernism in pre and post WWII California. The class will investigate responses to climatic, technological, and cultural changes that were specific to the state but have now become an idealized tread. We will look at architects and landscape architects who apprenticed with significant design leaders and track how their involvement and explore resulted in changes in building technologies, and influenced the next generation of design thinking and experimentation. The investigations will occur through research, drawings and models, as well as site visits.

CEE 32V. Architectural Design Lecture Series Course. 1 Unit.
Seminar will be a companion to the Spring Architecture and Landscape Architecture Lecture Series. Students will converse with lecturers before the lectures, attend the lecture, and prepare short documents (written, graphic, exploratory) for two of the lectures. The course meeting dates will correspond with the lecture dates listed below.nApril 12: Kai-Uwe Bergmann of BIG; April 26: Olle Lundberg of Lundberg Design; May 10: Ma Yansong of MAD Architects; May 24: Thomas Woltz of Nelson Byrd Woltz; June 8: Gregg Pasquarelli of SHoP Architects.

CEE 32W. Making Meaning: A Purposeful Life in Design. 3 Units.
As designers, how do we lead a life with meaning? What is a fuulfilling life in design and how do we develop personal and professional practices that support this aim? This experiential course will explore how to nourish a purposeful life amidst a culture that can value productivity over presence in the field, identifying "busyness" as a marker of personal worth. How do we bring depth to not only the design process but our individual and collective lives as well? Investigations will include: exploring personal passions, discovering meaningful work in design, understanding work/life/play balance, practicing self-reflection, integrating wellness, cultivating community, and practicing design with integrity. Our time in class will be enjoyed sharing meals, discourse, play, and reflections with both the class cohort and designers that lead lives or purpose and meaning.

CEE 32X. Modern and Contemporary World Architecture: A Cultural History in Twenty Five Buildings. 4 Units.
This survey course is a guided tour of twenty five case studies from the last hundred years; interrogates how architecture responds to the aesthetic, technological, political, and cultural issues of the societies they belong to, all over the world.
Same as: ARTHIST 141

CEE 32Y. Architecture & Gender. 4 Units.
This advanced seminar introduces students to the seemingly inconspicuous relation between architecture and gender. The course studies how modern societies create easily, controlled docile spaces, thus pursuing the absent bodies of its members - be it through symbolic or material means. This troubled history of the powers of architecture to neglect sexuality and impose strict gender roles is analyzed in class discussions through recent feminist and queer theoretical approaches and tested on case studies.
Same as: ARTHIST 248A

CEE 32Z. The Intersection of Performance, Architecture & Design. 2 Units.
In this class we will create a performance installation utilizing our expressive talents, but also accessing the ways that we are dancing and singing through life. Drawing from the everyday and extra daily movements, we will create a `sneaker ballet¿ to integrate our everyday experiences into our wild imaginings. Students will participate in a Chocolate Heads collaborative making process which will include observing peripatetic crowds, , sharing our individual and collective expressive expertise in movement, music and art while also integrating and learning art forms and ways of thinking from other members of the class. Working in art spaces and galleries, students will gain awareness of spatial relationships and site navigation from the vantage point of architecture, theater, and dance. Though field trips, guest artists and lecturers, and collaborative sharing, teaching and learning, students will create a performance event for an art gallery space that will foster community, unique expressivity, cultural understanding and fun. Designed for all levels. Admission by application. See dschool.stanford.edu/classes for more information.
Same as: DANCE 22

CEE 33A. Michelangelo Architect. 5 Units.
The architecture of Michelangelo Buonarroti (1475-1564), "Father and Master of all the Arts," redefined the possibilities of architectural expression for generations. This course considers his civic, ecclesiastic, and palatial works. It proceeds from his beginnings in Medicean Florence to his fulfillment in Papal Rome. It examines the anxiety of influence following his death and his enduring legacy in modernism. Topics include: Michelangelo's debt to Classical and Early Renaissance prototypes; his transformation of the canon; the iterative sketch as disegno; architecture and the body; the queering of architectural language; sketch, scale, and materiality; Modernism and Michelangelo. The historiography of Michelangelo has predominantly favored studies in painting and sculpture. Our focus on architecture encourages students to test new ideas and alternative approaches to his work.
Same as: ARTHIST 216A, ARTHIST 416A, ITALIAN 216

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: EARTHSYS 49N, ESS 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, atmosphere/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 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 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 frosh. 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. Water: An Introduction. 3 Units.
Lake Tahoe's waters are so clear you can follow a diver 70 feet below your boat. A Lake Erie summer often means that nearshore waters have a green surface scum obscuring everything below. California, suffering from drought, is seriously considering reclamation and direct potable reuse of sewage -- aka toilet to tap. Can we (or should we) do this? Why is Tahoe clear, Erie green? This class introduces students to the fundamental tools and science used to understand and manage both natural and human-engineered water systems. Each student will use these tools to explore a water topic of their choosing.

CEE 80N. Influences on Structural Design. 3 Units.
In this seminar, students will be introduced to the history of modern bridges, buildings and other large-scale structures. Classes will include presentations on transformations in structural design inspired by the development of new materials, increased understanding of hazardous overloads and awareness of environmental impacts. Basic principles of structural engineering and how to calculate material efficiency and structural safety of structural forms will be taught using case studies. The course will include a field trip to a Bay Area large-scale structure, hands-on experience building a tower and computational modeling of bridges, and a paper and presentation on a structure or structural form of interest to the student. The goal of this course is for students to develop an understanding and appreciation of modern structures, influences that have led to new forms, and the impact of structural design on society and the environment. Students from all backgrounds are welcome.

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 and open channels; elements of boundary-layer theory. The Tuesday lectures, which are preparation for the labs, will start at 12:30pm. Lab experiments will illustrate conservation principles and flows of real fluids, analysis of errors and modeling of simple fluid systems. Students seeking to take this course without the laboratory will need to enroll in CEE 162A but must get permission first from the instructor. Prerequisites: E14, Physics 41, Math 51, or CME 100.

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 107A. Understanding Energy. 3-5 Units.
Energy is a fundamental driver of human development and opportunity. At the same time, our energy system has significant consequences for our society, political system, economy, and environment. For example, energy production and use is the number one source of greenhouse gas emissions. In taking this course, students will not only understand the fundamentals of each energy resource -- including significance and potential, conversion processes and technologies, drivers and barriers, policy and regulation, and social, economic, and environmental impacts -- students will also be able to put this in the context of the broader energy system and think critically about how and why society has chosen particular energy resources. Both depletable and renewable energy resources are covered, including oil, natural gas, coal, nuclear, biomass and biofuel, hydroelectric, wind, solar thermal and photovoltaics (PV), geothermal, and ocean energy, with cross-cutting topics including electricity, storage, climate change, sustainability, green buildings, energy efficiency, transportation, and the developing world. The course is 4 units, which includes lecture and in-class discussion, readings and videos, assignments, and two off-site field trips. Enroll for 5 units to also attend the Workshop, an interactive discussion section on cross-cutting topics that meets once per week for 80 minutes (timing TBD based on student schedules). The 3-unit option requires instructor approval - please contact Diana Ginnebaugh. Website: http://web.stanford.edu/class/cee207a/ Course was formerly called Energy Resources.nPrerequisites: Algebra. May not be taken for credit by students who have completed CEE 107S.
Same as: CEE 207A, EARTHSYS 103

CEE 107F. Understanding Energy -- Field Trips. 1 Unit.
This course is only for students who have already taken CEE 107A/207A/Earthsys 103 -- Understanding Energy. Please contact Kirsten Stasio (kstasio@stanford.edu) for instructor consent code.
Same as: CEE 207F, EARTHSYS 103F

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 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 112A. Industry Applications of Virtual Design & Construction. 2-4 Units.
Building upon the concept of 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. 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 CEE112B/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: CEE110/210, 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 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 120A/220A and illustrates how BIM modeling tools are used to design, analyze, and model building systems including structural, mechanical, electrical, plumbing and fire protection. Course covers the physical principles, design criteria, and design strategies for each system and explores processes and tools for modeling those systems and analyzing their performance.nTopics include: building envelopes, access systems, structural systems modeling and analysis, mechanical / HVAC systems, plumbing and fire protection systems, electrical systems, and systems integration/coordination.
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.nnTopics to be featured include:n-Principles of parametric design vs. direct modelingn-Design exploration using parametric modeling platforms (Revit/FormIt, Rhino)n-Visual scripting languages and environments (Dynamo, Grasshopper, DesignScript)n-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 125. Defining Smart Cities: Visions of Urbanism for the 21st Century. 1-2 Unit.
In a rapidly urbanizing world, "the city" paves the way toward sustainability and social well-being. But what does it mean for a city to be smart? Does that also make it sustainable or resilient or livable? This seminar delves into current debates about urbanism through weekly talks by experts on topics such as big data, human-centered design, new urbanism, and natural capital. How urban spaces are shaped, for better or worse, by the complex interaction of cutting-edge technology, human societies, and the natural environment. The goal is to provoke vigorous discussion and to foster an understanding of cities that is at once technological, humanistic, and ecologically sound.
Same as: CEE 225, URBANST 174

CEE 126. International Urbanization Seminar: Cross-Cultural Collaboration for Sustainable Urban Development. 4-5 Units.
Comparative approach to sustainable cities, with focus on international practices and applicability to China. Tradeoffs regarding land use, infrastructure, energy and water, and the need to balance economic vitality, environmental quality, cultural heritage, and social equity. Student teams collaborate with Chinese faculty and students partners to support urban sustainability projects. Limited enrollment via application; see internationalurbanization.org for details. Prerequisites: consent of the instructor(s).
Same as: EARTHSYS 138, IPS 274, URBANST 145

CEE 126A. Stanford Sustainable Living Lab I. 1-3 Unit.
This course introduces students to the concepts of industrial ecology, sustainability science, and green thinking. The quarter-long focus of the course will be a quantitative and qualitative assessment of the sustainability of an on-campus system. Examples of such systems are an on-campus dormitory (e.g. Roble Hall), service provider (e.g. Axe and Palm Restaurant), or infrastructure system (e.g. campus water system). Students interested in the course as a seminar should elect for the 1 unit option. Students interested in the courswe to fulfill programmatic requirements should elect for the 3 unit option. (This course must be taken for a minimum of 3 units to satisfy a Ways requirement.).

CEE 126B. Stanford Sustainable Living Lab II. 3 Units.
This course introduces students to the concepts of sustainability economics, system optimization, and life cycle costing. In essence, students will be building the "business case" for various proposed sustainability efforts tied to an on-campus system. Examples of such systems are on an on-campus dormitory (.e.g Roble Hall), service provider (e.g. Axe and Palm Restaurant), or infrastructure system (e.g. campus water system). Students interested in CEE 126B do not need to have taken CEE 126B as a prerequisite. This course is an approved equivalent for CEE 146A/246A.

CEE 126C. Stanford Sustainable Living Lab III. 3 Units.
This course is a project-based, self-directed course focused on actual implementation of various proposed sustainability efforts tied to an on-campus system. Examples of such systems are an on-campus dormitory (e.g. Roble Hall), service provider (e.g. Axe and Palm Restaurant), or infrastructure system (e.g. campus water system). Students interested in CEE 126 do not need to have taken CEE 126A or 126B as a prerequisite.

CEE 126X. Hard Earth: Stanford Graduate-Student Talks Exploring Tough Environmental Dilemmas. 1 Unit.
Stanford's graduate students are a trove of knowledge -- and, just as important, curiosity -- about environmental sustainability. This seminar will feature talks by graduate students that explore the biggest, most bedeviling questions about environmental sustainability locally and around the world. The course will be structured as follows: every other week, we will hear hour-long graduate student talks about sustainability questions and their research, and on the off weeks, we will discuss the unanswered, debatable questions that relate to the previous week's talk.
Same as: EARTH 126X

CEE 126Y. Hard Earth: Stanford Graduate-Student Talks Exploring Tough Environmental Dilemmas. 1 Unit.
Stanford's graduate students are a trove of knowledge -- and, just as important, curiosity -- about environmental sustainability. This seminar will feature talks by graduate students that explore the biggest, most bedeviling questions about environmental sustainability locally and around the world. The course will be structured as follows: every other week, we will hear hour-long graduate student talks about sustainability questions and their research, and on the off weeks, we will discuss the unanswered, debatable questions that relate to the previous week's talk.
Same as: EARTH 126Y

CEE 126Z. Hard Earth: Stanford Graduate-Student Talks Exploring Tough Environmental Dilemmas. 1 Unit.
Stanford's graduate students are a trove of knowledge -- and, just as important, curiosity -- about environmental sustainability. This seminar will feature talks by graduate students that explore the biggest, most bedeviling questions about environmental sustainability locally and around the world. The course will be structured as follows: every other week, we will hear hour-long graduate student talks about sustainability questions and their research, and on the off weeks, we will discuss the unanswered, debatable questions that relate to the previous week's talk.
Same as: EARTH 126Z

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/seaports2100.
Same as: CEE 229S

CEE 130. Architectural Design: 3-D Modeling, Methodology, and Process. 5 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 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 program. Course deliverables will include three short assignments and a final project consisting of basic schematic drawings for the selected project.nnGuest presenters will cover topics of interest. Lectures, discussions, in-class studio-work and an oral presentation.nPre-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. nnThe 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. Students will focus on one of 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. nnReadings 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 131C. How Buildings are Made -- Materiality and Construction Methods. 4 Units.
This course will provide an introduction to the materials and methods used in building construction. A combination of in-class lectures, reading assignments, and building site visits will provide students with an awareness of construction materials and their use within building systems. All relevant building types and construction materials will be explored, including wood, steel, concrete and masonry. Building foundations and basic structural systems will be explained. Building envelope elements will be considered, with an analysis of various glass and glazing materials, cladding types, and roofing systems. Interior Floor, wall and ceiling finishes will be discussed. New and emerging building trends will also be examined, wuch as prefabricated and modular construction. Guest presenters, drawn from Bay Area consulting firms, will cover several topics of interest. Students will have an opportunity to experience real world material applications at local construction sites, and gain a thorough understanding of the construction process.

CEE 131D. Urban Design Studio. 5 Units.
The practical application of urban design theory. Projects focus on designing neighborhood and downtown regions to balance livability, revitalization, population growth, and historic preservation.
Same as: URBANST 171

CEE 131F. Activating Urban Spaces. 4 Units.
This course will look at how public urban spaces are structured with a particular eye to the involvement of art and artists, whether formally or informally, in shaping the built and social environment of the city. Throughout the course particular focus will consider the possibilities for engaging social justice outcomes through spatial intervention drawing on examples from around the world. Interventions in urban spaces enact local change by making art the language of civic engagement; in this way a mural or performance or reconceptualized public space can become a method to address issues of locally prioritized inequality. We will use Stanford University and the Bay Area as our local research sites, making trips into the field to analyze methods, approaches, and experiences of urban spaces in action as well as bringing experts who work in related fields into the classroom. Sites of study include parks, public art, and street festivals by looking at arts organizations, city projects, community groups, and individual artists. The class will operate as a hybrid seminar and collaborative studio workspace which supports students in using ethnographic, visual, mapping, historical, and participatory methods in developing projects that respond to a particular site of their choosing.
Same as: ARTSINST 182, URBANST 182

CEE 131Q. How to be Governed Otherwise: Art, Activism, and the City. 4 Units.
This course will introduce you to contemporary art¿s engagement with political activism. This introduction will focus on the city as, at once, a field and target of activism¿a field of public appearance, artistic intervention, and political action, as well as a target of claims to residence, livelihood, recognition, justice, and collectivity. We will pose activist politics, artistic intervention, and urban space as mutually imbricated, each shaping the possibilities, programs, and histories of the other¿a perspective that offers insights into the spatiality, materiality, and visuality of political identity, agency, and action. Over the quarter, we will study some of the many artistic interventions that are encompassed by urban activism, from informal and everyday practices to protest, resistance, and occupation. Comparative case studies will be drawn from a global context. You will investigate these case studies through both research on urban activism and activist practice; the seminar will therefore invite you to explore the militant possibilities of research, the research possibilities of activism, and the implications of each for the production of art.
Same as: ARTSINST 180Q, URBANST 180Q

CEE 132H. Responsive Structures. 2 Units.
This Design Build seminar investigates the use of metal as a structural, spatial and organizational medium. We will examine the physical properties of post-formable plywood, and develop a structural system and design which respond to site and programmatic conditions. The process includes model building, prototyping, development of joinery, and culminates in the full scale installation of the developed design on campus. This course may be repeated for credit (up to three times).
Same as: CEE 32H

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 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 translate subjects onto a two-dimensional 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 133G. Architectural History & Drawing in Eastern Europe. 2 Units.
Students in this seminar will travel to Prague, Czech Republic and Krakow, Poland for a week of historical morning walks and discussions about architectural and urbanism in each city. Afternoon sketching sessions will focus attention on some of the locations visited earlier that day. Buildings, sites and monuments from the Middle Ages to the present will be assessed, questioned, and drawn. Short reading assignments and/or films provide a background for each day's examination of a section of these two cities. Possible day trips may include site visits to Auschwitz and the Wieliczka Salt Mine. Casual late afternoon excursions will complement themes of the course. Upon returning to Stanford, the seminar will meet four times to discuss observations and organize a small exhibition of the sketches made during the trip.

CEE 134B. Intermediate Arch Studio. 5 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 137B. Advanced Architecture Studio. 6 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. May be repeat for credit. Total completions allowed: 3. 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 139. Design Portfolio Methods. 4 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.
Same as: CEE 239

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.
Nine current global infrastructure projects presented by top project executives or company leaders from industry. Water, transportation, energy and communication projects are featured. Course provides comparisons of project development, win and delivery approaches for mega-projects around the world. Alternative project delivery methods, the role of public and private sector, different project management and construction strategies, and lessons learned. The course also includes field trips to local mega-projects.
Same as: CEE 241C

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, wells 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.n nStudents 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.
Fundamentals of financial and economic analysis. Engineering Economy Principles. Interest rates, Present value, annual cash flow, internal rate of return, benefit-cost analysis. Economic Life, Life Cycle Costs. Replacement analysis. Project Selection - Mutually Exclusive Alternatives, Multiple Objective Criteria. Depreciation. Inflation and Taxes. Sensitivity and risk analysis. Uncertainty and Probability. Decision Trees. Capital Budgeting. 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 246A

CEE 146E. SENSA Lab Social Enterprise Seminar. 1 Unit.
Students attend a weekly seminar and meet with mentors to discuss and get feedback on SENSA labs social enterprise projects. Attendance at all seminars is required for credit.
Same as: CEE 246E

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; students should enroll on Axess and complete the application on Coursework before March 18.
Same as: CEE 251, EARTH 251

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 161C. Natural Ventilation of Buildings. 3 Units.
An introduction to natural ventilation design, including an in-depth discussion of the fluid mechanics of natural ventilation, and a review of models and measurements of naturally ventilated buildings. Overview of the design process, from assessing feasibility to commissioning. Discussion of physical processes in natural ventilation, including buoyancy- and wind- driven flow, and important fluid mechanics and heat transfer concepts and equations. Steady flow characteristics of openings, steady and unsteady envelope models. Internal air motion, zonal models and stratification. CFD and its applications, scale modeling and full-scale measurements. Throughout the course the Y2E2 building natural ventilation system and temperature measurements will be used to illustrate the different concepts and methods.

CEE 161I. Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the atmospheric circulation. Topics include the global energy balance, the greenhouse effect, the vertical and meridional structure of the atmosphere, dry and moist convection, the equations of motion for the atmosphere and ocean, including the effects of rotation, and the poleward transport of heat by the large-scale atmospheric circulation and storm systems. Prerequisites: MATH 51 or CME100 and PHYSICS 41.
Same as: CEE 261I, EARTHSYS 146A, EARTHSYS 246A, ESS 146A, ESS 246A, GEOPHYS 146A, GEOPHYS 246A

CEE 162A. Mechanics of Fluids. 3 Units.
Formerly CEE 101X. Course content is the same as CEE 101B but without the Tuesday lecture and lab component. Permission of the instructor is required first to enroll in CEE 162A. Prerequisites: E14, Physics 41 (formerlyl 63) Math 51.

CEE 162D. Introduction to Physical Oceanography. 4 Units.
Formerly CEE 164. The dynamic basis of oceanography. Topics: physical environment; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 41 (formerly 53).
Same as: CEE 262D, EARTHSYS 164, ESS 148

CEE 162E. Rivers, Streams, and Canals. 3-4 Units.
Formerly CEE 161A/264A. 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 or CEE 162A.
Same as: CEE 262E

CEE 162F. Coastal Engineering. 4 Units.
This course provides an introduction to the relevant processes that shape the coastline, including the hydrodynamical forcing and the resultant coastal morphology. it discusses the natural response of coastal systems to forcing by the environment (e.g. waves, tides, storms), discusses how these affect the sediment budget along the coast, and uses this to explain typical coastal features. Finally we consider different engineering solutions that are available to mitigate erosion, how they influence the system, and what their relative advantages and disadvantages are. Prereq: CEE 101B or equivalent.

CEE 162I. Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the large-scale ocean circulation. This course will give an overview of the structure and dynamics of the major ocean current systems that contribute to the meridional overturning circulation, the transport of heat, salt, and biogeochemical tracers, and the regulation of climate. Topics include the tropical ocean circulation, the wind-driven gyres and western boundary currents, the thermohaline circulation, the Antarctic Circumpolar Current, water mass formation, atmosphere-ocean coupling, and climate variability. Prerequisites: EESS 146A or EESS 246A, or CEE 162D or CEE 262D, or consent of instructor.
Same as: CEE 262I, EARTHSYS 146B, EARTHSYS 246B, ESS 146B, ESS 246B

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 andn 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 165D. 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.
Same as: CEE 265D

CEE 166A. Watersheds and Wetlands. 4 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: CEE 101B or CEE 162A or equivalent. (Freyberg).
Same as: CEE 266A

CEE 166B. Floods and Droughts, Dams and Aqueducts. 4 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.
Intended primarily for juniors and seniors; first year graduate students welcome. Course introduces key environmental policy design and implementation concepts and provides opportunities to work with a range of environmental planning methods. Environmental laws and regulations (e.g., US Clean Water Act and the US National Environmental Policy Act) are examined. Course demonstrates how firms have gone beyond regulatory compliance and introduced environmental sustainability issues into core business strategies. Course uses a simulated negotiation of a financial penalty between a student team representing the US EPA (and other government agencies) and a team representing a firm that is out of compliance with Clean Water Act regulations. Professionals with experience in such negotiations provide coaching for student teams. Prerequisites: MATH 51. Recommended: 70.

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. Limited enrollment, preference to CEE students. Prerequisites: Math 42 or 21 and CEE 70, or equivalents.
Same as: CEE 278C

CEE 172S. 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 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.
This interdisciplinary course integrates the legal, scientific, and policy dimensions of how we characterize and manage resource use and allocation along the California coast. We will use this geographic setting as the vehicle for exploring more generally how agencies, legislatures, and courts resolve resource-use conflicts and the role that scientific information and uncertainty play in the process. Our focus will be on the land-sea interface as we explore contemporary coastal land-use and marine resource decision-making, including coastal pollution, public health, ecosystem management; public access; private development; local community and state infrastructure; natural systems and significant threats; resource extraction; and conservation, mitigation and restoration. Students will learn the fundamental physics, chemistry, and biology of the coastal zone, tools for exploring data collected in the coastal ocean, and the institutional framework that shapes public and private decisions affecting coastal resources. There will be 3 to 4 written assignments addressing policy and science issues during the quarter, as well as a take-home final assignment. Special Instructions: In-class work and discussion is often done in interdisciplinary teams of students from the School of Law, the School of Engineering, the School of Humanities and Sciences, and the School of Earth, Energy, and Environmental Sciences. Students are expected to participate in class discussion and field trips. Elements used in grading: Participation, including class session and field trip attendance, writing and quantitative assignments. Cross-listed with Civil & Environmental Engineering (CEE 175A/275A), Earth Systems (EARTHSYS 175/275), Law (LAW514), and Public Policy (PUBLPOL 175/275). Open to graduate students and to advanced undergraduates with instructor consent.
Same as: CEE 275A, EARTHSYS 175, EARTHSYS 275, PUBLPOL 175, PUBLPOL 275

CEE 175P. Persuasive Communication for Environmental Scientists, Practitioners, and Entrepreneurs. 2 Units.
Achieving environmental goals depends not only on innovative ideas and great science but also persuasive communication. What makes communication persuasive? The ability of the communicator to create value for his or her audience. This course will teach students how to: 1) focus on their audience and 2) create value for their audience using research-proven communication techniques. Students will master these techniques through oral and written exercises so that, after taking this course, they will speak and write more persuasively.
Same as: CEE 275P

CEE 175Q. Changing Human Behavior: Drivers and Barriers in Environmental Action. 2 Units.
Beyond the scientific and technological challenges of climate change, there are important psychological factors and barriers to individual attitude and behavior change. Students will analyze and identify barriers to individual action; distinguish between targeting individual behaviors vs. attitudes; understand specific psychological challenges and opportunities that climate change raises; develop strategies to address these factors in contexts where behavior change is sought. Students will propose and develop their own ideas for addressing a specific psychological barrier to individual action in an environmental context.
Same as: CEE 275Q

CEE 175S. Environmental Entrepreneurship and Innovation. 3 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.
Quantitative evaluation of technologies and techniques for reducing energy demand of residential-scale buildings. Heating and cooling load calculations, financial analysis, passive-solar design techniques, water heating systems, photovoltaic system sizing for net-zero-energy all-electric homes. Offered for 3 or 4 units; the 4-unit option includes a lab.

CEE 176B. Electric Power: Renewables and Efficiency. 3-4 Units.
This course introduces analysis, sizing and performance estimations (electrical and financial) of renewable energy systems on both sides of the electric meter with an emphasis on photovoltaics and wind-power systems. Basic electric power generation, transmission and distribution, as well as distributed generation will be introduced. Optional Laboratory section for a 4th unit of credit.

CEE 176C. Energy Storage Integration - Vehicles, Renewables, and the Grid. 3 Units.
This course will provide in-depth introduction to existing energy storage solutions being used on the electric grid and in vehicles with a primary focus on batteries and electrochemical storage. We will discuss the operating characteristics, cost and efficiency of these technologies and how tradeoff decisions can be made. Special attention will be given to system-level integration of new storage technologies, including chargers, inverters, battery management systems and controls, into the existing vehicle and grid infrastructure. Further investigations include issues relating to integration of electric vehicle charging with demand-side management, scheduled renewable energy absorption and local grid balancing. Class format involves regular guest lectures, required lab participation, and field trips to relevant sites. Enrollment is limited; if you are interested in taking the course, please fill out a brief questionnaire at http://goo.gl/forms/i3YH91Qx05 n Please contact jtaggart@stanford.edu with any questions regarding the application or course information.
Same as: CEE 276C

CEE 176G. Sustainability Design Thinking. 3 Units.
Application design thinking to make sustainability compelling, impactful and realizable. Analysis of contextual, functional and human-centered design thinking techniques to promote sustainable design of products and environments by holistically considering space, form, environment, energy, economics, and health. Includes Studio project work in prototyping, modeling, testing, and realizing sustainable design ideas.
Same as: CEE 276G

CEE 177. 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 biochemistry of aquatic microbial life; and biogeochemical processes that govern the fate of nutrients and metals in the environment and in engineered systems. Prerequisite: CHEM 31.

CEE 177L. Smart Cities & Communities. 3 Units.
A city is comprised of people and a complex system of systems. Data provides the connective tissue between those systems. Smart cities use information technology (IT) to harness that data for operational efficiency, efficacy of government services, and sustainability. Key enablers covered include: IoT, open data, analytics, cloud and cognitive computing, and systems of engagement. System case studies will include: water, energy, transportation, buildings, food production, urban design, and social services. The evolving relationship between a city and its citizens as well as the risks / challenges of smart cities will also be explored.
Same as: CEE 277L

CEE 177S. 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 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. (Cardinal Course certified by the Haas Center). 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 179F. Frontiers of Anaerobic Treatment. 1 Unit.
This seminar will present the latest findings on the operation and performance of ground-breaking anaerobic treatment processes for domestic wastewater. Specifically, this seminar will examine the performance of the Staged Anaerobic Fluidized-bed Membrane Bioreactor (SAF-MBR) using results from ongoing operations at the Codiga Resource Recover Center and from previous and parallel research efforts. The seminars will incorporate a description of the fundamentals of anaerobic treatment processes, a discussion of how the SAF-MBR process is different from typical anaerobic processes, and insights from operations along with implications for system design. Course work will include explorations of the costs, benefits, and market potential of this technology.
Same as: CEE 279F

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, ESS 179S

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 architectural, construction and other project requirements. Prerequisites: CEE 180, 181, 182; CEE 120 (or equivalent background in BIM), 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: GS 1, MATH 51.
Same as: GS 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: GS 1 or consent of instructor.
Same as: GS 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.n (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.nn 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 and the first five weeks of Wednesday classes.

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

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 207A. Understanding Energy. 3-5 Units.
Energy is a fundamental driver of human development and opportunity. At the same time, our energy system has significant consequences for our society, political system, economy, and environment. For example, energy production and use is the number one source of greenhouse gas emissions. In taking this course, students will not only understand the fundamentals of each energy resource -- including significance and potential, conversion processes and technologies, drivers and barriers, policy and regulation, and social, economic, and environmental impacts -- students will also be able to put this in the context of the broader energy system and think critically about how and why society has chosen particular energy resources. Both depletable and renewable energy resources are covered, including oil, natural gas, coal, nuclear, biomass and biofuel, hydroelectric, wind, solar thermal and photovoltaics (PV), geothermal, and ocean energy, with cross-cutting topics including electricity, storage, climate change, sustainability, green buildings, energy efficiency, transportation, and the developing world. The course is 4 units, which includes lecture and in-class discussion, readings and videos, assignments, and two off-site field trips. Enroll for 5 units to also attend the Workshop, an interactive discussion section on cross-cutting topics that meets once per week for 80 minutes (timing TBD based on student schedules). The 3-unit option requires instructor approval - please contact Diana Ginnebaugh. Website: http://web.stanford.edu/class/cee207a/ Course was formerly called Energy Resources.nPrerequisites: Algebra. May not be taken for credit by students who have completed CEE 107S.
Same as: CEE 107A, EARTHSYS 103

CEE 207F. Understanding Energy -- Field Trips. 1 Unit.
This course is only for students who have already taken CEE 107A/207A/Earthsys 103 -- Understanding Energy. Please contact Kirsten Stasio (kstasio@stanford.edu) for instructor consent code.
Same as: CEE 107F, EARTHSYS 103F

CEE 207S. 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

CEE 209A. 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 handlingn 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 209B. Disaster Risk and International Development Seminar. 2 Units.
The human and economic impacts of natural disasters are ever increasing and disproportionately affecting lower-income countries. In act there is mounting evidence that these ever more frequent shocks threaten to reverse development progress in low-income countries. This seminar course will explore the theory and practice of disaster risk reduction in international development contexts. Weekly readings (and occasional guest lectures) will cover key issues in development theory, a history of "a risk society", participation, human-centered planning, ethics in engineering, and other topics. The seminar will be structured through weekly readings, brief writing responses and group discussion.

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 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: 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 217. Renewable Energy Infrastructure. 2 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 120A/220A and illustrates how BIM modeling tools are used to design, analyze, and model building systems including structural, mechanical, electrical, plumbing and fire protection. Course covers the physical principles, design criteria, and design strategies for each system and explores processes and tools for modeling those systems and analyzing their performance.nTopics include: building envelopes, access systems, structural systems modeling and analysis, mechanical / HVAC systems, plumbing and fire protection systems, electrical systems, and systems integration/coordination.
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.nnTopics to be featured include:n-Principles of parametric design vs. direct modelingn-Design exploration using parametric modeling platforms (Revit/FormIt, Rhino)n-Visual scripting languages and environments (Dynamo, Grasshopper, DesignScript)n-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 Built Environments. 3 Units.
In this course, students will learn about new and traditional construction materials for use in sustainable building and infrastructure projects. Materials will include cement-based materials and fiber-reinforced polymer composites for structural and non-structural applications, as well as novel materials for e.g., facades, insulation, and paving. Material properties, their performance over time and their impact on people and the environment will be discussed. Pre-requisite: CEE 101A or equivalent.

CEE 223A. Cement-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 224S. Sustainable Urban Systems Seminar. 1 Unit.
The Sustainable Urban Systems (SUS) Seminar Series will feature speakers from academia, practice, industry, and government who are on the forefront of research and innovation in sustainable urban systems. The SUS Seminar will be open to the public; students will have the option of obtaining 1 unit of course credit based on attendance and completion of writing assignments.

CEE 224X. Sustainable Urban Systems Project. 2-5 Units.
Sustainable Urban Systems (SUS) Project is a project-based learning experience being piloted for an upcoming new SUS M.S. Program within CEE. For a minimum 2 units (open enrollment, engineers and non-engineers, undergraduate and graduate level), students attend lectures/discussions on Tuesdays and labs/workshops on Thursdays and complete light weekly assignments. For an optional added 1-3 units (by application only), students are placed in small interdisciplinary teams and work on complex design, engineering, and policy problems presented by external partners in a real-world urban setting. Multiple projects are offered throughout the academic year and may span multiple quarters. Students are expected to interact with professionals and community stakeholders, conduct independent team work outside of class sessions, and submit deliverables over a series of milestones. For more information and to apply, visit http://sus.stanford.edu.

CEE 224Y. Sustainable Urban Systems Project. 2-5 Units.
Sustainable Urban Systems (SUS) Project is a project-based learning experience being piloted for an upcoming new SUS M.S. Program within CEE. Students are placed in small interdisciplinary teams (engineers and non-engineers, undergraduate and graduate level) to work on complex design, engineering, and policy problems presented by external partners in a real urban setting. Multiple projects are offered throughout the academic year and may span multiple quarters. Students are expected to interact with professionals and community stakeholders, conduct independent team work outside of class sessions, and submit deliverables over a series of milestones. To view project descriptions and apply, visit http://sus.stanford.edu/courses/.

CEE 224Z. Sustainable Urban Systems Project. 3-5 Units.
Sustainable Urban Systems (SUS) Project is a project-based learning experience being piloted for an upcoming new SUS M.S. Program within CEE. Students are placed in small interdisciplinary teams (engineers and non-engineers, undergraduate and graduate level) to work on complex design, engineering, and policy problems presented by external partners in a real urban setting. Multiple projects are offered throughout the academic year and may span multiple quarters. Students are expected to interact with professionals and community stakeholders, conduct independent team work outside of class sessions, and submit deliverables over a series of milestones. To view project descriptions and apply, visit http://sus.stanford.edu/courses/.

CEE 225. Defining Smart Cities: Visions of Urbanism for the 21st Century. 1-2 Unit.
In a rapidly urbanizing world, "the city" paves the way toward sustainability and social well-being. But what does it mean for a city to be smart? Does that also make it sustainable or resilient or livable? This seminar delves into current debates about urbanism through weekly talks by experts on topics such as big data, human-centered design, new urbanism, and natural capital. How urban spaces are shaped, for better or worse, by the complex interaction of cutting-edge technology, human societies, and the natural environment. The goal is to provoke vigorous discussion and to foster an understanding of cities that is at once technological, humanistic, and ecologically sound.
Same as: CEE 125, URBANST 174

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 biobased products, building materials, building integrated photovoltaics, and alternative design strategies, such as remanufacturing, dematerialization, LEED, and Design for Environment: DfE. Student teams complete a life cycle assessment of a product or system chosen from industry.

CEE 226E. Advanced Topics in Integrated, Energy-Efficient Building Design. 2-3 Units.
This class explores innovative methods for designing, developing, and financing high performance, low energy buildings. Students will learn best practices to reduce building energy buildings. Students will learn best practices to reduce building energy use and integrate solar PV generation in pursuit of commercial Net Zero Energy buildings. Lectures include presentations and panels featuring leading practitioners and researchers in the field. Optional site visits to local Net Zero Energy and LEED buildings provide context to support lectures. CEE 176A and CEE 156/256 or similar courses are recommended prerequisites but not required. All students are expected to participate in a group-based, term project focused on the design and development of a Net Zero Energy building. Students taking the course for two units will not be required to complete in-class assignments for individual homework assignments.

CEE 227. Global Project Finance. 3-5 Units.
Public and private sources of finance for large, complex, capital-intensive projects in developed and developing countries. Benefits and disadvantages, major participants, risk sharing, and challenges of project finance in emerging markets. Financial, economic, political, cultural, and technological elements that affect project structures, processes, and outcomes. Case studies. Limited enrollment.

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 234B. Intermediate Arch Studio. 5 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 235. CapaCity Design Studio. 5 Units.
Silicon Valley's rapid expansion has created explosive urban development in a fragile and under-prepared natural context. Delicate coastal ecology and rapid urbanization (expanding technology headquarters, new residential housing, parking, services, etc.) are competing for space. The same land also serves the regional functions of transport, open space, recreation, water supply, flood protection and wastewater treatment. Compounding the problems between these competing factors are global climate change instabilities increasing the certainty of catastrophic flooding, infrastructure collapse, and other urban resilience challenges. Students will be immersed in a process that allows them to understand and spatially identify these risks, develop a vocabulary and understanding of innovative tools to respond to them, and then work with expert practitioners to create unique design responses. Students will be provided with urban design frameworks (for planning, site development, and conservation) combined with advanced sustainable design concepts (such as resource co-optimization, and adaptable infrastructure platforms, and high performance urban ecology) by working with expert lecturers and in small groups. Students will ultimately develop a series of visual and technical presentations to propose a final thesis for a local intervention that could be replicated in other coastal contexts globally. This course has been designed to develop student learning through a project-based format. Students will be organized into design teams of 3 or 4 and will have the semester to collaborate with partners on an interdisciplinary proposal including policy and design recommendations.

CEE 237B. Advanced Architecture Studio. 6 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. May be repeat for credit. Total completions allowed: 3. 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 239. Design Portfolio Methods. 4 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.
Same as: CEE 139

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.
Nine current global infrastructure projects presented by top project executives or company leaders from industry. Water, transportation, energy and communication projects are featured. Course provides comparisons of project development, win and delivery approaches for mega-projects around the world. Alternative project delivery methods, the role of public and private sector, different project management and construction strategies, and lessons learned. The course also includes field trips to local mega-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; scope management with 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 242. Organization Design for Projects and Companies. 3-4 Units.
Introduction to organizational behavior and organizational design for construction projects and companies. Class incorporates readings, individual, small group and large group case study assignments. Students use computer simulation to design real-world project organizations.

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 243. Intro to Urban Sys Engrg. 3 Units.
This course is an introduction to the interdisciplinary domain of urban systems engineering. It will provide you with a high-level understanding of the motivation for studying sustainable cities and urban systems, systems-based modeling approaches and the social actor theories embedded in the urban sustainability decision making process. Coursework will be comprised of three group mini-projects corresponding to course modules.

CEE 244. Accounting, Finance & Valuation for Engineers & Constructors. 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 245. Network Analysis for Urban Systems. 3 Units.
This course will introduce and develop the mathematical theory of networks, metrics of networks, static and dynamic network models and apply them to analysis of urban systems. Students are expected to have a strong background in calculus and linear algebra before taking this course and should be comfortable with the calculation and manipulation of matrices. Experience in a numerical scripting language (preferably Python, R or Matlab) is necessary for the final project. Coursework will consist of weekly graded problem sets pertaining to both theory of networks and applications to urban systems. There will be a final project where students will be required to apply network based methods to the analysis of real data of an urban system. (subject to change).

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. Students must submit the following application before enrolling in this course: https://goo.gl/forms/F61Uul9x2120tR8D2.

CEE 246A. Engineering Economy. 3 Units.
Fundamentals of financial and economic analysis. Engineering Economy Principles. Interest rates, Present value, annual cash flow, internal rate of return, benefit-cost analysis. Economic Life, Life Cycle Costs. Replacement analysis. Project Selection - Mutually Exclusive Alternatives, Multiple Objective Criteria. Depreciation. Inflation and Taxes. Sensitivity and risk analysis. Uncertainty and Probability. Decision Trees. Capital Budgeting. 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 Development and Finance. 3 Units.
Introduction to the Real Estate Development Process from conception, feasibility analysis, due diligence, entitlements, planning, financing, market analysis, contract negotiation, construction, marketing, asset management and disposition. Pro-forma and Financial modeling in Real Estate. Financing options for different types of Real Estate projects and products. Redevelopment projects. Affordable Housing. The class will combine lectures, case studies, field work (Group Project) and guest speakers. Recommended knowledge of spreadsheets. Prerequisites: Engineering Economy or CEE 246A or similar. Attendance to the first class is mandatory.

CEE 246E. SENSA Lab Social Enterprise Seminar. 1 Unit.
Students attend a weekly seminar and meet with mentors to discuss and get feedback on SENSA labs social enterprise projects. Attendance at all seminars is required for credit.
Same as: CEE 146E

CEE 246S. Real Estate Finance Seminar or Real Estate Career Development Seminar. 1 Unit.
Real Estate Development and Finance presented by industry guest speakers. Executives from different Real Estate companies will give an overview of their business and projects. (Residential, Retail, Commercial, Mixed Used, REITs, Redevelopment Projects, Affordable Housing, public and private real estate companies, real estate funds, etc.). Short Real Estate Case Studies will be given as homework. Two optional field trips. Attendance to the first class is mandatory.

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. Introduction to Real Estate Development. 2 Units.
This course 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, marketed and then sold and/or rented. There will be nine 1.5-hour lectures (robust class discussion encouraged). Throughout the quarter, the students will work on a group case study assignment about one local project that is currently being built or was recently completed. This assignment will be due in the form of a presentation during the final exam period. No prior knowledge of real estate is required. Classes commence on April 6th and complete on June 1st. Number of students is limited to 30. Undergraduates must apply by submitting a one-page essay explaining their interest in taking the class to amabella@stanford.edu by March 1, 2017.

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; students should enroll on Axess and complete the application on Coursework before March 18.
Same as: CEE 151, EARTH 251

CEE 252. Construction Methods for Concrete and Steel Structures. 3 Units.
Providing technical support for concrete and steel construction operations on buildings or infrastructure projects. Concrete materials, construction properties of fresh concrete. Resources and operations for batching, transporting, placing, finishing, and curing concrete. Design, fabrication, and use of formwork. Special operations and formwork systems. Detailing, fabricating, erecting, and connecting structural steel. Lifting equipment and lift planning. Welding processes, operations, and quality control. Readings, exercises and course projects.

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 CEE252P 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, completing group exercises and projects, and preparing an individual final paper. The exercises, completed by all 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, solar thermal power plant, and wind turbine power plant.

CEE 252Q. Construction Engineering Fundamentals. 2 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 252Q 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 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 Unit.
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 Unit.
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: ESS 220

CEE 260B. Surface and Near-Surface Hydrologic Response. 3 Units.
Quantitative review of process-based hydrology and geomorphology. Introduction to finite-difference and finite-element methods of numerical analysis. Topics: biometeorology, unsaturated and saturated subsurface fluid flow, overland and open channel flow, and physically-based simulation of coupled surface and near-surface hydrologic response. Links hydrogeology, soil physics, and surface water hydrology.
Same as: GS 237

CEE 260C. Contaminant Hydrogeology and Reactive Transport. 4 Units.
Decades of industrial activity have released vast quantities of contaminants to groundwater, threatening water resources, ecosystems and human health. What processes control the fate and transport of contaminants in the subsurface? What remediation strategies are effective and what are the tradeoffs among them? How are these processes represented in models used for regulatory and decision-making purposes? This course will address these and related issues by focusing on the conceptual and quantitative treatment of advective-dispersive transport with reacting solutes, including modern methods of contaminant transport simulation. Some Matlab programming / program modification required. Prerequisite: Physical Hydrogeology ESS 220 / CEE 260A (Gorelick) or equivalent and college-level course work in chemistry.
Same as: ESS 221, GS 225

CEE 261A. The Atmospheric Boundary Layer: Fundamental Physics and Modeling. 3 Units.
An introduction to the Atmospheric Boundary Layer (ABL), including measurements and simulations of ABL flows. Wind and flow, turbulent transport, buoyancy and virtual potential temperature, the diurnal cycle. Derivation of the governing equations, simplifications and assumptions. Turbulence kinetic energy and its budget, ABL stability, the Richardson number and teh Obukhov length. Analysis of boundary layer turbulence. Overview of field and wind tunnel measurement techniques, and of computational models from meso- to micro-scale. a Discussion of micro-scale applications, including pedestrian wind comfort, pollutant dispersion and wind loading, and an introduction to uncertainty quantification for ABL flows. Prerequisites: Knowledge of fluid mechanics.

CEE 261B. Physics of Wind Energy. 3 Units.
Formerly CEE 261. An introduction to the analysis and modeling of wind energy resources and their extraction. Topics include the physical origins of atmospheric winds; vertical profiles of wind speed and turbulence over land and sea; the wind energy spectrum and its modification by natural topography and built environments; theoretical limits on wind energy extraction by wind turbines and wind farms; modeling of wind turbine aerodynamics and wind farm performance. Final project will focus on development of a new wind energy technology concept. Prerequisites: CEE 262A or ME 351A.
Same as: ME 262

CEE 261I. Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the atmospheric circulation. Topics include the global energy balance, the greenhouse effect, the vertical and meridional structure of the atmosphere, dry and moist convection, the equations of motion for the atmosphere and ocean, including the effects of rotation, and the poleward transport of heat by the large-scale atmospheric circulation and storm systems. Prerequisites: MATH 51 or CME100 and PHYSICS 41.
Same as: CEE 161I, EARTHSYS 146A, EARTHSYS 246A, ESS 146A, ESS 246A, GEOPHYS 146A, GEOPHYS 246A

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.
Application of fluid mechanics to problems of pollutant transport and mixing in the water environment. Mathematical models of advection, diffusion, and dispersion. Application of theory to problems of transport and mixing in rivers, estuaries, and lakes and reservoirs. Recommended: 262A and CME 102 (formerly ENGR 155A), or equivalents.

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.
Formerly CEE 164. The dynamic basis of oceanography. Topics: physical environment; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 41 (formerly 53).
Same as: CEE 162D, EARTHSYS 164, ESS 148

CEE 262E. Rivers, Streams, and Canals. 3-4 Units.
Formerly CEE 161A/264A. 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 or CEE 162A.
Same as: CEE 162E

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. Sediment Transport Modeling. 3 Units.
Formerly CEE 264. 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 262I. Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the large-scale ocean circulation. This course will give an overview of the structure and dynamics of the major ocean current systems that contribute to the meridional overturning circulation, the transport of heat, salt, and biogeochemical tracers, and the regulation of climate. Topics include the tropical ocean circulation, the wind-driven gyres and western boundary currents, the thermohaline circulation, the Antarctic Circumpolar Current, water mass formation, atmosphere-ocean coupling, and climate variability. Prerequisites: EESS 146A or EESS 246A, or CEE 162D or CEE 262D, or consent of instructor.
Same as: CEE 162I, EARTHSYS 146B, EARTHSYS 246B, ESS 146B, ESS 246B

CEE 263A. Air Pollution Modeling. 3-4 Units.
The numerical modeling of urban, regional, and global air pollution focusing on gas chemistry and radiative transfer. Stratospheric, free-tropospheric, and urban chemistry. Methods for solving stiff systems of chemical ordinary differential, including the multistep implicit-explicit method, Gear's method with sparse-matrix techniques, and the family method. Numerical methods of solving radiative transfer, coagulation, condensation, and chemical equilibrium problems. Project involves developing a basic chemical ordinary differential equation solver. Prerequisite: CS 106A or equivalent.

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 weather prediction model. 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 Niño, la Niña, 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 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 Reqs: GER: DBNatSci.
Same as: CEE 64

CEE 263G. Energy Policy in California. 1 Unit.
This seminar will provide an in-depth analysis of the role of California state agencies in driving energy policy development, technology innovation, and market structures. The course will cover three areas: 1) roles and responsibilities of key state agencies; 2) current and evolving energy and climate policies; and 3) development of California's 21st century energy systems. Presentations will include experts from the California Energy Commission, the California Public Utilities Commission, the California Air Resources Board, the California Independent System Operator, the California Legislature, and the Governor's office. This class is required for all Stanford Energy internships in California (SEIC) fellowship awardees and is open to other interested undergraduate and graduate students. May be repeated for credit. Class dates are: April 22 (10am-2pm); May 13 (10am-1pm); June 3 (10am-1pm). Interested students please contact Jon Lo at cyjlo@stanford.edu.
Same as: POLISCI 73, PUBLPOL 73

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 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 andn 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.
Same as: CEE 165D

CEE 266A. Watersheds and Wetlands. 4 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: CEE 101B or CEE 162A or equivalent. (Freyberg).
Same as: CEE 166A

CEE 266B. Floods and Droughts, Dams and Aqueducts. 4 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 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 Engineering & Science Seminar. 1 Unit.
Presentations on current research in environmental engineering and science by Civil & Environmental Engineering faculty.
Same as: CEE 279A

CEE 269B. Environmental Engineering & Science Seminar. 1 Unit.
Presentations on current research, practice and thinking in environmental engineering and science by visiting academics and practitioners.
Same as: CEE 279B

CEE 269C. Environmental Engineering and Science Seminar. 1 Unit.
Presentations on current research, practice and thinking in environmental engineering and science by visiting academics and practitioners.
Same as: CEE 279C

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 skillls. 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.
Physical and chemical unit operations for water treatment, emphasizing process combinations for drinking water supply. Application of the principles of chemistry, rate processes, fluid dynamics, and process engineering to define and solve water treatment problems by flocculation, sedimentation, filtration, disinfection, oxidation, aeration, and adsorption. Investigative paper on water supply and treatment. Prerequisites: CEE 101B (or CEE 162A); CEE 270. Recommended: 273.

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 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 273. Aquatic Chemistry. 3 Units.
Chemical principles and their application to the analysis and solution of problems in aqueous geochemistry (temperatures near 25° C and atmospheric pressure). Emphasis is on natural water systems and the solution of specific chemical problems in water purification technology and water pollution control. Prerequisites: CHEM 31 and 33, or equivalents.

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 273B. The Business of Water. 2 Units.
One of the fastest growing economic sectors is the water field, and private water companies are playing an increasingly important role in improving water management around the world. In some cases, however, the involvement of private companies in the water sector has also proven controversial (e.g., when private companies have taken over public water supply systems in developing countries such as Bolivia). This course will look at established or emerging businesses in the water sector and the legal, economic, and social issues that they generate. These businesses include investor-owned water utilities, water technology companies (e.g., companies investing in new desalination or water recycling technologies), water-right funds (who directly buy and sell water rights), social impact funds, innovative agricultural operations, water concessionaires, and infrastructure construction companies and investors. Each week will focus on a different business and company. Company executives will attend the class session and discuss their business with the class. In most classes, we will examine (1) the viability and efficacy of the company's business plan, (2) the legal and/or social issues arising from the business' work, and (3) how the business might contribute to improved water management and policy. Each student will be expected to write (1) two short reflection papers during the course of the quarter on businesses that present to the class, and (2) a 15-page paper at the conclusion on the class on either a water company of the student's choice or a policy initiative that can improve the role that business plays in improving water management (either in a particular sector or more generally). Elements used in grading: Attendance, Class Participation, Written Assignments, Final Paper. Cross-listed with Civil & Environmental Engineering (CEE 273B).
Same as: LAW 2508

CEE 273C. Environmental Engineering Applications of Membrane Technology. 3 Units.
Introduction to membrane technology and processes with applications in R&D, water/wastewater treatment, and renewable energy. Membrane separation principles, reverse osmosis, nanofiltration, membrane characterization techniques, mass transport phenomena, fouling processes, rejection of salts and trace organics, brine disposal system design, energy and cost considerations, and pre- and post-treatment procedures. Case studies in environmental sustainability issues related to full scale treatment engineering.

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 273F. Urban Water Use Efficiency and Conservation. 2 Units.
Introduction to water reuse, including membrane treatment, groundwater infiltration, artificial turf, and runoff collection and use.

CEE 274A. Environmental Microbiology I. 3 Units.
Basics of microbiology and biochemistry. The biochemical and biophysical principles of biochemical reactions, energetics, and mechanisms of energy conservation. Diversity of microbial catabolism, flow of organic matter in nature: the carbon cycle, and biogeochemical cycles. Bacterial physiology, phylogeny, and the ecology of microbes in soil and marine sediments, bacterial adhesion, and biofilm formation. Microbes in the degradation of pollutants. Prerequisites: CHEM 33, 35, and BIOSCI 41, CHEMENG 181 (formerly 188), or equivalents.
Same as: CHEMENG 174, CHEMENG 274

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 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 and CEE 274B, or equivalents.
Same as: BIO 274S, BIOHOPK 274, ESS 253S

CEE 275A. California Coast: Science, Policy, and Law. 3-4 Units.
This interdisciplinary course integrates the legal, scientific, and policy dimensions of how we characterize and manage resource use and allocation along the California coast. We will use this geographic setting as the vehicle for exploring more generally how agencies, legislatures, and courts resolve resource-use conflicts and the role that scientific information and uncertainty play in the process. Our focus will be on the land-sea interface as we explore contemporary coastal land-use and marine resource decision-making, including coastal pollution, public health, ecosystem management; public access; private development; local community and state infrastructure; natural systems and significant threats; resource extraction; and conservation, mitigation and restoration. Students will learn the fundamental physics, chemistry, and biology of the coastal zone, tools for exploring data collected in the coastal ocean, and the institutional framework that shapes public and private decisions affecting coastal resources. There will be 3 to 4 written assignments addressing policy and science issues during the quarter, as well as a take-home final assignment. Special Instructions: In-class work and discussion is often done in interdisciplinary teams of students from the School of Law, the School of Engineering, the School of Humanities and Sciences, and the School of Earth, Energy, and Environmental Sciences. Students are expected to participate in class discussion and field trips. Elements used in grading: Participation, including class session and field trip attendance, writing and quantitative assignments. Cross-listed with Civil & Environmental Engineering (CEE 175A/275A), Earth Systems (EARTHSYS 175/275), Law (LAW514), and Public Policy (PUBLPOL 175/275). Open to graduate students and to advanced undergraduates with instructor consent.
Same as: CEE 175A, EARTHSYS 175, EARTHSYS 275, PUBLPOL 175, PUBLPOL 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 275P. Persuasive Communication for Environmental Scientists, Practitioners, and Entrepreneurs. 2 Units.
Achieving environmental goals depends not only on innovative ideas and great science but also persuasive communication. What makes communication persuasive? The ability of the communicator to create value for his or her audience. This course will teach students how to: 1) focus on their audience and 2) create value for their audience using research-proven communication techniques. Students will master these techniques through oral and written exercises so that, after taking this course, they will speak and write more persuasively.
Same as: CEE 175P

CEE 275Q. Changing Human Behavior: Drivers and Barriers in Environmental Action. 2 Units.
Beyond the scientific and technological challenges of climate change, there are important psychological factors and barriers to individual attitude and behavior change. Students will analyze and identify barriers to individual action; distinguish between targeting individual behaviors vs. attitudes; understand specific psychological challenges and opportunities that climate change raises; develop strategies to address these factors in contexts where behavior change is sought. Students will propose and develop their own ideas for addressing a specific psychological barrier to individual action in an environmental context.
Same as: CEE 175Q

CEE 275S. Environmental Entrepreneurship and Innovation. 3 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. Energy Storage Integration - Vehicles, Renewables, and the Grid. 3 Units.
This course will provide in-depth introduction to existing energy storage solutions being used on the electric grid and in vehicles with a primary focus on batteries and electrochemical storage. We will discuss the operating characteristics, cost and efficiency of these technologies and how tradeoff decisions can be made. Special attention will be given to system-level integration of new storage technologies, including chargers, inverters, battery management systems and controls, into the existing vehicle and grid infrastructure. Further investigations include issues relating to integration of electric vehicle charging with demand-side management, scheduled renewable energy absorption and local grid balancing. Class format involves regular guest lectures, required lab participation, and field trips to relevant sites. Enrollment is limited; if you are interested in taking the course, please fill out a brief questionnaire at http://goo.gl/forms/i3YH91Qx05 n Please contact jtaggart@stanford.edu with any questions regarding the application or course information.
Same as: CEE 176C

CEE 276G. Sustainability Design Thinking. 3 Units.
Application design thinking to make sustainability compelling, impactful and realizable. Analysis of contextual, functional and human-centered design thinking techniques to promote sustainable design of products and environments by holistically considering space, form, environment, energy, economics, and health. Includes Studio project work in prototyping, modeling, testing, and realizing sustainable design ideas.
Same as: CEE 176G

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 277L. Smart Cities & Communities. 3 Units.
A city is comprised of people and a complex system of systems. Data provides the connective tissue between those systems. Smart cities use information technology (IT) to harness that data for operational efficiency, efficacy of government services, and sustainability. Key enablers covered include: IoT, open data, analytics, cloud and cognitive computing, and systems of engagement. System case studies will include: water, energy, transportation, buildings, food production, urban design, and social services. The evolving relationship between a city and its citizens as well as the risks / challenges of smart cities will also be explored.
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 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. (Cardinal Course certified by the Haas Center). Instructor consent required.
Same as: CEE 177X

CEE 278A. Air Pollution Fundamentals. 3 Units.
The sources and health effects of gaseous and particulate air pollutants. The influence of meteorology on pollution: temperature profiles, stability classes, inversion layers, turbulence. Atmospheric diffusion equations, downwind dispersion of emissions from point and line sources. Removal of air pollutants via settling, diffusion, coagulation, precipitation, Mechanisms for ozone formation, in the troposphere versus in the stratosphere. Effects of airborne particle size and composition on light scattering/absorption, and on visual range. Prerequisites: MATH 51 or equivalent. Recommended: 101B, CHEM 31A, or equivalents.

CEE 278C. 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. Limited enrollment, preference to CEE students. Prerequisites: Math 42 or 21 and CEE 70, or equivalents.
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 school year. Must prepare a publication synopsis, and maintain log of seminar attendance. See Aut Qtr CEE 279 syllabus for details on course requirements. Contact hildemann@stanford.edu to be added to Coursework website.

CEE 279A. Environmental Engineering & Science Seminar. 1 Unit.
Presentations on current research in environmental engineering and science by Civil & Environmental Engineering faculty.
Same as: CEE 269A

CEE 279B. Environmental Engineering & Science Seminar. 1 Unit.
Presentations on current research, practice and thinking in environmental engineering and science by visiting academics and practitioners.
Same as: CEE 269B

CEE 279C. Environmental Engineering and Science Seminar. 1 Unit.
Presentations on current research, practice and thinking in environmental engineering and science by visiting academics and practitioners.
Same as: CEE 269C

CEE 279F. Frontiers of Anaerobic Treatment. 1 Unit.
This seminar will present the latest findings on the operation and performance of ground-breaking anaerobic treatment processes for domestic wastewater. Specifically, this seminar will examine the performance of the Staged Anaerobic Fluidized-bed Membrane Bioreactor (SAF-MBR) using results from ongoing operations at the Codiga Resource Recover Center and from previous and parallel research efforts. The seminars will incorporate a description of the fundamentals of anaerobic treatment processes, a discussion of how the SAF-MBR process is different from typical anaerobic processes, and insights from operations along with implications for system design. Course work will include explorations of the costs, benefits, and market potential of this technology.
Same as: CEE 179F

CEE 279S. 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, EARTHSYS 179S, ESS 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¿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 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 single 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. Topics will include flexural behavior, prestressed concrete design, and two-way slab design & analysis, among others.

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-excursion 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.
Vector and tensor algebra; vector and tensor analysis; kinetics, basic physical quantities, global and local balance laws, representative material models of 1D and 3D continua at small strains; thermodynamics of general internal variable formulations of inelasticity; integration algorithms for inelastic 1D and 3D materials; basic solution techniques for boundary value problems in 1D and 3D.

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 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 298. Structural Engineering and Geomechanics Seminar. 1 Unit.
Recommended for all graduate students. Lectures on topics of current interest in professional practice and research.

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, MS&E 494

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 307. Structural Design Optimization. 4 Units.
Introduction to optimization (design variables, objective functions, constraints, etc); Multi-objective concept; Pareto optimization; Solution of optimization problems using differential and variational calculus; Mathematical programming methods; Lagrange multipliers and mini-max problems; Penalty function methods; Karush-Kuhn-Tucker (KKT) optimality conditions; Sensitivity analysis (analytical, semi-analytical and numerical methods); Introduction to topology optimization; Optimization process in practice (many applications); Graphics statics. Rapid prototyping and 3D printing techniques; Prerequisite: CEE 280 or equivalent in advanced structural analysis, and Matlab programming. Recommended: CEE 281 or equivalent in finite element analysis.

CEE 308. Topics in Disaster Resilience Research. 1 Unit.
This seminar will explore past and current research on disaster risk and resilience, towards the development of new frontiers in resilience engineering science research. Designed for graduate students engaged in the topic of risk and resilience research, the seminar will be organized around weekly readings and discussion groups. May be repeat for credit.
Same as: GEOPHYS 308

CEE 309. Engineering Seismology. 3 Units.
Introduction to the physical processes which cause earthquakes, and the relationships describing the frequency of occurrence of earthquakes in a regional-and fault-specific context. Characterization of strong ground motions. Seismic hazard analysis and determination of design ground motion intensity measures. Selection and modification of recorded ground motions for use in dynamic seismic response analyses. Overview of physics-based methods for simulating ground motion acceleration time series for engineering analysis.

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 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 324. Industrialized Construction. 1-2 Unit.
The course will present driving forces, comprehensive concepts, technologies, and managerial aspects of Industrialized Construction. Further a series of case studies of successful and failed industry implementations in Sweden, North America and Japan will be presented, showcasing process and technology platforms; use of renewable resources and other sustainable design and construction practices. The contrast between industrialized construction practices in Sweden, the U.S. and other countries is highlighted. Project-orientated vs. product-oriented approaches are essential, along with business models and strategies for industrialized construction companies and their opportunities for innovations. The course includes lectures, case studies, and course group-project assignments with leading companies in the industry.nnVisiting lecturer Dr Jerker Lessing, one of Sweden's leading experts on industrialized construction with more than 15 years of experience in this field, is giving this course. This is a unique opportunity to learn about this comprehensive, emerging construction concept. Dr Lessing's research at Lund University has pioneered the area of industrialized construction and established models and strategic perspectives that are widely adopted throughout academia and industry. Dr Lessing has published articles and books and he frequently lectures on the topic in Sweden and internationally. He is the Director and General manager of Research and Development at BoKlok, an industrialized house-building company which is a joint venture of the construction company SKANSKA and furniture giant IKEA. The class will be taught as a condensed two week course. Readings and discussions will be organized in the weeks before the lecture component of the class, a group project after. During weeks 1-5, class will not meet regularly and only meet a few times for reading discussions and guest speakers. When they occur, these meetings will be held either Tuesday or Thursday 8-9am in Y2E2 292A. A detailed class schedule will be available before the start of the quarter.nnNotes:nAttendance Mandatory. No Exam. Case and Problem Discussion. CR/NC and Auditing Not Allowed.nEligible for SDC Building & Infrastructure Development concentration area requirement.nnNumber of students limited to 20; prerequisites: CEE100 or equivalent. Please direct questions to jerker.lessing@boklok.se or adusser@stanford.edu and co.

CEE 325. CapaCity Design Studio. 5 Units.
Silicon Valley¿s rapid expansion has created explosive urban development in a fragile and under-prepared natural context. Delicate coastal ecology and rapid urbanization (expanding technology headquarters, new residential housing, parking, services, etc.) are competing for space. The same land also serves the regional functions of transport, open space, recreation, water supply, flood protection and wastewater treatment. Compounding the problems between these competing factors are global climate change instabilities increasing the certainty of catastrophic flooding, infrastructure collapse, and other urban resilience challenges.nnStudents will be immersed in a process that allows them to understand and spatially identify these risks, develop a vocabulary and an understanding of innovative tools to respond to them, and then work with expert practitioners to create unique design responses. Students will be provided with urban design frameworks (for planning, site development, and conservation) combined with advanced sustainable design concepts (such as resource co-optimization, adaptable infrastructure platforms, and high performance urban ecology) by working with expert lecturers and in small groups. Students will ultimately develop a series of visual and technical presentations to propose a final thesis for a local intervention that could be replicated in other coastal contexts globally.nnThis course has been designed to develop student learning through a project-based format. Students will be organized into design teams of 3 or 4 and will have the semester to collaborate with partners on an interdisciplinary proposal including policy and design recommendations.

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 Multidsiciplinary 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 361. 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 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 363B. Chaos and Turbulence. 3 Units.
An overview of the statistical analysis of unsteady flows, with a focus on chaos and turbulence. Topics will include random variables and statistical analysis; self-similarity, scaling, and symmetries; the turbulent energy cascade and the Kolmogorov similarity hypotheses; intermittency, refined similarity, and multifractal analysis; mixing and transport in chaotic and turbulent flows; and an overview of the effects of additional conservation laws on flow statistics. Prerequisites: CEE 262A or ME 351A, or permission of instructor.

CEE 363F. Oceanic Fluid Dynamics. 3 Units.
Dynamics of rotating stratified fluids with application to oceanic flows. Topics include: inertia-gravity waves; geostrophic and cyclogeostrophic 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: ESS 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 363H. Topics in Stratified Turbulence. 2 Units.
An exploration of classical and current papers dealing with the behavior of turbulence in stratified environments. This is a seminar-style class where each student will be expected to make presentations and lead discussions during the course of the quarter. Enrollment is limited and is based on the consent of the instructor. Prerequisites -- graduate coursework in turbulence and stratified flows.

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: ESS 364F

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 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 374M. Advanced Topics in Watershed Systems Modeling. 4 Units.
Basic principles of watershed systems analysis is required for water resources evaluation, watershed-scale water quality issues, and watershed-scale pollutant transport problems. The dynamics of watershed-scale processes and the human impact on natural systems, and for developing remediation strategies are studied, including terrain analysis and surface and subsurface characterization procedures and analysis.

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. 1-18 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 375A. Water, Climate, and Health. 3 Units.
Students in this course will review and discuss current literature on the water, climate, and human health nexus. We will review the climate-change projections from the most recent IPCC assessment and discuss their implications for water access and human health, with an emphasis on low- and middle-income countries. Each student will take responsibility for leading at least one class discussion, and will write a research proposal describing novel research on the water, climate and human health nexus. Course enrollment is capped. Permission to enroll must be obtained from the instructors through an application process.

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 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 379. Introduction to PHD Studies in Civil and Environmental Engineering. 1 Unit.
This seminar course will cover important topics for students considering a PhD in Civil and Environmental Engineering. Sessions will include presentations and discussions on career development, exploring research and adviser options, and the mechanics of PhD studies, including General Qualifying Exam requirements for all CEE PHD Students. In addition, CEE faculty will give presentations on their research. This seminar is required for CEE students considering a PHD or preparing to sit for the General Qualifying Exam in Civil and Environmental Engineering.

CEE 381. Advanced Engineering Informatics. 1-4 Unit.
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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 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.
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Same as: Engineer Degree

CEE 802. TGR Dissertation. 0 Units.

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Same as: PhD degree