Civil and Environmental Engineering

Chair
• Michelle Scherer

Undergraduate majors: civil engineering (B.S.E.); environmental engineering (B.S.E.)
Graduate degrees: M.S. in civil and environmental engineering; Ph.D. in civil and environmental engineering
Faculty: https://cee.engineering.uiowa.edu/people
Website: https://cee.engineering.uiowa.edu/

Civil and environmental engineering is one of the three largest fields of engineering. It traditionally has been concerned with infrastructure facilities that are both large in scale and essential to modern life. Civil and environmental engineering projects include transportation systems and their components, such as bridges, highways, public transit systems, railways, harbors, airports, and seaports; large-scale structures and office buildings that provide enclosed working and living space; environmental and hydraulic systems that provide clean water and air, including filtration plants and distribution systems for municipal and industrial water supplies, wastewater treatment plants, dams, levees, and irrigation systems.

Growth areas of civil and environmental engineering include water sustainability, infrastructure development, construction management, computer-aided design, hazardous waste management, and engineered environmental systems. In the future, civil and environmental engineers will be called upon to design structures for earth, prevent erosion and sedimentation of our rivers, predict effects of global climate change on the environment, provide modern and efficient transportation systems, and ensure the quality of our air and our surface waters and groundwaters.

In planning and design, civil and environmental engineers work with other engineers, architects, landscape architects, planners, economists, financiers, sociologists, lawyers, and other specialists as members of the design team. Some civil engineers work in engineering offices; others may be called upon to construct or supervise outdoor projects they have designed. These field assignments, many of which are in remote and fascinating parts of the world, are particularly appealing to many civil and environmental engineers. There also is significant potential for entrepreneurial work by civil and environmental engineers as they start their own companies.

In addition to the degree programs offered by the Department of Civil and Environmental Engineering, the department also participates in two Graduate College programs: Applied Mathematical and Computational Sciences, an interdisciplinary doctoral program; and Transportation Studies, a graduate certificate program.

Certificate in Wind Energy

The Departments of Mechanical and Industrial Engineering, Civil and Environmental Engineering, and Electrical and Computer Engineering and the Department of Geographical and Sustainability Sciences (College of Liberal Arts and Sciences) administer the undergraduate certificate program in wind energy; see Certificate in Wind Energy in the Catalog.

Related Certificate: Transportation Studies

The Transportation Studies Program offers the Certificate in Transportation Studies, which requires 18 s.h. of graduate credit. The program focuses on the varied and complex problems of transportation and on interdisciplinary approaches to addressing them. The Departments of Civil and Environmental Engineering, Mechanical and Industrial Engineering, and Geographical and Sustainability Sciences (College of Liberal Arts and Sciences) and the School of Urban and Regional Planning (Graduate College) participate in the program.

The certificate is coordinated by the School of Urban and Regional Planning. See Certificate in Transportation Studies for more information about the certificate.

Programs

Undergraduate Program of Study

Major
• Major in Civil Engineering (Bachelor of Science in Engineering)
• Major in Environmental Engineering (Bachelor of Science in Engineering)

Graduate Programs of Study

Majors
• Master of Science in Civil and Environmental Engineering
• Doctor of Philosophy in Civil and Environmental Engineering

Facilities

Undergraduate Core

The first-year engineering course ENGR:1100 Introduction to Engineering Problem Solving includes an introduction to the college’s Engineering Computer Services. Students in the course use computer-aided design tools on engineering work stations. All civil engineering courses require knowledge of personal computers and contain significant computer content.

For information about laboratories affiliated with core courses coordinated by other engineering departments, see the Catalog section for each of the departments.

Required and Elective Undergraduate Laboratories

CEE:2015 Civil Engineering Tools (2 s.h.), CEE:3763 Principles of Transportation Engineering (3 s.h.), and CEE:3084 Project Design and Management in Civil Engineering (3 s.h.): use of a state-of-the-art laboratory for computer-aided design and drawing.

CEE:3530 Geomechanics (4 s.h.): equipped for determining the classification, seepage characteristics, stress-strain properties, and strength of soils.

CEE:3155 Principles of Environmental Engineering (4 s.h.): conducted at the University Water Treatment Plant and Iowa
City Wastewater Plant for demonstrations of unit operations and processes of water and wastewater treatment, and applications in environmental chemistry and microbiology.

CCE:3371 Principles of Hydraulics and Hydrology (3 s.h.): hydraulics of pressure conduits and open channels, dimensional analysis, flow measurements, hydraulic machinery, with laboratory.

CCE:3586 Civil Engineering Materials (3 s.h.): structure, strength and failure, durability, deformation, practice, and processing for primary construction materials systems, including steel, aluminum, concrete, asphalt, fiber-reinforced composites, masonry, timber.

CCE:5153 Fundamentals of Environmental Sampling and Analysis (3 s.h.): experiments to demonstrate fundamental principles of aquatic chemistry and chemical analyses for characterization of water and wastewater quality, conducted in the Environmental Engineering Laboratories.

CCE:5154 Environmental Microbiology (3 s.h.): typical microorganisms isolated and their physiology and metabolic characteristics studied in the Environmental Engineering Laboratories.

CCE:5155 Biological Treatment Processes (3 s.h.) and CCE:5156 Physical-Chemical Process Fundamentals (3 s.h.): unit operations, processes studied in bench scale experiments; use of typical process analytical parameters; experiments conducted in the Environmental Engineering Laboratories, University Water Plant, and Iowa City Wastewater Treatment Plant.

**Graduate Laboratories**

**Environmental Engineering and Science**

The Environmental Engineering and Science Laboratories provide state-of-the-art facilities, equipment, and expertise to support both undergraduate and graduate-level instruction and research. The labs support research in contaminant fate and transport in various media (air, water, soil, plants, and microbes), drinking water disinfection and distribution, wastewater treatment, geochemical-contaminant interactions, bioremediation, and phytoremediation. They also provide resources for analytical chemistry, electrochemistry, molecular biology, microscopy, computer modeling, and simulated environments on the bench- and pilot-scale levels.

The Environmental Engineering and Science Laboratories are affiliated with the University's Center for Health Effects of Environmental Contamination and its Center for Global and Regional Environmental Research, and with the UI Environmental Health Sciences Research Center, an affiliate of the National Institute of Environmental Health Sciences (NIEHS).

**Hydraulics, Hydrology, and Water Resources**

The teaching and research functions of the department are closely connected to the research activities of IIHR—Hydroscience & Engineering. The institute houses some of the most modern research facilities in the world, including a 100-meter towing tank, a wave basin facility for ship hydrodynamics research, several flumes, an array of field instrumentation for hydrologic experiments, extensive laboratory space for hydraulic modeling, state-of-the-art instrumentation for flow measurements and visualization, and comprehensive computational facilities.

Research related to ecohydraulics and the environment takes place at the Lucille A. Carver Mississippi Riverside Environmental Research Station. IIHR—Hydroscience & Engineering operates the 250-square-foot facility, which is located on the Mississippi River near Muscatine, Iowa. The station provides engineers and biological scientists with an ideal facility in which to examine the multifaceted ecohydraulic processes of the upper Mississippi. It is equipped with water quality laboratories, research boats, and a seminar room.

**Structures, Mechanics, and Materials**

Facilities for computations, materials testing, geotechnical experiments, and small-scale structural testing are available for research and teaching. Faculty, staff, and students in structures, mechanics, and materials (SMM) have access to the computing resources of Engineering Computer Services and the Center for Computer-Aided Design (CCAD). Both centers continuously update their computing facilities to maintain pace with the rapidly changing field.

A wide range of experimental facilities is available for testing structural materials such as Portland cement concrete, asphalt, metals, timber, and composites. These facilities include several loading frames (purely uniaxial, purely torsional, and axial-torsional) that are available with computer-based control and data collection systems. Facilities for creep testing, triaxial soil testing, and high-cycle fatigue testing also are available. The laboratories have a variety of ovens and other facilities for preparation and treatment of test specimens.

Four well-equipped physical testing laboratories are dedicated to SMM teaching and research: the Civil Materials Laboratory, Soil Mechanics Laboratory, Plasticity Laboratory, and the Asphalt Laboratory. The Civil Materials Laboratory currently has a small-scale single-degree-of-freedom shaker table. Faculty, staff, and students have access through CCAD to a six-degree-of-freedom man-rated shaker table with 4000-pound payload and a 12-camera Vicon motion-capture system.

**Transportation Engineering**

The department's Asphalt Laboratory is equipped with a set of SuperPave testing equipment and asphalt mixture performance testing equipment, which can measure dynamic modulus and flow number of asphalt mixtures. The lab has a Hamburg Wheel Tracking Device for measuring the moisture sensitivity of asphalt mixtures; asphalt foaming equipment for mix design of cold in-place recycled asphalt using foamed asphalt; and equipment for Marshall mix design, indirect tensile strength test, and volumetric analysis of asphalt mixtures. The Asphalt Laboratory is one of the department's group of laboratories for testing the strength behavior of other materials.
Civil and Environmental Engineering Courses

CEE:0000 Civil Engineering Internship/Co-op 0 s.h.
Civil engineering students participating in the Cooperative Education Program register in this course during work assignment periods; registration provides a record of participation in the program on the student’s permanent record card. Requirements: admission to the Cooperative Education Program.

CEE:1010 Introduction to Careers in Environmental Engineering 0 s.h.
Past, present, and future roles of environmental engineers in society; introduction to the discipline’s historical roots and early visionary leaders in sanitation engineering and public health; growth during the environmental movement, and current role of environmental engineers in modern society as stewards for clean air, water, and energy; range of career opportunities available to environmental engineering majors, particularly in the emerging role of ambassadors for sustainable development.

CEE:1030 Introduction to Earth Science 3-4 s.h.
Relationships between plate tectonics, geologic time, and the rock cycle with volcanoes and igneous, sedimentary, metamorphic rocks; fossils; radioactive isotopes; landscape evolution; mountain building; natural resources; their impacts on civilization. GE: Natural Sciences with Lab; Natural Sciences without Lab. Same as EES:1030.

CEE:1031 Introduction to Earth Science Laboratory 1 s.h.
Laboratory component of EES:1030. Requirements: completion of 3 s.h. in EES:1030 or CEE:1030. Same as EES:1031.

CEE:2000 Civil and Environmental Engineering Sophomore Seminar 0 s.h.
Introduction to civil and environmental engineering curriculum and profession; presentations by senior undergraduate students, faculty, and professionals; lifelong learning skills and requirements for professional licensure in civil engineering. Requirements: sophomore standing.

CEE:2010 Civil and Environmental Engineering Professional Practice and Ethics 1 s.h.
Practical issues associated with civil engineering practice; topics may include safety and OSHA regulations, engineering specifications/building codes, contracts, liability, and ethics; role that a professional engineering license plays in the student’s career and professional/ethical obligations that come with it; history of civil engineering and development of civil practice in the United States.

CEE:2015 Civil Engineering Tools 2 s.h.
Tools and methods used in civil engineering career: AutoCAD, programming, project estimating, heavy equipment productivity estimation, and earthwork estimation.

CEE:2050 Severe and Unusual Weather 3 s.h.
Basic weather concepts behind severe weather phenomena and essential safety information; how weather events cause billions of dollars in damage and thousands of casualties; winter storms can impact half of the nation, paralyzing the transportation network with icy roads and wind driven snow; tornadoes can strike within minutes tearing apart homes; hurricanes can destroy entire communities with strong winds, heavy rain, and deadly storm surge; understanding severe weather and knowing what to do before, during, and after an event can significantly reduce injury, deaths, and property damage. Same as CBE:2050.

CEE:2150 Natural Environmental Systems 3-4 s.h.
Environmental chemistry and biology of air, water, and soil quality, air and water pollution, limnology, global atmospheric change, fate and transport of pollutants; hazardous substances, risk analysis, standard setting. Prerequisites: CHEM:1110. Same as GHS:2150.

CEE:2240 Digital Drafting with AutoCAD 3 s.h.
Basic principles of 2-D and 3-D computer-aided drafting; use of AutoCAD software to draw plans, elevations, and sections for objects and interior spaces. Prerequisites: CERM:2010 or SCPL:2810 or TDSN:2210 or MTLS:2910. Same as TDSN:2240.

CEE:3001 Leadership Skills for Engineers 1 s.h.
Survey of leadership ideas and principles as applied to situations commonly encountered in civil engineering practice, especially as they relate to challenges that beginning engineers face; speakers in selected engineering professions provide context and examples; exercises on leadership principles. Requirements: junior standing in civil and environmental engineering.

CEE:3002 Technical Communication in Civil and Environmental Engineering 1 s.h.
Development of communication skills through writing and oral presentations; impact of engineering solutions in a global, economic, environmental, and societal context; writings and presentations on current or historical engineering solutions; exposure to professionals with significant experiences to share in these areas. Requirements: junior standing.

CEE:3003 Project Management Skills 1 s.h.
Review and extension of civil and environmental engineering project management skills in preparation for capstone senior design course; project scheduling, cost estimating, contract types, construction phasing; review for Fundamentals of Engineering Exam (FE) and practice tests in four subdisciplinary areas. Requirements: senior standing.

CEE:3084 Project Design and Management in Civil Engineering 3 s.h.
Design of civil engineering systems, individual and team design projects oriented toward the solution of local problems, project management, construction management, contracts, budgeting, bidding. Prerequisites: CEE:3763 and CEE:3533 and CEE:3371 and CEE:3155 and CEE:3003. Requirements: senior standing.

CEE:3136 Design of Concrete Structures 3 s.h.
Fundamental analysis and design of reinforced concrete members and structures, flexure, shear, bond, continuity, beams, one-way slab system; columns. Corequisites: CEE:3533.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites/Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE:3142</td>
<td>Quality Control</td>
<td>3 s.h.</td>
<td>Basic techniques of statistical quality control; application of control charts for process control variables; design of inspection plans and industrial experimentation; modern management aspects of quality assurance systems. Offered fall semesters. Prerequisites: STAT:2020. Same as IE:3600, STAT:3620.</td>
</tr>
<tr>
<td>CEE:3228</td>
<td>Fluvial Geomorphology</td>
<td>3 s.h.</td>
<td>Hydrologic principles, stream channel processes, and fluvial geomorphology within drainage basin systems; spatial and temporal variations in water distribution, analysis of hydrological data, flow mechanisms, sediment transport, forecasting procedures, hydrograph construction, modeling. Requirements: EES:3020 or another 3000-level geology or hydraulics course. Same as EES:3380.</td>
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<tr>
<td>CEE:3371</td>
<td>Principles of Hydraulics and Hydrology</td>
<td>3 s.h.</td>
<td>Hydraulics of pressure conduits and open channels, dimensional analysis, flow measurements, hydraulic machinery, laboratory. Prerequisites: ENGR:2510.</td>
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<tr>
<td>CEE:3430</td>
<td>Water Treatment</td>
<td>4 s.h.</td>
<td>Physical, chemical, and biological processes and operations to remove and treat chemical and pathogenic pollutants and protect human and environmental health; relevant to drinking water, municipal wastewater, water reuse, stormwater, industrial process water, agricultural wastewater; modern technologies and appropriate designs for the developing world; theory and applications; hands-on laboratory. Prerequisites: CEE:2150 and ENGR:2510.</td>
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<tr>
<td>CEE:3530</td>
<td>Geomechanics</td>
<td>4 s.h.</td>
<td>Identification and classification of earth materials; hydraulic and mechanical properties of soils; soil improvement; laboratory testing. Prerequisites: ENGR:2750.</td>
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<tr>
<td>CEE:3533</td>
<td>Principles of Structural Engineering</td>
<td>4 s.h.</td>
<td>Fundamental principles of structural analysis applied to statically determinate and indeterminate structures, continuous beams, trusses, and frames; external and internal equilibrium, compatibility of deformation, influence lines, virtual work; parallel use of classical and matrix formulation; slope deflection, flexibility and stiffness methods; use of computers. Prerequisites: ENGR:2750.</td>
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<tr>
<td>CEE:3566</td>
<td>Civil Engineering Materials</td>
<td>3 s.h.</td>
<td>Structure, strength and failure, durability, deformation, practice, and processing for primary construction materials systems, including steel, aluminum, concrete, asphalt, fiber-reinforced composites, masonry, timber. Prerequisites: ENGR:2750.</td>
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<tr>
<td>CEE:3783</td>
<td>Surveying and Remote Sensing</td>
<td>3 s.h.</td>
<td>Engineering surveying measurements, methods, computations. Prerequisites: ENGR:1100.</td>
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<tr>
<td>CEE:3790</td>
<td>Resilient Infrastructure and Emergency Response</td>
<td>3 s.h.</td>
<td>Concepts of resilient cities with specific emphasis on role of infrastructure and built environment; risk analysis, hazard mitigation and emergency response to various threats; resiliency through good design.</td>
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<tr>
<td>CEE:3997</td>
<td>Engineering Service Project</td>
<td>1-3 s.h.</td>
<td>Provides support of student learning associated with a variety of international engineering service projects facilitated by the Department of Civil and Environmental Engineering; service projects are usually designed and built as part of an Engineers Without Borders USA and/or a Bridges to Prosperity (Continental Crossings) approved program; active involvement by students in these organizations required.</td>
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<tr>
<td>CEE:3998</td>
<td>Individual Investigations: Civil Engineering</td>
<td>arr.</td>
<td>Individual projects for civil engineering undergraduate students: laboratory study, engineering design project, analysis and simulation of an engineering system, computer software development, research.</td>
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<tr>
<td>CEE:4097</td>
<td>Topics in Teaching and Learning</td>
<td>1 s.h.</td>
<td>Overview of Iowa's hydroclimate; emphasis on discharge, rainfall, and temperature; how to address basic research questions related to Iowa's climate and extreme events; hands-on exercises.</td>
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<td>CEE:4102</td>
<td>Groundwater</td>
<td>3 s.h.</td>
<td>Groundwater quality and quantity; Darcy's Law, 2-D flow equation, unsaturated zone, contaminant transport, redox reactions, drinking water quality, bio remediation; laboratories in permeameter testing, porous media grain size analysis, pump testing, monitoring well installation.</td>
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<tr>
<td>CEE:4103</td>
<td>Water Quality</td>
<td>3 s.h.</td>
<td>Sources, availability, uses, characteristics, criteria, best management practices for surface waters; protection of waters impaired by eutrophication, soil erosion and sedimentation; pathogenic organisms, habitat destruction, wastewater discharges, contaminated sediments, atmospheric deposition, watershed development, invasive species, irrigation return flows, stormwater discharges, nonpoint sources, agricultural runoff; laboratory component, measurement of water quality characteristics in the field. Requirements: junior or higher standing.</td>
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<tr>
<td>CEE:4104</td>
<td>Groundwater Modeling</td>
<td>3 s.h.</td>
<td>Groundwater flow and contaminant transport modeling; numerical methods, applications of groundwater modeling to water supply, groundwater resources evaluation, remediation design using software; GMS (MODFLOW, MODPATH, and MT3D). Prerequisites: MATH:1860 and (EES:4630 or CEE:4103). Same as EES:4660.</td>
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<tr>
<td>CEE:4107</td>
<td>Sustainable Systems</td>
<td>3 s.h.</td>
<td>New and emerging concepts in sustainable systems design and assessment. Same as CBE:4410.</td>
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<tr>
<td>CEE:4116</td>
<td>Computer-Aided Design for Civil and Environmental Engineering</td>
<td>3 s.h.</td>
<td>Introduction to engineering design process and graphical communications tools used by civil engineers; fundamentals of engineering drawing, descriptive geometry, multiview projection, graphical analysis, coordinate systems, database manipulation, building information modeling (BIM); AutoCAD. Prerequisites: CEE:2015. Requirements: civil and environmental engineering major.</td>
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</tbody>
</table>
CEE:4118 Probabilistic Methods in Hydroscience 3 s.h.
Common probabilistic models used in hydrology, hydraulics, and water resources; derived distributions; multivariate models and estimation of model parameters; analysis of data and model building; uncertainty analysis. Prerequisites: STAT:2020 and MATH:2560.

CEE:4119 Hydrology 3 s.h.
Overview of fundamental processes in water cycle, including precipitation, evaporation, infiltration, and runoff; quantitative approaches for predicting streamflow and design discharges; applications to flood hazard assessment and stormwater management. Prerequisites: ENGR:2510.

CEE:4120 Water Resources Sustainability 3 s.h.
Effect of human impact on hydrologic ecosystems (aquifers, watersheds, coastal zones, lakes, and wetlands); quantitative measures of impact and mitigation/attenuation efforts; key questions addressed (What does water resources sustainability mean? How can it be measured? How can it be implemented?); worldwide case studies that illustrate the detrimental effects of unsustainable resource utilization and the benefits of implementing sustainable resource management strategies.

CEE:4123 Hydroclimatology 3 s.h.
Introduction to fundamental processes governing climate system and hydrological cycle, links between them; measurements of atmospheric and terrestrial components; atmosphere-ocean interactions (e.g., El Nino, Pacific Decadal Oscillation); teleconnections; climatology of atmospheric storms and impacts (e.g., atmospheric rivers, tropical cyclones, floods, droughts); climate change and variability; tools for analysis of climate data. Recommendations: CEE:4118, CEE:4119, CEE:4180, and CEE:4378.

CEE:4131 Impacts of Technological Singularity 3 s.h.
Technological singularity—what it is, its current standing, impacts, implications; bio-, nano-, and information technologies; how new technologies affect sustainability; ethical issues raised by technologies.

CEE:4135 Structural Modeling and Health Monitoring 3 s.h.
Measurements, structural modeling, structural analysis, stiffness method, trusses and frames, structural testing, modal analysis. Prerequisites: CEE:3533 and ENGR:2750.

CEE:4146 Multiscale Hydrology: Introduction to Multiscale Hydrologic Phenomena 3 s.h.
Hydrologic principles over the last century developed from experimentation at laboratory and small plot scales; major scientific and engineering challenges, including links between statistical fluctuations that data exhibits; physical, chemical, and biological principles through appropriate mathematical theories, numerical models, and field observations; coupled hydrologic processes at larger scales using newly built on abstraction; observations used in hydrologic engineering at larger scales for several decades and missing a coherent theory that ties them together. Prerequisites: MATH:6600 and ENGR:2510. Requirements: three semesters of calculus and college physics, an introductory hydrology course, and a probability and statistics course.

CEE:4147 Decentralized Wastewater Treatment 3 s.h.
Established and innovative technologies used in decentralized wastewater treatment; lagoons, constructed wetlands, sand filters, and other ecological technologies appropriate for small wastewater flows; need for more sustainable treatment of small wastewater flows; Iowa’s approximately 739 unsewered communities throughout the state, high-growth areas surrounding Des Moines and Cedar Rapids-Iowa City corridor with small developments in need of wastewater treatment, developing countries. Prerequisites: CEE:2150 and CEE:3155 and CEE:3371.

CEE:4157 Environmental Engineering Design 3 s.h.
Application of physical, chemical, and biological operations and processes to the design of water and wastewater treatment systems; applications in solid and hazardous waste treatment. Prerequisites: CEE:3155.

CEE:4158 Solid and Hazardous Wastes 3 s.h.

CEE:4159 Air Pollution Control Technology 3 s.h.
Sources, environmental and health impacts, regulations, modeling of air pollution; processes and alternative strategies for control; global climate considerations. Prerequisites: CEE:2150. Same as CBE:4459, IGP:4159.

CEE:4160 Introduction to Bridge Engineering 3 s.h.
Bridge engineering and design; history of the bridge; factors that affect bridge design; bridges according to use (e.g., road, rail, pedestrian and bicycle) and type (e.g., suspension, cable stay, truss); how sustainability concepts may impact bridge design; substantial design exercise. Prerequisites: CEE:3533.

CEE:4162 Structural Systems for Buildings 3 s.h.
Detailed analysis and design of gravity and lateral force resisting systems for buildings; roof, floor, and bearing wall gravity systems; steel braced frames, steel and concrete moment frames, and masonry and timber shear walls lateral systems; introduction to tall building structures. Prerequisites: CEE:3533.

CEE:4164 Design of Wood Structures 3 s.h.
Framing layout and analysis of wood frame structures for gravity and lateral loads; design of structural members for bending, axial load, and shear, including joists, beams, columns, engineered lumber, bearing walls, shear walls, and diaphragms; introduction to connection design. Prerequisites: CEE:3533.

CEE:4167 Public Transit Operations and Planning 3 s.h.
Bus, light and heavy rail, and paratransit modes; transit operations, planning, modeling and optimization, transit agency economics, transit finance, and evolving transportation policy; skills essential to planners and engineers who intend to work for a either planning agency, transportation provider, or a transportation or planning consulting firm; individual and group projects involving transit operations. Requirements: undergraduate or graduate standing in engineering, or graduate standing in urban and regional planning. Same as URP:4195.
CxEE:4176 Transportation Demand Analysis 3 s.h.
City planning procedures and traffic engineering techniques applied to transportation problems; trip generation, distribution, assignment, mode choice models; travel surveys, data collection techniques; arterial flow, intersection performance, parking; transit system analysis. Same as URP:4262.

CxEE:4180 Fundamentals of Atmospheric Science 3 s.h.
Review of fundamental principles in atmospheric sciences needed for study of interdisciplinary topics involving the Earth’s atmosphere; understanding weather and climate processes to address problems in engineering; hydrometeorology of rainfall and its measurement by remote sensing; impact of climate anomalies and climate change on water resources; exchange of water, energy, and chemicals at the land-atmosphere boundary; forecasting of atmospheric chemistry and air quality. Prerequisites: ENGR:2510.

CxEE:4187 Statistics for Experimenters 3 s.h.
Application of statistical techniques to evaluate data derived from experimental samples designs; use of spreadsheets, statistical software; design and analysis of experiments; regression analysis; model building; practical applications. Same as OEH:4540.

CxEE:4210 Foundations of Environmental Chemistry and Microbiology 3 s.h.
Investigation of chemical and biological processes at the food-energy-water nexus; example topic areas include biogeochemical cycling of nutrients, biomass conversion, resource recovery from wastewater, removing pollutants from drinking water sources, water reuse, engineered natural treatment systems, pollutant transformation and control, treatment of process waters. Requirements: undergraduate senior standing or graduate standing.

CxEE:4317 Remote Sensing 3 s.h.
Fundamentals of electromagnetic waves, atmospheric radiative transfer, passive remote sensing, weather radar, hydrologic application of remote sensing.

CxEE:4370 Flow in Open Channels 3 s.h.
In-depth analysis of governing flow equations; steady uniform flow in channels of different resistance and cross section; flow control sections; specific energy considerations; analysis and computation of gradually varied profiles and spatially varied flow affected by lateral outflow and inflow; unsteady flow; flood routing. Prerequisites: CxEE:3371.

CxEE:4371 Water Resources Engineering 3 s.h.
Planning and economics of varied water resources projects; stochastic basis for design; flood damage mitigation, reservoirs, river morphology, economic analysis of water projects, urban water requirements, water supply, hydroelectric power systems, river navigation; contemporary civil-engineering problems and issues associated with water infrastructure development. Corequisites: CxEE:3371.

CxEE:4373 River Mechanics 3 s.h.
Laws governing fall velocity, applications to particle-size analysis; incipient motion, bed forms, bed load, suspended load, natural river processes; theory and practice of movable-bed model experiments. Prerequisites: CxEE:4370.

CxEE:4374 Water Resource Design 3 s.h.
Prerequisites to storm water management systems design, including design flows and rates; analysis and design of storm sewers, detention basins, street and highway drainage facilities, culverts, dams, spillways, measures for energy dissipation; review of wastewater transfer systems and design. Prerequisites: CxEE:3371.

CxEE:4378 Hydrometeorology 3 s.h.
Atmospheric thermodynamics; precipitation processes; evaporation; infiltration; surface runoff; hydrographs, runoff relations; runoff hydrography; storage problems; frequency, intensity, duration studies of storms, floods, droughts; hydrometeorological observations and network design; watershed modeling; urban hydrology climate.

CxEE:4385 International Perspectives in Water Sciences and Management 3 s.h.
Internationalization and water, with focus on a country or a world region; intensive, in-depth exposure to complex issues that affect planning and execution of water projects in large-scale watersheds.

CxEE:4410 Interdisciplinary Scientific Visualization 3 s.h.
Fundamentals of data visualization and practice communicating with data; techniques and algorithms for creating effective visualizations for engineers based on principles from graphic design, visual arts, human perception, and effective storytelling; targeted towards students interested in using visualization in their own work, as well as students interested in building better visualization tools and systems; examples might include interactive visualization systems, augmented/virtual reality applications, data and visual analytics tools, or new applications of existing visualizations methods.

CxEE:4511 Numerical Calculations 3 s.h.
Development of algorithms for functional approximations, numerical differentiation and integration; solution of algebraic and differential equations, with emphasis on digital computations; initial and boundary value problems. Prerequisites: MATH:2560. Same as ME:4111.

CxEE:4512 Engineering Design Optimization 3 s.h.
Engineering design projects involving modeling, formulation, and analysis using optimization concepts and principles; linear and nonlinear models, optimality conditions, numerical methods. Prerequisites: ENGR:2110 and MATH:2550. Requirements: junior standing. Same as ME:4112.

CxEE:4515 Computer-Aided Engineering 3 s.h.
Computational engineering modeling and simulation, geometric modeling, grid generation, finite-element and finite-volume methods, uncertainty analysis, optimization, engineering applications. Prerequisites: ME:3052 and ENGR:2750. Same as ME:4110.

CxEE:4532 Fundamentals of Vibrations 3 s.h.
Vibration of linear discrete and continuous mechanical and structural systems; harmonic, periodic, and arbitrary excitation; modal analysis; applications. Prerequisites: ENGR:2750. Same as ME:4153.

CxEE:4533 Finite Element I 3 s.h.
One- and two-dimensional boundary value problems; heat flow, fluid flow, torsion of bars; trusses and frames; isoparametric mapping; higher order elements; elasticity problems; use of commercial software. Prerequisites: ENGR:2750. Same as IGPI:4115, ME:4115.

CxEE:4535 Design of Steel Structures 3 s.h.
Concepts and procedures in steel design; LRFD (load and resistance factor design) methodology for beams/columns; analysis and design of indeterminate structures. Prerequisites: CxEE:3371.
CEE:4539 Foundations of Structures 3 s.h.
Application of soil mechanics to analysis of structural foundations; slope stability analysis; bearing capacity and settlement of shallow and deep foundations; retaining structures, braced cuts, reinforced earth structures; usage of computational models; subsurface exploration methods. Prerequisites: CEE:3530.

CEE:4560 Pavement Engineering 3 s.h.
Fundamental design principles; characterization and testing of asphalt and concrete paving materials; stresses and strain development within pavement structure; basic principles of mechanistic-empirical pavement design procedures. Prerequisites: CEE:3763.

CEE:4730 Transportation Infrastructure Construction and Management 3 s.h.
Analytical methods for developing transportation infrastructure construction and management systems; e-construction, transportation infrastructure condition evaluation, performance modeling, maintenance and rehabilitation optimization, asset management, development of transportation infrastructure construction and management system; application of information technology and mobile computing to solving transportation infrastructure construction and management problems. Prerequisites: CEE:3763.

CEE:4762 Design of Transportation Systems 3 s.h.
Overview of different modes within transportation systems; concepts of sustainability and livability in transportation system design; derivation of standards for geometric design of highways; roundabout design; cross-sectional and longitudinal geometric design of highways. Prerequisites: CEE:3763.

CEE:4763 Traffic Engineering 3 s.h.
Design of traffic control devices; evaluation and analysis of intersections and transportation networks using appropriate computer software. Prerequisites: CEE:3763.

CEE:4764 Winter Highway Maintenance 3 s.h.
Aspects of winter highway maintenance; current and innovative practices and the theory that underpins them.

CEE:4788 International Perspectives: Xicotepec 2-3 s.h.
Introduction to providing service to a community in a less developed country; student projects intended to improve community life in Xicotepec. Requirements: P3 standing. Same as GHS:4126, PHAR:8788, THTR:4265.

CEE:4995 Contemporary Topics in Civil and Environmental Engineering arr.
New topics or areas of study not formally offered in other civil and environmental courses; ice engineering, chaos and strange attractors, remote sensing, nonlinear dynamics of hydrologic processes, advanced water and wastewater treatment processes, hazardous waste control, global climate change, damage mechanics; based on faculty/student interest.

CEE:5083 Introduction to Comp Flow in Pipes and Channels 3 s.h.
General review of numerical methods in hydraulics (finite-difference, finite-element, and method of characteristics); stability and accuracy of numerical schemes; steady free surface flows; flow transients in pipelines and channels. Prerequisites: ME:5160.

CEE:5091 Graduate Seminar: Structure, Mechanics, Materials 0 s.h.
Presentation and discussions of recent advances and research in structures, mechanics, and materials engineering by guest lecturers, faculty, students. Requirements: senior or graduate standing.

CEE:5092 Graduate Seminar: Environmental Engineering Seminar 0 s.h.
Presentation and discussion of current topics, case studies, and research in environmental science and engineering by students, guest lecturers, faculty. Requirements: senior or graduate standing.

CEE:5093 Graduate Seminar: Hydraulics, Hydrology, and Water Resources 0 s.h.
Presentation and discussions of recent advances and research in hydraulics, hydrology, and water resources by guest lecturers, faculty, students. Requirements: senior or graduate standing.

CEE:5094 Graduate Seminar: Transportation 0 s.h.
Recent advances and research in transportation engineering. Requirements: senior or graduate standing.

CEE:5095 Career Paths in Sustainable Water Development 0 s.h.
Introduction to different career paths in the food, energy, and water (FEW) sector; speakers from a variety of different careers—including researchers, professors, entrepreneurs, consultants, and civic, professional, and global engineers—discuss their own career paths as well as current opportunities in their fields; students prepare individual development plans that identify their preferred career (i.e., training) path, a plan of study (i.e., path course work), mentors, and their preferred research area. Requirements: graduate standing in sustainable water development program.

CEE:5096 Water, Energy, and Food Nexus Seminar 0 s.h.
Invited presentations on research, policy, economics, and social drivers of water, energy, and food in the 21st century.

CEE:5097 Coaching Seminar on Communicating Water Science 0 s.h.
Presentation of student research on water, energy, and food in the 21st century; students receive live, immediate feedback from their peers and faculty coaches on best practices to improve their oral communication skills.

CEE:5098 Graduate Seminar in Structures, Materials, Mechanics, and Transportation 0 s.h.
Presentation and discussion of recent advances and research in structures, mechanics, materials, and transportation engineering by guest lecturers, faculty, and students. Requirements: graduate standing.

CEE:5100 Cultural Competence for Sustainable Water Development Engineers 0 s.h.
Skills needed to be culturally responsive to a wide range of communities in which sustainable water development engineering students interact with during their professional careers; series of three workshops; focus on how to identify cultural strengths that support development in underserved, resource-constrained communities; how to engage, build trust, and bridge differences with diverse stakeholders; how to conduct culturally sensitive interviews; how to communicate effectively across culture; preparation for Capstone Community Engagement project. Requirements: graduate standing in sustainable water development program.
CEE:5115 Atmospheric Chemistry and Physics 3 s.h.
Principal chemical and physical processes affecting atmospheric trace gas and pollutant cycles; emphasis on atmospheric photochemistry, aerosol science, major sources and removal processes. Corequisites: CBE:3120. Same as CEE:5425.

CEE:5129 Information Systems for Resource Management 3 s.h.
Understanding and managing natural and engineered resources requiring data-reach foundation; management of data; complex data-driven technologies integrated into data and information systems (DIS); hands-on opportunity to develop or use capabilities of DIS for study or research area of interest (science, engineering, industrial operation); wind power generation, an emerging field in Iowa, used as a case study for illustrating key DIS components, links, and functionalities. Same as ECE:5129, GEOG:5129, IE:5129, ME:5129.

CEE:5137 Composite Materials 3 s.h.
Mechanical behavior of composite materials and their engineering applications; composite constituents (fibers, particles, matrices) and their properties and behavior; macromechanical behavior of composite laminate; micromechanical predictions of composite overall properties; classical lamination theory; composite beams and plates. Prerequisites: ENGR:2750. Same as ME:5167.

CEE:5150 Environmental Chemistry 3 s.h.
Principles of general, physical, organic chemistry applied in water and air systems; emphasis on qualitative and quantitative understanding of chemical kinetics and equilibrium; acid-base reactions, complex formation, precipitation, dissolution, and oxidation-reduction reactions; organic nomenclature. Prerequisites: CHEM:1120. Same as CEE:5150.

CEE:5153 Fundamentals of Environmental Sampling and Analysis 3 s.h.
Laboratory experiments to demonstrate important concepts in environmental chemistry and to familiarize students with procedures used to characterize water and wastewater and evaluate certain treatment processes. Prerequisites: CHEM:1120. Corequisites: CEE:5152.

CEE:5154 Environmental Microbiology 3 s.h.
Microorganisms possess diverse metabolic functions, inhabit a myriad of environments, and play important roles in global biogeochemical cycles; environmental microbiology concepts with emphasis on metabolic diversity and application of molecular methods to characterize microbial community structure and function in ecosystems (polymerase chain reaction, next-generation DNA sequencing, proteomics); biodegradation and bioremediation of hydrocarbon pollutants in groundwater, biological processes relevant to food-water-energy nexus (nitrogen cycling in agriculturally-impacted watersheds), and microbial ecology of marine environments (hydrothermal vent plumes, oxygen minimum zones). Corequisites: CEE:5152.

CEE:5155 Biological Treatment Processes 3 s.h.

CEE:5156 Physical-Chemical Process Fundamentals 3 s.h.
Theory of physical and chemical operations and processes in water and wastewater treatment, including fundamental aspects of process dynamics; lectures, laboratory. Prerequisites: CEE:5152 and CEE:2130. Corequisites: CEE:3155.

CEE:5179 Continuum Mechanics 3 s.h.
Mechanics of continuous media; kinematics of deformation, concepts of stress and strain; conservation laws of mass, momentum and energy; constitutive theories; boundary and initial value problems. Prerequisites: ENGR:2750 or ENGR:2510. Same as ME:5179.

CEE:5186 Introduction to Hydroinformatics 3 s.h.
Hydroinformatics as the study, design, development, and deployment of cyberinfrastructure systems for hydrologic data collection, distribution, interpretation, visualization, and analysis to aid in the understanding and management of geospatial data; introduction to fundamental and advanced hydroinformatics concepts and procedures including automated data collection, relational databases, data management, metadata and semantics, data formats and standards, data transformations and processing to support modeling and analysis, and scientific visualization of hydroclimate data.

CEE:5188 Computational Methods in Water Resources 3 s.h.
Computational methods for solution of problems; emphasis on problems in water resources; standard methods for problem solutions using computers; problems of interest in hydraulics/hydrology. Recommendations: some programming ability.

CEE:5210 Developing Professional Service Business 2-3 s.h.
Use of professional skills and functional knowledge in creating a specialized service business. Same as ENTR:9000.

CEE:5236 Optimization of Structural Systems 3 s.h.
Advanced topics; optimization of structural topology, shape, and material; finite dimensional dynamic response optimization, sensitivity analysis, distributed parameter systems; projects. Same as BME:5720, ME:5236.

CEE:5310 Informatics for Sustainable Systems 3 s.h.
Introduction to fundamental and advanced environmental informatics concepts and procedures including automated data collection, data management, data transformations, and processing to support modeling and analysis; scientific visualization of environmental data to support management of food, energy, and water (FEW) resources; sustainability in FEW systems.

CEE:5350 Watershed Hydrology and Ecosystem Processes 3 s.h.
Introduction to hydrologic and ecosystem processes within a watershed; description of water, energy, and nutrient cycling in watersheds; focus on hydrologic and water-quality issues in agricultural Midwest; watershed modeling techniques, ecosystem goods and services, and selected case studies in watershed and ecosystem management problems. Requirements: graduate standing.

CEE:5369 Intermediate Mechanics of Fluids 3 s.h.
Basic concepts and definitions; pressure distribution in a fluid; governing equations and boundary conditions; integral and differential analysis; dimensional analysis and similarity; experimental analysis; laminar and turbulent internal and external flows; potential flows; engineering applications. Prerequisites: ENGR:2510. Same as ME:5160.
CEE:5372 Experimental Methods in Fluid Mechanics and Heat Transfer  3 s.h.
Hands-on experience in methodology of conducting experiments in fluid mechanics and heat transfer from design to data acquisition and processing; essential theoretical elements, experimental methodologies, data acquisition systems, uncertainty analysis; wide variety of instruments for fundamental and applied experimentation; work in small groups; design, implement, test, and report an experiment in area of interest. Same as ME:5162.

CEE:5374 Environmental Fluid Dynamics  3 s.h.
Introduction to the fundamentals of fluid dynamics with emphasis on application to natural flows of air and water in environmental systems; physical laws describing fluid dynamics, focus on development of physical insight of environmental fluids problems and strategies for solving them; analysis tools for solving various problems related to the movement of mass, momentum, and energy in natural and urban environments; systems include the atmospheric boundary layer, rivers, and streams, lakes, wetlands, and coastal zones; topics include incompressible viscous fluid flows, turbulence, waves, effects of rotation and stratification, scaling analysis, and scalar transport. Prerequisites: ENGR:2510. Requirements: working knowledge of multivariate calculus, partial differential equations, statistics, hydrology/hydraulics, and elementary fluid mechanics.

CEE:5380 Fluid Flows in Environmental Systems  3 s.h.
Introduction to environmental fluid flows and transport processes with focus on application and developing a language of environmental fluid mechanics; topics include physical and mathematical description of conservation and transport laws, statistical techniques for analyzing environmental flow data, scaling and similarity, stratification, turbulent flux measurement and modeling, environmental boundary conditions; application to surface waters and the planetary boundary layer; applied project involving collection and analysis of environmental flow data.

CEE:5390 PCBs in the Environment  3 s.h.
Polychlorinated biphenyls (PCBs) as potent carcinogens and linked to metabolic syndrome, autism, learning disabilities, hearing loss, and neurological disorders; how these compounds become to be such ubiquitous environmental pollutants; what the impact of their presence is; how sites are remediated and exposures reduced; in-depth examination through literature review, laboratory experiments, computational modeling, final written reports, and presentations. Recommendations: laboratory experience.

CEE:5410 Politics and Economics of the Food, Energy, Water Nexus  3 s.h.
Focus on the relationships between food, energy, and water resources; current and future political and economic frameworks that shape the food, energy, and water nexus.

CEE:5440 Foundations of Environmental Chemistry and Microbiology  3 s.h.
Investigation of chemical and biological processes at the food-energy-water nexus; example topic areas include biogeochemical cycling of nutrients, biomass conversion, resource recovery from wastewater, removing pollutants from drinking water sources, water reuse, engineered natural treatment systems, pollutant transformation and control, treatment of process waters. Requirements: undergraduate senior standing or graduate standing.

CEE:5513 Mathematical Methods in Engineering  3 s.h.

CEE:5540 Intermediate Mechanics of Deformable Bodies  3 s.h.
Application of equilibrium analyses, strain-displacement relations, and constitutive relationships to practical structural systems and elementary plane elasticity problems. Prerequisites: ENGR:2750. Same as BME:5660, ME:5150.

CEE:5549 Fracture Mechanics  3 s.h.
3-D stress states, definition and criteria for failure, nominal and local yield phenomena, linear elastic and elastic-plastic fracture mechanics, plane stress and plane strain fracture toughness, J-Integral, crack opening displacement, environmental assisted cracking, fatigue crack growth, fail safe, and damage tolerant design. Prerequisites: BME:4910 or ME:4055 or ME:5150. Same as ME:5159.

CEE:5578 Application Simulation to Transportation  3 s.h.
Transportation system management and traffic engineering, application of real-time simulation and visualization. Prerequisites: CEE:3763 or CEE:4763. Same as URP:5678.

CEE:5875 Perspectives in Biocatalysis  1-3 s.h.
Applied enzymology, protein design, structure-activity relationships, biosensor technology, microbial transformations, biodegradation of environmental pollutants. Requirements: graduate standing in a participating department supported by the Predoctoral Training Program in Biotechnology. Same as BIOC:5875, CBE:5875, CHEM:5875, MICR:5875, PHAR:5875.

CEE:5990 Structural Engineering Practicum A  2 s.h.
Students select a design project and develop two or more alternative design concepts in consultation with a three-member advisory committee consisting of at least one faculty member and one design professional; entire design process documented in a written report. Prerequisites: CEE:3136 and CEE:4535.

CEE:5991 Structural Engineering Practicum B  1 s.h.
Detailed design development of one of the concepts developed in CEE:5990: students perform detailed design calculations using applicable structural analysis and design software, produce professional quality structural plans including connection details, and defend design to a threemember advisory committee. Prerequisites: CEE:5990.

CEE:5998 Individual Investigations: Civil and Environmental Engineering  arr.
Individual projects for civil and environmental engineering graduate students; laboratory study, engineering design project, analysis and simulation of an engineering system, computer software development, research. Requirements: graduate standing.

CEE:5999 Research: Civil and Environmental Engineering M.S. Thesis  arr.
Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for the M.S. with thesis in civil and environmental engineering. Requirements: graduate standing.

CEE:6151 Environmental Systems Modeling  3 s.h.
Mathematical modeling of environmental systems, including rivers, lakes, estuaries, treatment systems for conventional and toxic pollutants. Prerequisites: CEE:5152 and CEE:2150 and CEE:3155. Same as IGPI:6151.
CEE:6223 Environmental Boundary Layers 4 s.h.
Fundamentals of environmental boundary layer dynamics and thermodynamics of natural and engineered systems; atmospheric boundary layers and aquatic surface layer dynamics; land-atmosphere interaction, air-water exchange, and turbulent transport in aquatic ecosystems; turbulence, surface energy balance, spectral analysis, similarity theory; flow over homogeneous and heterogeneous surfaces, thermal stratification effects, measurement, simulation of turbulent and surface fluxes; applications to environmental modeling, urban meteorology, ecosystem dynamics, renewable energy; recent and current research topics. Prerequisites: ENGR:2510.

CEE:6225 Communicating Science 3 s.h.
Writing and speaking about environmental engineering and science research; key principles of writing with clarity and cohesion, and practice applying these principles on a piece of research writing that students are currently working on; review best practices for presenting research to peers and at conferences; students are required to share their work with peers through writing and presentations. Recommendations: graduate standing in earth and environmental sciences; M.S. students must be thesis option.

CEE:6253 Environmental Organic Chemistry 3 s.h.
Environmental factors that govern processes that determine fate of organic chemicals in natural and engineered systems; knowledge of chemical fate applied toward quantitatively assessing environmental behavior of organic chemicals; holistic view on physical-chemical properties of organic compounds, including aspects of gas-solid partitioning, bioaccumulation, and transformations in the atmosphere.

CEE:6255 Environmental Biotechnology and Bioremediation 3 s.h.
Concepts in molecular microbial ecology and bioremediation; microbial diversity and genetics, evolution of biodegradation pathways, application of quantitative PCR, high-throughput amplicon and metagenomic and transcriptomic sequencing, proteomics, stable isotopes; bioremediation research and practice. Prerequisites: CEE:5154.

CEE:6310 Analytical Methods in Mechanical Systems 3 s.h.
Vector and function spaces; functionals and operators in Hilbert spaces; calculus of variations and functional analysis with application to mechanics; Ritz and Galerkin methods. Prerequisites: ME:5113. Same as ME:6214.

CEE:6372 Environmental Dispersion Processes 3 s.h.
Review of classical diffusion theories; longitudinal dispersion, transverse and vertical mixing in free-surface turbulent shear flow; application to natural channels; selected topics including stream-tube models, mixing and dispersion of heated effluents. Corequisites: CEE:5369.

CEE:6376 Viscous Flow 3 s.h.
Equations of viscous flow; classical analytical and numerical solutions; flow regimes and approximations; laminar boundary layers—equations, solution methods, applications; stability theory and transition; incompressible turbulent flow—mean-flow and Reynolds-stress equations, modeling, turbulent boundary layers and free shear flows. Requirements: for ME:6260—ME:5160; for CEE:6376—CEE:5369. Same as ME:6260.

CEE:6520 Watershed Sedimentation 3 s.h.
Exploration of rich and complex field of sediment transport, geomorphology, and contaminant transport; associated physical, chemical, and biological processes with associated mathematical modeling; investigation of current topics not covered elsewhere, including physical processes affecting stability/mobility, transport, and fate of soil/sediments; lack of general understanding in development of fine-scale sedimentary structure in different systems, particularly contamination and contamination release; suspension effects on turbulent flows. Prerequisites: CEE:4370 and CEE:4373.

CEE:6532 Finite Element II 3 s.h.
Computer implementation; plate and shell elements; mixed and hybrid formulations; nonlinear analysis; recent development; introduction to boundary element method. Prerequisites: CEE:4533. Same as IGPI:6216, ME:6215.

CEE:6534 Applied Optimal Design 3 s.h.
Optimal design problem formulation; optimality conditions; linear, quadratic, convex, and nonlinear programming; Lagrangian duality; numerical algorithms for unconstrained and constrained design problems, design sensitivity analysis, engineering applications. Prerequisites: CEE:5513. Same as ME:6534.

CEE:7197 Teaching Undergraduate Science and Engineering arr.
Basic skills to be a successful undergraduate instructor; teaching of technical subjects and solving problems; emphasis on practical applications of lesson material and class demonstrations; techniques for teaching effective classes; opportunity for students to teach; intended for graduating Ph.D. students with a career interest in a university environment.

CEE:7250 Advanced Fracture Mechanics 3 s.h.
Fracture of modern engineering materials; linear-elastic fracture; computational methods; functionally graded materials; elastic-plastic fracture; multiscale fracture and fatigue crack initiation. Prerequisites: ME:5113 and (ME:5159 or CEE:4533). Same as ME:7250.

CEE:7549 Multiscale Modeling 3 s.h.
Computational modeling of engineering materials ranging from molecular to continuum scales, molecular dynamics and Monte Carlo methods, nanoscale continuum modeling, scale-coupling methods. Prerequisites: ME:5143 or CEE:4533. Same as ME:6255.

Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for the Ph.D. in civil and environmental engineering.