Civil and Environmental Engineering

CIVIL ENGINEERING

Civil engineering occupies a prominent position as one of the major fields in the engineering profession. Civil engineers are concerned with all aspects of the conception, planning, design, construction, operation, and maintenance of major physical works and facilities that are essential to modern life. Civil engineering projects are typically characterized by extreme size, complexity, durability, and cost. Examples include bridges, buildings, transportation facilities, tunnels, coastal facilities, dams, foundations, and waterways.

The **Mission** of our Civil Engineering Bachelor of Science degree program is to educate students in the principles and methods essential to the practice and advancement of the interdisciplinary field of civil engineering. The program is proactive and continues to incorporate new and emerging paradigms in all aspects of teaching and education while maintaining rigorous standards in traditional approaches to engineered solutions of civil problems. Our goal is to prepare students to apply and continually cultivate knowledge that will enable them to become successful practitioners, innovators and leaders in serving the needs of a complex society.

The **Program Educational Objectives** of our Civil Engineering Bachelor of Science program are to prepare Civil Engineering Graduates to :

1. Develop careers in civil engineering and other professionally related fields.
2. Seek additional professional training and personal development.
3. Apply their skills to develop innovative solutions and technologies.
4. Pursue professional licensure and/or certification.
5. Advance to become members of professional societies and future leaders in their profession.

To achieve the program education objectives, the civil engineering program has adopted the following seven ABET student outcomes:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

ENVIRONMENTAL ENGINEERING

Environmental Engineering is an interdisciplinary branch of the engineering profession where science and engineering principles are combined to provide healthy soil, water and air; remediate contaminated sites; and to improve the overall quality of the environment through the development of sustainable processes. Example activities include design of water and wastewater treatment facilities; detecting and modeling fate and transport of contaminants in both natural and engineered environments; developing technology-based solutions for restoring environmental quality; and developing and/or modifying industrial processes for ecological preservation and enhanced sustainability.

The **Mission** of our Environmental Engineering Bachelor of Science degree program is to educate students in the principles and methods essential to the practice and advancement of the interdisciplinary field of environmental engineering. The program is proactive and continues to incorporate new and emerging paradigms in all aspects of teaching and education while maintaining rigorous standards in traditional approaches to engineered solutions of environmental problems. Graduates of the program possess technical expertise required to maintain a healthy balance between societal welfare, economic growth and the environment surrounding us.

The **Program Educational Objectives** of our Environmental Engineering Bachelor of Science program are to prepare environmental engineering graduates to:

1. Develop careers in environmental engineering and other professionally related fields.
2. Seek additional professional training and personal development.
3. Apply their skills to develop innovative solutions and technologies.
4. Pursue professional licensure and/or certification.
5. Advance to become members of professional societies and future leaders in their profession.

To achieve the program education objectives, the environmental engineering program has adopted the following seven ABET student outcomes:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

EDUCATIONAL AND CAREER OPPORTUNITIES

In each curriculum, emphasis is placed on the development of a solid knowledge of civil or environmental engineering fundamentals. Both undergraduate programs include a strong base of mathematics, including calculus, probability and statistics, and the physical sciences, followed by a course in planning and engineering economics. A broad range of required and elective courses in engineering science, analysis and design in the areas listed above meet each set of program objectives. Elective courses in the programs extend across a wide array of areas including structural engineering, geotechnical engineering, water resources engineering, environmental engineering, transportation engineering, construction management, and project management. Additional elective courses in the environmental engineering program are available from chemical engineering, chemistry, biology, and earth and environmental science. Five-year programs are available for students interested in a second bachelor's degree in a major in the College of Arts and Sciences (see listings under Arts-Engineering (http://catalog.lehigh.edu/coursesprogramsandcurricula/engineeringandappliedscience/artsengineering/); Civil Engineering and Earth and Environmental Sciences (http://catalog.lehigh.edu/coursesprogramsandcurricula/engineeringandappliedscience/civilandenvironmentalengineeringandearthandenvironmentalsciences/)) and the Bachelor's to Master's Accelerated Program is available for eligible students interested in continuing for a master's degree at Lehigh (see listing under the P.C. Rossin College of

Engineering and Applied Science (https://catalog.lehigh.edu/coursesprogramsandcurricula/engineeringandappliedscience/)).

The civil and environmental engineering programs prepare individuals for entry into the engineering profession or for entry into high-quality programs of graduate study. With proper selection of electives, students may also prepare for entrance into schools of law or medicine, or into master's-level programs in engineering management or business administration.

For additional useful information visit our departmental website https://engineering.lehigh.edu/cee (https://engineering.lehigh.edu/cee/).

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B.S. IN CIVIL ENGINEERING

Required Courses

A total of 130 credit hours are required for graduation with the degree of Bachelor of Science in Civil Engineering.

Recommended Sequence of Courses

The HSS Advanced Requirement of 13 credits is shown below as three 3-credit courses and one 4-credit course. Other options are possible.

First Year

First Semester	Credits	Second Semester	Credits
ENGR 005	2	CHM 030	4
MATH 021	4	ECO 001	4
PHY 011	4	ENGR 010	2
PHY 012	1	MATH 022	4
WRT 001	3	WRT 002	3
	14		**17**

Second Year

First Semester	Credits	Second Semester	Credits
CEE 003	3	CEE 059	3
CEE 010 or 195	3	CEE 117	2
CEE 011	1	CEE 170	4
CEE 012	2	MATH 205	3
MATH 023	4	PHY 021	4
HSS Humanities/Social Sciences Elective	3	PHY 022	1
	16		**17**

Third Year

First Semester	Credits	Second Semester	Credits
CEE 122	3	CEE 123	3
CEE 142	3	CEE 202	3
CEE 159	4	CEE 222	3
BSE Basic Science Elective[1]	3	CEE 242	3
HSS Humanities/Social Sciences Elective	4	CEE 262 or 264	3
		AE CEE Approved Elective[2]	3
	17		**18**

Fourth Year

First Semester	Credits	Second Semester	Credits
CEE 203	2	CEE 290	3
AE CEE Approved Electives[2]	8	AE CEE Approved Electives[2]	6
HSS Humanities/Social Sciences Elective	3	HSS Humanities/Social Science Elective	3
FE Free Elective	3	FE Free Elective	3
	16		**15**

Total Credits: 130

1

Basic Science Elective; list of approved courses is available from CEE department.

2

Seventeen CEE elective credits approved by the CEE department; list available from department.

The selection of elective courses is to be in consultation with student's academic adviser in the Department of Civil and Environmental Engineering.

B.S. IN ENVIRONMENTAL ENGINEERING

Required Courses

A total of 131 credit hours are required for graduation with the degree Bachelor of Science in Environmental Engineering.

Recommended Sequence of Courses

The HSS Advanced Requirement of 13 credits is shown below as three 3-credit courses and one 4-credit course. Other options are possible. Three of these HSS credits must be an approved course that meets the Environmental Studies Requirement.

First Year

First Semester	Credits	Second Semester	Credits
ENGR 005	2	ENGR 010	2
CHM 030	4	MATH 022	4
MATH 021	4	PHY 011	4
WRT 001	3	PHY 012	1
FE Free Elective	3	WRT 002	3
	16		**14**

Second Year

First Semester	Credits	Second Semester	Credits
CEE 003, MECH 002, or MECH 003	3	CEE 170	4
CEE 012	2	CEE 272	2
ECO 001	4	CHM 031	4
EES 022	1	MATH 205	3
MATH 023	4	PHY 021	4
ESR Earth Science Requirement[3]	3	PHY 022	1
	17		**18**

Third Year

First Semester	Credits	Second Semester	Credits
CEE 122	3	CEE 202	3
CEE 142	3	CEE 222	3
CEE 375	3	CEE 274	3
CHE 031	3	CEE 275	2
CHM 110	3	EBR Environmental Biology Requirement[4]	3
CHM 111	1	HSS Humanities/Social Sciences Elective[1]	4
	16		**18**

Fourth Year

First Semester	Credits	Second Semester	Credits
CEE 203	2	CEE 377	3
CEE 378	3	AE Approved Electives[2]	6
AE Approved Elective[2]	6	HSS Humanities/Social Science Elective[1]	6

HSS Humanities/Social Sciences Elective[1]	3	
FE Free Elective	3	
	17	**15**

Total Credits: 131

1

HSS Advanced requirement is 13 credits, three credits of which must be an approved course that meets the Environmental Studies Requirement; the list of approved courses is available from CEE department.

2

Twelve approved elective credits to satisfy proficiency in four focus areas of water supply and resources, environmental chemistry, waste management, and biological processes. Approved list of courses available from CEE department.

3

Earth Science Requirement, list of approved courses is available from CEE department.

4

Environmental Biology Requirement, list of approved courses is available from CEE department.

The selection of elective courses is to be in consultation with student's academic adviser in the Department of Civil and Environmental Engineering.

TECHNICAL MINOR IN ENVIRONMENTAL ENGINEERING

A technical minor in Environmental Engineering is available for students outside the department. At least two of the courses must be from the CEE department.

CHM 031	Chemical Equilibria in Aqueous Systems (Prerequisite)	4
Select three of the following required courses:		9-10
CEE 170	Introduction to Environmental Engineering	
CEE 274	Environmental Water Chemistry	
CEE/CHE 373	Fundamentals of Air Pollution	
CEE/CHE 375	Environmental Engineering Processes	
Select one additional course from the required list or from the following:		3
CEE 222	Water Resources Engineering	
CEE/EES 323	Environmental Groundwater Hydrology	
CEE/EES 327	Surface Water Quality Modeling	
CEE 345	Geo-Environmental Engineering	
CEE 370	Environmental Separation and Control	
CEE 371	Reaction Kinetics in Environmental Engineering	
Other courses may be selected with the minor adviser's approval.		

GRADUATE PROGRAMS

The Department of Civil and Environmental Engineering (CEE) has graduate degree programs leading to Master's and Ph.D. degrees in: Civil Engineering, Structural Engineering, and Environmental Engineering.

The department offers advanced work in the specialty areas of **structural engineering**, **geotechnical engineering**, **water resources engineering**, and **environmental engineering.** Degrees offered are:

M.Eng., M.S., Ph.D. in Structural Engineering

M.Eng., M.S., Ph.D. in Civil Engineering

M.Eng., M.S., Ph.D. in Environmental Engineering

The programs educate students through coursework and independent study and research. Our programs are designed to provide students with the knowledge and analytical problem-solving capabilities needed to lead and innovate within multi-disciplinary teams in technologically-complex environments.

Graduate studies in the department of civil and environmental engineering enable the student to build upon the broad background of undergraduate education in preparation for professional practice at an advanced level, for research and development, or for teaching.

A graduate program leading to the M.S. normally is concentrated in one, or possibly two, of the technical specialty areas, and consists of a number of courses designed to fulfill the individual student's program objectives. Each candidate for the M.S. is required to submit a thesis representing three to six credit hours (CEE 491), or alternatively, a report based on a research course of at least three credits (CEE 429, CEE 439, CEE 449, CEE 479 or CEE 481). The balance of the program will consist of courses in the specialty area(s).

A graduate program leading to the M.Eng. degree stresses engineering applications and design. The department offers two different M.Eng. degrees. The M.Eng. in Structural Engineering focuses specifically on structural engineering. Candidates for the M.Eng. in Structural Engineering degree complete a group design project and an individual project as part of a 3-course design project sequence (CEE 416, CEE 417, CEE 418). The M.Eng. degrees in Civil Engineering and Environmental Engineering allow students to select courses across the various specialty areas of civil and environmental engineering. Candidates for the M.Eng. degrees in Civil Engineering and Environmental Engineering have the option to complete an individual engineering project or a research report, representing 3 to 6 credits (CEE 480), or may take 30 course credits with no project or report.

The doctoral program, which leads to the Ph.D., normally includes courses in the major field, courses in minor fields, and a dissertation presenting results of original research. Holders of master's degrees planning to become candidates for the Ph.D. take a qualifying examination. After qualification, the candidate, the candidate's departmental Ph.D. committee, and the department chair formulate the program of work.

The departmental laboratories are located in the Fritz Engineering Laboratory and in the STEPS Building. The laboratories offer outstanding facilities for research and instruction in structural engineering, geotechnical engineering, water resources engineering, and environmental engineering. In particular, the structural testing equipment includes dynamic testing machines, a five-million-pound universal hydraulic testing machine, and other state-of-the-art facilities. Included in the latter are the facilities of the Center for Advanced Technology for Large Structural Systems (ATLSS center) located on the Mountaintop campus. These include the largest 3-dimensional test bed in the U.S.A. and specialized earthquake testing facilities of the NSF George E. Brown, Jr. Network Earthquake Engineering Simulation (NEES). The water resources facilities include a wave tank, several flumes, a 10-cfs recirculating flow system, and two multipurpose tanks for model studies. The geotechnical facilities include state-of-the-art, fully automated triaxial compression and permeability machines for multiple simultaneous tests. The environmental facilities include state-of-the-art laboratories and analytical instrumentation for analysis of chemical, physical and microbiological systems.

In addition to departmental courses, a number of courses offered by the departments of mechanical engineering and mechanics, chemistry, chemical engineering, materials science and engineering, earth and environmental sciences, and biology may also be considered a part of the major field in civil and environmental engineering. A number of research and teaching assistantships are available to provide financial support to students of outstanding promise. The research or teaching activities required of holders of assistantships provides a valuable educational experience that supplements the formal course offerings. A very limited number of scholarships and fellowships are available to provide financial support for full-time study.

Courses

CEE 003 Engineering Statics 3 Credits
Force and moment vectors, resultants. Principles of statics and free-body diagrams. Applications to simple trusses, frames, and machines. Distributed loads. Internal forces in beams. Properties of areas, second moments. Laws of friction. is intended as a prerequisite for CEE 059.
Prerequisites: PHY 011 and (MATH 022 or MATH 096)
Can be taken Concurrently: MATH 022, MATH 096

CEE 010 (ARCH 010) Engineering/Architectural Graphics and Design 0,3 Credits
Graphical communication of civil engineering and architectural projects using manual techniques and commercial state-of-the-art computer software. Topics include visualization and sketching; orthographic, isometric and other drawings; points, lines and planes in descriptive geometry; site design; overview of geographical information systems and 3-D applications. Teamwork on design projects with oral and graphical presentations. Open to a limited number of architecture, design arts or other students with project roles consistent with students' background. Not available to students who have taken ME 010.
Attribute/Distribution: AL

CEE 011 Surveying 0,1 Credits
Theory and practice of basic engineering surveying measurements and analysis. Topics to include field note taking, datums and measurement precision, equipment and techniques for measuring distance, elevation and angles, electronic distance measurement, topographic surveys, GPS and hydrographic surveys. Hands on experience with the use of survey levels, transits/theodolites and a total station will be provided.

CEE 012 Engineering Probability and Statistics 2 Credits
Basic engineering statistics with a civil & environmental engineering focus. Topics to include: random variables and histograms; central tendency, dispersion and skew; probability density functions and cumulative distribution functions, basic probability concepts and selected probability models, return period analysis, linear regression and least squares, correlation analysis, propagation of errors.
Prerequisites: MATH 021

CEE 059 Strength of Materials 3 Credits
Analysis of stress and strain; Hooke's law; effect of axial load, bending moment, transverse shear, and torsion in beams of generic cross section; composite beams; inelastic bending; eccentric axial loading; shear center; Euler's instability; Mohr's circle for stress; stress combination; failure criteria.
Prerequisites: CEE 003 and MATH 023
Can be taken Concurrently: MATH 023

CEE 102 (CGH 102) Community Health and Engineering 3 Credits
This course is an introduction to public health engineering. Students will learn to define hazards and risks to community health such as air pollution; water, sanitation, and hygiene; food; and settlement/safety. The focus of the course will be on understanding engineering controls to reduce risk and improve communicable and non-communicable disease outcomes. This course includes elements of waterborne disease control, hazardous materials management, occupational health and safety, and environmental interventions.

CEE 104 Readings in Civil Engineering 1-4 Credits
Study of selected technical papers, with abstracts and reports. Consent of the department chair required.

CEE 117 Numerical Methods in Civil Engineering 2 Credits
Techniques for computer solution of linear and non-linear simultaneous equations; eigenvalue analysis; finite differences; numerical integration; numerical solutions to ordinary differential equations. Case studies in the various branches of civil engineering.
Prerequisites: MATH 205
Can be taken Concurrently: MATH 205

CEE 122 Fluid Mechanics 0,3 Credits
Fluid properties and statics; concepts and basic equations for fluid dynamics. Forces caused by flowing fluids and energy required to transport fluids. Dynamics similitude and modeling of fluid flows. Includes laboratory experiments to demonstrate basic concepts.
Prerequisites: MECH 002 or MECH 003 or CEE 003

CEE 123 Civil Engineering Materials 0,3 Credits
Properties of commonly used civil engineering materials including aggregate, Portland cement concrete, asphalt, concrete, wood, metals, and polymer based synthetics. Standard test methods. Includes laboratory work and reporting of results.
Prerequisites: CEE 059 or MECH 012

CEE 142 Soil Mechanics 0,3 Credits
Physical properties of soils; mineralogy, composition and fabric. Phase and weight-volume relationships, consistency, gradation and classification of soils. Fluid flow through porous media. Stress-strain behavior; stresses within a soil mass, deformation behavior, measurement of stress-strain properties, shear strength of soil. Volume change in soils; compressibility, pore water pressure, consolidation and settlement. Laboratory experiments to measure physical and mechanical properties of soils.
Prerequisites: MECH 002 or MECH 003 or CEE 003

CEE 159 Structural Analysis I 0,4 Credits
Elastic analysis of statically determinate beams, frames, and trusses; deflections by the methods of virtual work and moment area; influence lines for determinate structures; modeling for structural analysis; flexibility, stiffness, and approximate methods of analysis of indeterminate structures.
Prerequisites: CEE 059

CEE 170 Introduction to Environmental Engineering 0,4 Credits
Characterization and evaluation of natural water resources. Principles of basic water chemistry. Water and wastewater treatment processes. Sludge treatment, air pollution and multi-media transport. Pollutants mass balance and oxygen transfer. Field trips to water and wastewater process facilities. Laboratory experiments on water and wastewater characterization.
Prerequisites: CHM 030

CEE 171 (CHE 171, EMC 171) Fundamentals of Environmental Technology 4 Credits
Introduction to water and air quality, water, air and soil pollution. Chemistry of common pollutants. Technologies for water purification, wastewater treatment, solid hazardous waste management, environmental remediation, and air quality control. Global changes, energy and environment. Constraints of environmental protection on technology development and applications. Constraints of economic development on environmental quality. Environmental life cycle analysis and environmental policy. Not available to students in RCEAS.

CEE 202 CEE Planning and Engineering Economics 3 Credits
The planning and management of civil engineering projects. Modeling and optimization methods, project management techniques. Financial decision-making among alternatives. Present value and discounted cash flow analysis; incremental analysis and rate-of-return criteria.

CEE 203 Professional Development 2 Credits
Elements of professionalism; professional ethics; engineering registration; continuing education; responsibilities of an engineer in industry, government, private practice; role of professional and technical societies.

CEE 205 Design Problems 1-3 Credits
Supervised individual design problems, with report. Consent of the department chair required.
Repeat Status: Course may be repeated.

CEE 207 Transportation Engineering 3 Credits
Principles of the design of transportation facilities with emphasis on highways and airports in the areas of geometric, drainage, and pavement design. Design problems.
Prerequisites: CEE 011

CEE 211 Research Problems 1-3 Credits
Supervised individual research problems, with report. Consent of the department chair required.
Repeat Status: Course may be repeated.

CEE 222 Water Resources Engineering 0,3 Credits
Pipe and pump hydraulics, surface and ground water hydrology, and open channel hydraulics. Laboratory experiments in applied hydraulics.
Prerequisites: CEE 122 or ME 231

CEE 242 Geotechnical Engineering 3 Credits
The principles related to analysis and evaluation of earthen infrastructure. Site characterization and in-situ testing of soils. Advanced stress-strain behavior, failure theories and stress path application. Stability of earthen structures; slopes, dams and levees. Stability of retaining structures; lateral earth pressures. Introduction to shallow foundations; bearing capacity and settlement.
Prerequisites: CEE 142

CEE 258 Structural Laboratory 3 Credits
Experimental study of behavior of members and structures. Planning, executing, and reporting experimental studies. Introduction to instrumentation and data acquisition. Nondestructive testing of civil engineering structures. Steel, rein-forced concrete, and other materials.
Prerequisites: CEE 262 and CEE 264

CEE 262 Fundamentals of Structural Steel Design 3 Credits
Introduction to steel structures. Behavior, strength and design of structural members, including members subjected to axial tension, axial compression, flexure and combined compression and flexure. Basic methods of joining members to form a structural system. Use of design specifications.
Prerequisites: CEE 159

CEE 264 Fundamentals of Structural Concrete Design 3 Credits
Analysis, design, and detailing of reinforced concrete members and simple systems for strength and serviceability requirements, including beams, columns, and slabs. Introduction to prestressed concrete.
Prerequisites: CEE 159

CEE 266 Construction Management 3 Credits
An overview of management and construction techniques used in engineering ventures and projects. Scheduling, estimation, construction methods, financial controls, contracts, labor relations and organizational forms. Case studies and lecturers from industry.
Prerequisites: CEE 202

CEE 272 Environmental Risk Assessment 2 Credits
Effects of chemical releases on human health; ecological risks. Application of risk assessment methodology, including hazard identification, exposure assessment, toxicity assessment, and risk characterization. Accounting for uncertainty in data during risk management, risk reduction and implementation of regulations and environmental policy.

CEE 274 Environmental Water Chemistry 3 Credits
Chemical principles and applications of those principles to the analysis and understanding of aqueous environmental chemistry in natural waters and wastewaters. The chemistry of ionic equilibria, redox reactions, precipitation/dissolution, acid-base concepts, buffer capacity, complexation, hydrolysis and biological reactions.
Prerequisites: CHM 031 or CEE 170

CEE 275 Environmental, Geotechnics and Hydraulics Laboratory 0,2 Credits
Applying fundamentals of soil properties, hydraulics and environmental science through appropriate laboratory experiments for solution of environmental engineering problems. Experiments will include solute transport in surface and subsurface medium; characterization of soils, sludges and water; treatment of water and wastewater including biological processes. Illustration of techniques to generate design parameters for scale-up.
Prerequisites: CEE 170 and CEE 274
Can be taken Concurrently: CEE 274

CEE 279 Microbial Ecology 4 Credits
The role of microorganisms in the environment. Topics include: Survey of microbial classification, structure, and metabolism; study of microbes at population, community, and ecosystem levels of organization; the role of microbes in biogeochemical cycles; application of microbes to bioremediation and resource recovery problems.
Prerequisites: EES 152

CEE 281 Special Topics 1-3 Credits
A study of selected topics in civil and environmental engineering not included in other formal courses. A design project or an interdisciplinary study of a problem related to civil or environmental engineering may be included. Civil and environmental engineering students working on design projects involving students from other departments or colleges working in cross-disciplinary teams may be included. A report is required. Consent of the department chair required.
Repeat Status: Course may be repeated.

CEE 290 CEE Design Project 3 Credits
Supervised design projects. Multidisciplinary teams applying the fundamentals of engineering science and the concepts of planning and systems analysis in the design of practical engineering works. The scope includes needs analysis, formulation of the design problem statement and evaluative criteria; analysis of alternative solutions and the generation of specifications. Includes most of the following considerations: economic, sustainability, manufacturability, ethical, social, environmental, aesthetic, political, health and safety. Practicing professional engineers are invited to serve as consultants. Written and oral reports are required. Must have senior standing in CEE department.

CEE 301 Modeling Environmental Systems 3 Credits
Apply flow and contaminant transport models to engineered environments and surface and subsurface natural environments. Formulation of problem statements in terms of ordinary and partial differential equations, boundary conditions, and parameters. Apply finite difference techniques using contemporary software. Solution of systems of linear and nonlinear equations. Introduction to finite elements.
Prerequisites: CEE 121 or MATH 205

CEE 316 (EES 316) Hydrogeology 0-4 Credits
Water plays a critical role in the physical, chemical, and biological processes that occur at the Earth's surface. This course is an introduction to surface and groundwater hydrology in natural systems, providing fundamental concepts and a process-level understanding using the hydrologic cycle as a framework. Geochemistry will be integrated to address natural variations and the human impact on the environment. Topics covered include: watershed hydrology, regional and local groundwater flow, water chemistry, and management of water resources. Lectures and laboratory.
Prerequisites: (EES 080 and EES 115 or EES 131 or EES 152) or (CEE 170)
Can be taken Concurrently: EES 115, EES 131, EES 152
Attribute/Distribution: NS, Q, W

CEE 320 (EES 320) Engineering Hydrology 3 Credits
Rainfall-runoff analysis, overland flow, hydrograph theories, modeling. Frequency analysis of extreme events. Flood routing. Design storms. Floodplain hydraulics, floodplain delineation.
Prerequisites: (CEE 222)
Attribute/Distribution: NS

CEE 322 Water Resources Engineering II 3 Credits
Advanced topics in fluid mechanics, free surface flows, hydraulic structures, and in pipe hydraulics including pipe network systems.
Prerequisites: CEE 222

CEE 323 (EES 323) Environmental Groundwater Hydrology 3 Credits
The study of subsurface water, its environment, distribution, and movement. Included are flow patterns, well hydraulics, and an introduction to the movement of contaminants. Design problems are included to simulate flow with analytical and numerical models, and contaminant migration using analytical models.
Prerequisites: CEE 122 or CEE 316 or EES 316 or ME 231 or CHE 044

CEE 325 Hydraulics of Sediment Transport 3 Credits
Hydrodynamic forces on particles, settling velocity. Sediment transport in open channel: tractive force theory, bed load and suspension theory, total load and wash load. Bedform mechanics, cohesive channel hydraulics. Sediment transport in closed conduits. Shore processes and coastline hydraulics. Students cannot receive credit for both CEE 325 and 425.
Prerequisites: CEE 222

CEE 326 GIS for Civil and Environmental Engineering 3 Credits
Introduction to theory, concepts and techniques related to the creation, manipulation, processing, and basic analysis of spatial data using geographical information systems (GIS) for real world engineering problems. Topics include: basic GIS concept, map projection and coordinate system, spatial data format and editing, spatial analysis, network analysis and developing simple GIS models. Multiple GIS tools are introduced. Lecture and laboratory.

CEE 327 (EES 327) Surface Water Quality Modeling 3 Credits
Fundamentals of modeling water quality parameters in receiving water bodies, including rivers, lakes, and estuaries. Modeling of dissolved oxygen, nutrients, temperature, and toxic substances. Emphasis on water quality control decisions as well as mechanics and model building.
Prerequisites: (CEE 122 or ME 231 or CHE 044) and CEE 222

CEE 331 Catastrophe Modeling and Resilience 3 Credits
Introduction to catastrophe modeling and resilience terminology, methods, and tools. General framework of catastrophe modeling and resilience assessment, with simple applications to various fields. Description of hazard, fragility, vulnerability and portfolio analysis. Effect of climate change. Research methods, scientific communication. Use of catastrophe risk and resilience modeling software and databases. Societal impact and ethical concerns raised by catastrophe insurance and resilience enhancement. Guest lectures from experts and term project. This undergraduate version of CAT 401 has simplified assignments.

CEE 332 Applications of Catastrophe Modeling and Resilience 3 Credits
Advanced analyses of various applications of catastrophe models, such as natural disasters or health-related threats to inform management and policies. Course activities include 1) reading recent publications on catastrophe model development, application and limitations, 2) practical exercises, in-class and as homework, about deterministic and stochastic model construction, and 3) result visualization of disaster impacts via geographic information systems. Theory and context-dependent practical problems on catastrophe model parameterization are covered. This undergraduate version of CAT 402 has simplified assignments.
Prerequisites: CEE 331 or CAT 401
Can be taken Concurrently: CEE 331, CAT 401

CEE 337 Interdependent Sustainable Urban Systems 3 Credits
Multidisciplinary application of modelling, optimization and control principles to interactive cyber-physical systems (CPSs) such as water, energy, transportation, and buildings. Analysis of complex urban systems, which are large-scale nonlinear civil systems composed of interconnected or interwoven parts. Topics include differential equation-based models of civil infrastructure systems; time and frequency domain representations; linear and non-linear model predictive control methods; dynamical behavior of the system; model analysis; and controllability. Students cannot receive credit for both CEE 337 and CEE 437.
Prerequisites: MATH 205

CEE 340 Advanced Foundation Engineering 3 Credits
Current theory and practice relating to the design of deep foundations supporting buildings and other structures. Construction practices; analysis and design (bearing capacity, settlement, dynamic effects); site investigations; load-resistance-factor design (LRFD) criteria for foundations.
Prerequisites: CEE 242

CEE 341 Ground Improvement and Site Development 3 Credits
Soil stabilization; grouting and injection methods; preloading and dynamic consolidation; deep compaction; drainage and dewatering; application of geotextiles and geomembranes; soil nailing and reinforcement methods. Use of in-situ test for soil properties and site characterization; procedures and calibration methods for the basic in-situ tests - SPT, CPT, CPTU, DMT; theoretical, experimental and empirical interpretive methods for in-situ test results.
Prerequisites: CEE 142

CEE 342 Experimental Geotechnical Engineering 3 Credits
Experimental studies dealing with the measurement of soil and other particulate materials properties, and behavior in the laboratory. Test procedures, calibration, data acquisition, interpretation of apparatus limitations and potential error sources, specimen preparation, data analysis and interpretation; designing experiments. Senior standing required.
Prerequisites: CEE 242

CEE 344 Behavior of Soils as Engineering Materials 3 Credits
Soil mineralogy, bondage, crystal structure and surface characteristics; clay-water electrolyte system; soil fabric and its measurement; soil structure and physical property relationships; soil depositional and compositional characteristics; engineering properties of soils as they relate to soil mineralogy, fabric and composition: volume change behavior, intergranular stresses, shear strength and deformation behavior, conduction behavior, coupled and direct flow phenomena.
Prerequisites: CEE 142

CEE 345 Geo-Environmental Engineering 3 Credits
Principles of interaction of soil and rock with various environmental cycles. Physical and chemical properties of soil. Soil fabric and its measurement, clay-water electrolyte system, electrical double layer; contaminated site characterization, groundwater flow and contaminant transport; detection and quantification technologies; waste containment systems, landfills, liner systems, leachate collection; soil and groundwater cleanup technologies.
Prerequisites: CEE 142

CEE 346 Geotechnical and Environmental Applications of Geosynthetics 3 Credits
Fundamental and current theories of designing soil structures with geosynthetics. Waste containment systems; landfills, vertical barriers and slurry walls; erosion control; filtration and drainage systems; reinforced embankments and stabilized slopes.
Prerequisites: CEE 142

CEE 347 Foundation Engineering 3 Credits
Application of theories and principles of soil mechanics to geotechnical and structural foundation design. In-situ soil testing, subsurface exploration and soil sampling. Bearing capacity, settlement, lateral earth pressure principles. Design of shallow foundations: spread footings, beams on elastic foundations, mat foundations. Introduction to retaining walls: mechanically stabilized earth, concrete and sheet pile walls, walls for excavations. Design of deep foundations: single piles, pile foundations, drilled piers and caissons.
Prerequisites: CEE 242

CEE 351 Advanced Structural Concrete Design 3 Credits
Advanced analysis, design and detailing of reinforced concrete members and systems. Topics include two-way slab systems, biaxial bending of beam-columns, slender columns, torsion, yield line analysis, strut-and-tie models.
Prerequisites: CEE 264

CEE 352 Structural Dynamics 3 Credits
Analysis of linear structural systems to time-dependent loads. Free and forced vibration. Classical and numerical methods of solution. Lumped-mass techniques, energy methods, and introduction to matrix formulation of dynamic problems. Application to design.
Prerequisites: MATH 205 and CEE 159 and MECH 102

CEE 354 Sensors, Signals, and Systems 3 Credits
Characterization of sensing systems and analysis and processing of sensor data. Topics include formulation of signals in time and frequency domains: sampling, Nyquist theorem, interpolation, band-limited signals. Analysis of systems: LTI systems, convolution, Eigenfunctions, poles and zeros. Design and analysis of digital filters: ideal filters, FIR filters, filter behavior. Spectral analysis and system identification: stationary processes, power spectral density, frequency leakage. Fundamentals of sensing systems: piezoelectricity, actuation, measurement parameters.

CEE 358 Random Vibrations 3 Credits
Review of probability theory. General characterization and models of random functions for engineering applications (seismic ground motion, wind velocity, ocean waves, mechanical vibrations). Vibration of deterministic systems under random dynamic loads; applications to wind and seismic engineering. Uncertain systems under random perturbations, simulation of random functions for numerical solutions (non-stationary, non-Gaussian, multi-variate processes, multi-dimensional fields).
Prerequisites: CEE 352
Can be taken Concurrently: CEE 352

CEE 359 Structural Analysis I 3 Credits
Concepts of virtual work and applications to determination of equilibrium and deflections of structures. Analysis of statically indeterminate structures, methods of consistent deformations, slope deflection and moment distribution; consideration of side-sway and non-prismatic members. Flexibility and stiffness matrix methods for computerized analysis. Application of computer analysis software for advanced structural analysis. Graduate students who have not taken CEE 159 should contact instructor to inquire about a prerequisite waiver.
Prerequisites: CEE 159

CEE 361 Bridge Systems Design 3 Credits
Introduction to bridge structural systems in steel and concrete. Loads and specifications. Design and analysis of bridge structural components.
Prerequisites: CEE 359 and CEE 262 and CEE 264

CEE 363 Building Systems Design 3 Credits
Building structural systems in steel, reinforced concrete and composite steel and concrete. Design loads (dead, live and environmental) and methodologies. Structural systems behavior and design. Design of floor systems, beam-columns, connections, walls, and overall frames. Final design.
Prerequisites: CEE 359 and CEE 262 and CEE 264

CEE 364 Advanced Project Management 3 Credits
Interrelations of planning, design, construction, operation and maintenance, and decommissioning. Project life cycle cost analysis. Cost estimating and financial management principles. Economic feasibility studies. Advanced construction methods and construction contracting.
Prerequisites: (CEE 266)

CEE 365 Prestressed Concrete 3 Credits
Principles of prestressing. Analysis and design of basic flexural members. Instantaneous and time-dependent properties of materials. Prestress losses. Additional topics may include continuity, partial prestressing, compression members, circular prestressing, etc.
Prerequisites: CEE 264

CEE 366 Finite Element Method in Structural Engineering 3 Credits
The finite element method: fundamental concepts, theory, modeling, and computation for the analysis of structures. One, two, and three-dimensional finite elements. Isoparametric formulation and implementation for various kinds of elements. Applications to problems in the behavior of structural elements and systems including analysis of trusses, beams, plates, and frames and bridge systems. Extensions to nonlinear analysis and advanced topics. Use of contemporary commercial software.
Prerequisites: CEE 359

CEE 370 Environmental Separation and Control 3 Credits
Theory and application of adsorption, ion exchange, reverse osmosis, air stripping and chemical oxidation in water and wastewater treatment. Modeling engineered treatment processes.
Prerequisites: CEE 371

CEE 371 Reaction Kinetics in Environmental Engineering 3 Credits
Theory of reaction kinetics and its application to the design and operation of chemical, physico-chemical and biological reactions in water, wastewater, and hazardous waste treatment. Basic design equations for various types of reactors and migration of pollutants in the environment.
Prerequisites: CEE 375 or CHE 375

CEE 373 (CHE 373) Fundamentals of Air Pollution 3 Credits
Introduction to the problems of air pollution including such topics as: sources and dispersion of pollutants, sampling and analysis; technology of economics and control processes; legislation and standards. Must have senior standing in the College of Engineering and Applied Science.

CEE 375 (CHE 375) Environmental Engineering Processes 3 Credits
Fundamental physical, chemical and microbiological processes applied in environmental engineering for air pollution control, treatment of drinking water, municipal wastewater, industrial wastes, hazardous/toxic wastes, and environmental remediation. Kinetics, reactor theory, mass balances, application of fundamental physical, chemical and microbiological principles to analysis and design.
Prerequisites: CEE 170 and CHM 031

CEE 376 Environmental Biotechnology 3 Credits
Fundamentals of microbiology and biochemistry applied to natural and engineered environmental systems. Systems ecology, energetics and kinetics of microbial growth, nutrition and toxicology, use of microorganisms for pollution monitoring and control. Pathogenicity and disease transmission, water quality using biological indices.
Prerequisites: CEE 375 or CHE 375

CEE 377 Environmental Engineering Design 3 Credits
Team-oriented course to develop design skills in the area of environmental engineering. Project components typically include: air pollution, drinking water, municipal wastewater, industrial wastes, hazardous/toxic wastes, and environmental remediation. Project work typically includes: a background report, a design report, and an oral presentation. Tools used in the design process may include simulation models. Must have senior standing in CEE department.
Prerequisites: CEE 375

CEE 378 Hazardous Waste Treatment and Management 3 Credits
Regulations for collection, transportation, disposal and storage of hazardous wastes. Containment systems, monitoring, new and available technologies to minimize, transform, destroy, detoxify and eliminate the hazardous components of the wastes. Environmentally benign processes and life cycle analysis.
Prerequisites: CEE 375 or CHE 375

CEE 379 (EES 379) Environmental Case Studies 3 Credits
Case studies will be used to explore the impact of politics, economics, society, technology, and ethics on environmental projects and preferences. Environmental issues in both affluent and developing countries will be analyzed. Multidisciplinary student teams will investigate site characterization; environmental remediation design; environmental policy; and political, financial, social, and ethical implications of environmental projects.
Prerequisites: (EES 022 or CEE 375 or CHE 375)

CEE 381 Special Topics 1-3 Credits
A study of selected topics in civil and environmental engineering, not included in other formal courses. A report is required. Consent of the department chair required.

CEE 384 Advanced Environmental Chemistry 3 Credits
Environmental organic chemical classifications, chemical partitioning between phases (air-water, air-organic, and multi-phase partitioning), Linear Free Energy Relationships (LFER), sorption isotherms, organic chemical partitioning in living media, transformation reactions, and modeling of organic chemical transport with reactions.
Prerequisites: CEE 274 and CEE 375

CEE 385 Research Procedures Seminar 1 Credit
Planning and execution of research projects, survey of current research, elements of proposals and budgets. Literature search procedures. Presentation of data, and of written and oral reports. Guidelines for visual aids.

CEE 401 Modeling Environmental Systems 1-3 Credits
Apply flow and contaminant transport models to engineered environments and surface and subsurface natural environments. Formulation of problem statements in terms of ordinary and partial differential equations, boundary conditions, and parameters. Apply finite difference techniques using contemporary software. Solution of systems of linear and nonlinear equations. Introduction to finite elements. Students cannot receive credit for both CEE 401 and CEE 301.
Prerequisites: CEE 122 or MATH 205

CEE 404 Mechanics and Behavior of Structural Members 3 Credits
Behavior of structural members, under a variety of loading conditions in the elastic and inelastic range. Introduction to the theory of elasticity and plasticity. Basics of linear elastic fracture mechanics and fatigue. Analysis of structural member behavior in axial, bending, shear, and torsion. Stability analysis of beam-columns. Energy concepts and their use in structural analysis.

CEE 405 Analytical and Numerical Methods I 3 Credits
Analytical and numerical methods used in Civil Engineering, with emphasis on ordinary and partial differential equations. Analytical and numerical solutions of ordinary and partial differential equations. Initial and boundary value problems. Numerical integration, numerical error, and approximations of functions and data points. Finite differences, solution of systems of linear equations, eigenvalue problems, and solution of nonlinear equations.
Prerequisites: MATH 205

CEE 406 Structural Reliability of Components and Systems 3 Credits
Probabilistic time –invariant failure analysis of structural components and systems. Statistics and probability; component time-invariant reliability analysis; system time-invariant reliability analysis; reliability-based structural design; and reliability of structural systems using Monte-Carlo simulation. Solutions suitable for practical computer implementation.

CEE 409 Finite Element Method in Structural Mechanics 3 Credits
Basic principles and equations governing the finite element method. Analysis of planar, axisymmetric, plate and articulated structures, with emphasis on analytical modeling. Accuracy and convergence studies, utilizing different discretizations and various types of elements. Case studies include application and extension to material nonlinearities, bridges, containment vessels, and soil-structure interaction.
Prerequisites: CEE 405

CEE 412 Methodologies of Structural Design 2 Credits
Probabilistic analysis of uncertainties associated with structural design. Characterization of loads including dead and live loads, wind, earthquake, and vehicular loads. Variability of structural resistance based on strength limit states as well as serviceability. Assessment of safety and reliability. Deterministic and probabilistic methodologies of design.

CEE 414 Analysis and Design of Steel and Composite Structural Members 3 Credits
Fundamentals of limit state design. Ultimate strength analysis of steel and steel-and-concrete composite columns, beams, beam-columns, and members subjected to torsion and combined torsion and bending. Flexural and torsional instability. Background and requirements of current design codes.

CEE 415 Analysis and Design of Ductile Steel Structural Systems 3 Credits
Inelastic behavior of steel and steel structural members. Plastic limit strength analysis of continuous beams and frames. Effect of variable repeated loading. Methodology and code requirements for design based on plastic strength. Applications to seismic-resistant building structures. Current research.
Prerequisites: CEE 262

CEE 416 Design Project I 3 Credits
Introduction to the overall M.Eng. design project for a civil infrastructure facility. Design decision making and communication processes. Roles of various players in the execution of the project (e.g. owner, architect, engineer, fabricator, construction manager, contractor), and the mechanisms of communication of information in the design process (e.g. design drawings, shop drawings, erection drawings, as-built drawings). Roles of codes and standards. Enrollment limited to students in M.Eng. program.

CEE 417 Design Project II 0,3 Credits
Task-specific teams will be organized to perform preliminary designs of different design options for the ocerall design project. Determination of project goals, performance requirements, and functional specifications. Winnowing and selection of alternatives for final design. Professor of practice and external specialists will guide examination and evaluation of design options based on cost and performance criteria.
Prerequisites: CEE 416

CEE 418 Design Project III 0,3 Credits
Comprehensive, completed design of the civil infrastructure facility. Design project teams will address life cycle issues and integrated, multidisciplinary aspects of architecture, systems design, construction and management. Critical design reviews will be performed by teams of external specialists and members of the industrial advisory board.
Prerequisites: CEE 417

CEE 419 Structural Behavior Laboratory 3 Credits
Experimental study of behavior of members, assemblages and structural systems. Introduction to methods and equipment used in laboratory simulations, numerical simulations, laboratory and in-situ measurements. Planning, executing and reporting experimental studies on performance of materials and large-scale structural systems. Non-destructive evaluation and damage assessment.
Prerequisites: CEE 262 and CEE 264

CEE 420 Surface Wave Mechanics 3 Credits
Elements of hydrodynamics and wave boundary conditions; linear wave theory and wave characteristics; nonlinear wave theories and application; wind wave generation, analysis and prediction; long waves; design wave determination; laboratory investigation of surface waves. Consent of instructor required.

CEE 424 Surface Water Hydrology 3 Credits
Advanced analysis and methods in surface water hydrology. Linear and non-linear hydrograph methods. Kinematic wave and other hydraulic routing techniques. Advanced techniques for evaporation, infiltration, and snow melt.
Prerequisites: CEE 320 or EES 320

CEE 425 Hydraulics of Sediment Transport 3 Credits
Hydrodynamic forces on particles, settling velocity. Sediment transport in open channel: tractive force theory, bed load and suspension theory, total load and wash load. Bedform mechanics, cohesive channel hydraulics. Sediment transport in closed conduits. Shore processes and coastline hydraulics.

CEE 426 GIS for Civil and Environmental Engineering 3 Credits
Introduction to theory, concepts and techniques related to the creation, manipulation, processing, and basic analysis of spatial data using geographical information systems (GIS) for real world engineering problems. Topics include: basic GIS concept, map projection and coordinate system, spatial data format and editing, spatial analysis, network analysis and developing simple GIS models. Multiple GIS tools are introduced. Lecture and laboratory.

CEE 427 Transport of Contaminants in Groundwater 3 Credits
Theory of groundwater flow and transport of contaminants in the groundwater system. State-of-the-art groundwater flow and contaminant transport models used to solve governing equations of groundwater flow and transport of chemically reactive solutes. Selected case studies will be analyzed.
Prerequisites: CEE 323 or EES 323

CEE 428 Advanced Topics in Hydraulics 1-3 Credits
Recent developments in hydromechanics and hydraulics. Topics to be selected from: wave mechanics, theory of flow through porous media, dispersion, hydrodynamic forces on structures, potential flow, free streamline theory, open channel hydraulics, computer methods. Consent of department required.
Repeat Status: Course may be repeated.
Prerequisites: CEE 322

CEE 429 Hydraulic Research 1-6 Credits
Individual research problems with reports.
Repeat Status: Course may be repeated.

CEE 431 Life-Cycle of Structural Systems 3 Credits
Assessing the life-cycle performance of new and existing structural systems, designing structures for lifetime performance, and optimizing the remaining life of existing structures, considering uncertainties in structural performance, demands placed on structural systems, structural maintenance and monitoring, and costs.

CEE 432 Structural Safety and Risk 3 Credits
Assessing safety and risk of structural systems during their specified service life, designing structures for specified safety and risk criteria for a prescribed service life, introducing Markov, queueing and availability models, statistics of extremes, time-variant safety and structural health monitoring, and optimal decision making under uncertainty based on single objective or multiple objectives.

CEE 433 Structural Optimization 3 Credits
Problem formulation, relative merit of various numerical optimization techniques, possible difficulties in applications, and how alternative formulations and methods can be combined to solve different design problems. Numerical optimization techniques are in general terms and their application to structural design.

CEE 436 Advanced Topics in Coastal Engineering 1-3 Credits
Advanced study of selected topics in coastal engineering such as: non-linear wave theory, design of coastal structures, shore protection and stabilization, numerical solution of coastal hydrodynamics. Selection of topics will depend on particular qualifications of staff, as well as on the interests of the students.
Repeat Status: Course may be repeated.

CEE 437 Interdependent Sustainable Urban Systems 3 Credits
Multidisciplinary application of modelling, optimization and control principles to interactive cyber-physical systems (CPSs) such as water, energy, transportation, and buildings. Analysis of complex urban systems, which are large-scale nonlinear civil systems composed of interconnected or interwoven parts. Topics include differential equation-based models of civil infrastructure systems; time and frequency domain representations; linear and non-linear model predictive control methods; dynamical behavior of the system; model analysis; and controllability. Students cannot receive credit for both CEE 337 and CEE 437.

CEE 439 Coastal Engineering Research 1-6 Credits
Individual research problems with reports.
Repeat Status: Course may be repeated.

CEE 440 Ground Improvement and Site Development 3 Credits
Soil stabilization; grouting and injection methods; preloading and dynamic consolidation; deep compaction; drainage and dewatering; application of geotextiles and geomembranes; soil nailing and reinforcement methods. Use of in-situ test for soil properties and site characterization; procedures and calibration methods for the basic in-situ tests - SPT, CPT, CPTU, DMT; theoretical, experimental and empirical interpretive methods for in-situ test results. Students will be required to complete an additional project. Students cannot receive credit for both 341 and 440.

CEE 441 Dynamic Analysis in Geotechnical Engineering 3 Credits
Vibration of elementary systems, 1D wave propagation, dynamic soil properties, analysis of response of shallow and deep foundations to dynamic loads, soil liquefaction and earthquake problems; laboratory tests, geophysical methods and non-destructive tests of foundation systems; dynamic analysis of pile driving. Consent of department chair.
Prerequisites: CEE 347

CEE 443 Advanced Soil Mechanics 3 Credits
Characterization of particulate media; particle-fluid interaction; load deformation, thermoelastic and viscoelastic behavior; elastic waves in particulate media; electromagnetic properties; empirical and analytical models. Must have completed a course in soil mechanics.

CEE 444 Behavior of Soils as Engineering Material 3 Credits
Soil mineralogy, bondage, crystal structure and surface characteristics; clay-water electrolyte system; soil fabric and its measurement; soil structure and physical property relationships; soil depositional and compositional characteristics; engineering properties of soils as they relate to soil mineralogy, fabric and composition: volume change behavior, intergranular stresses, shear strength and deformation behavior, conduction behavior, coupled and direct flow phenomena. Students will be required to complete an additional project. Students cannot receive credit for both CEE 344 and 444.

CEE 445 Advanced Foundation Engineering 3 Credits
Current theory and practice relating to the design of deep foundations supporting buildings and other structures. Construction practices; analysis and design {bearing capacity, settlement, dynamic effects}; site investigations; load-resistance-factor design (LRFD) criteria for foundations. This course, a version of CEE 340 for graduate students, requires advanced assignments. Credit will not be given for both CEE 340 and CEE 445.

CEE 446 Geotechnical and Environmental Applications of Geosynthetics 3 Credits
Fundamental and current theories of designing soil structures with geosynthetics. Waste containment systems; landfills, vertical barriers and slurry walls; erosion control; filtration and drainage systems; reinforced embankments and stabilized slopes. Design of select geotechnical facilities with geosynthetics that such as landfill, highway embankments, slopes and barrier systems. Term project. Students cannot receive credit for both 346 and 446.

CEE 447 Advanced Topics in Geotechnical Engineering 1-3 Credits
Advanced studies in selected subjects related to geotechnical engineering. The general areas may include: stress-strain-time relationships of soils, colloidal phenomena in soils, ground water flow and see page, soil dynamics, soil plasticity, numerical methods applied to soil mechanics, earth dam design, theories of layered systems and their application to pavement design, rock mechanics. The studies specifically undertaken in any particular semester depend on the availability of staff and the interest of students. Consent of department chair required.
Repeat Status: Course may be repeated.

CEE 448 Constitutive Laws in Soil Mechanics 3 Credits
Basic methods and constitutive laws used for the analysis of boundary value problems in soil mechanics. Linear elasticity, nonlinear elastic, linear elastic-perfectly plastic and non-linear elastoplastic models; critical state soil mechanics; application of select computational models. Consent of instructor required.

CEE 449 Geotechnical Research 1-6 Credits
Individual research problems relating to soil engineering, with report. Must have completed a course in soil mechanics.

CEE 450 Advanced Structural Analysis I 3 Credits
Theory and methods of linear and second order structural analysis. Linear theory and stiffness properties of structural members and linear transformations of structural analysis. Application of virtual work principles and development of displacement (stiffness) method of analysis in matrix form. Introduction to second order theory of structural members and second order equations of structural analysis.
Prerequisites: CEE 359 or CEE 359

CEE 452 Fatigue and Fracture of Structures - An Interdisciplinary View 3 Credits
This course examines the fatigue and fracture characteristics of steel structures from metallurgical, mechanical and structural engineering views. Both theory and experimental background are provided and applied to case studies and code development.

CEE 453 Nonlinear Analysis of Structural Components and Systems 3 Credits
Nonlinear analysis of structural components and systems, considering the effects of material and geometric nonlinearities. Solution strategies; material constitutive models; nonlinear member section analysis; computational plasticity; nonlinear beam-column element formulations; second order analysis; structural stability; and nonlinear time history analysis of structural dynamic systems.
Prerequisites: CEE 352 and CEE 404 and CEE 450

CEE 454 Sensors, Signals, and Systems 3 Credits
Characterization of sensing systems and analysis and processing of sensor data. Topics include formulation of signals in time and frequency domains: sampling, Nyquist theorem, interpolation, band-limited signals. Analysis of systems: LTI systems, convolution, Eigenfunctions, poles and zeros. Design and analysis of digital filters: ideal filters, FIR filters, filter behavior. Spectral analysis and system identification: stationary processes, power spectral density, frequency leakage. Fundamentals of sensing systems: piezoelectricity, actuation, measurement parameters. Students cannot receive credit for both CEE 354 and CEE 454.

CEE 455 Advanced Structural Dynamics 3 Credits
Analysis and design of structures to resist wind, earthquake, and blast loading. Matrix methods and computer applications. Non-linear and elasto-plastic response. Damping characteristics of structures and structural components, spectral analysis, dynamic instability. Characteristics of aerodynamic and seismic forces and explosions. Introduction to vibration of three-dimensional structural systems.
Prerequisites: CEE 352 or MECH 406

CEE 456 Behavior and Design of Earthquake Resistant Structures 3 Credits
Characteristics of earthquakes, effects of earthquakes on structures. Response of linear elastic structures to earthquakes. Response of inelastic structures to earthquakes. Behavior of structural components under cyclic loading. Principles of earthquake-resistant design. Seismic design procedures and their implementation in codes.
Prerequisites: CEE 352

CEE 457 Behavior and Design of Blast Resistant Structures 3 Credits
Design and assessment of structures subject to blast demands generated from accidental or intentional detonation of high explosives. Topics include determination of blast demands, characterization of pressure distributions on structural systems and components, estimation of the response of systems to dynamic pressure demands, modeling techniques for structural components, dynamic time history analysis of systems, determination of allowable response limits and stand-off requirements for facilities, and design structures to resist the effects of close-in detonation of high explosives and the impact of ballistic fragments.

CEE 458 Random Vibrations 3 Credits
Review of probability theory. General characterization and models of random functions for engineering applications (seismic ground motion, wind velocity, ocean waves, mechanical vibrations). Vibration of deterministic systems under random dynamic loads; applications to wind and seismic engineering. Uncertain systems under random perturbations, simulation of random functions for numerical solutions (non-stationary, non-Gaussian, multi-variate processes, multi-dimensional fields). Students cannot receive credit for both CEE 358 and CEE 458.
Prerequisites: CEE 352

CEE 459 Advanced Topics in Plastic Theory 3 Credits
Fundamentals of the mathematical theory of plasticity; the general theorems of limit analysis and their applications to beams under combined loading, arches, space frames, plates and shells. Limit analysis of two- and three-dimensional problems in soil, concrete, rock, and metal. Current developments.
Prerequisites: CEE 404

CEE 461 Advanced Bridge Engineering 3 Credits
Students in CEE 461 cover the same topics described under CEE 361, but in more depth. In addition each student conducts an intensive study of a bridge-related topic of his or her choice. A short written technical report on the findings of this study is required.
Prerequisites: CEE 262 and CEE 264

CEE 462 Stability of Structural Systems 3 Credits
Stability analysis of structures systems, including moment-resisting and braced frames, trusses, and plate and box girders. Bracing requirements. Elastic and inelastic second-order analysis. Design considerations. Special topics.
Prerequisites: CEE 404

CEE 463 Advanced Mechanics of Reinforced Concrete 3 Credits
Consistent mechanics for the design of reinforced concrete with or without prestress. Limit theorems of the theory of plasticity and their application to beams, slabs, and disturbed regions. Applications may include beams in flexure and combined flexure, axial load, and torsion; slabs (strip method, yield line analysis); corbels, deep beams, and other disturbed regions (truss models, strut-and-tie models, and associated failure mechanisms).
Prerequisites: CEE 404

CEE 464 Condition Assessment of Existing Structures 3 Credits
Assessment of existing structures for strength and serviceability. Materials evaluation and testing. Overview of material degradation mechanisms. Nondestructive and destructive evaluation test methods. Basics of field instrumentation. Load tests. Planning condition assessment programs. Focus on steel, concrete and masonry structures. Presentation of case studies including buildings, bridges, foundations, dams, tunnels and other structures. May include some laboratory and / or field work.

CEE 465 Structural Fire Engineering 3 Credits
Design and assessment of structural systems subjected to fire. Emphasizes a 3-phase approach to structural-fire engineering: (1) fire modeling, (2) heat transfer modeling, and (3) structural modeling. Includes approaches to simulate combustion and heat release for indoor and outdoor fires. Heat transfer modeling focuses on calculating the temperature increase of fire-exposed structural elements. Mechanics of structural elements and assemblies consider thermal expansion and weakening due to increasing temperature. Design approaches to mitigate the effects of fire are introduced.

CEE 466 Advanced Finite Element Methods 3 Credits
Review of linear elastic Finite Element (FE) method and weak formulation of equilibrium. Implementation of a liner elastic FE code. Special topics including shear locking, reduced integration, non-homogeneous essential conditions, and imposed strains. Dynamic FE analysis: theory and implementation of modal and time-history analyses. Techniques to model structural masses and damping. Stochastic FE analysis: theory and implementation of methods to analyze uncertain structures. Examples using scientific and commercial software to highlight practical modeling issues. Lab-sessions and student projects are included.
Prerequisites: CEE 366

CEE 467 Advanced Topics in Structural Engineering 1-3 Credits
Advanced study of selected topics in structural mechanics and engineering, such as: finite element methods, suspension system; space frames; stability of nonlinear systems; coldformed and lightweight construction; optimization and reliability; second-order phenomena in structures; interaction of structures with the environment; structural use of plastics; composite construction, etc. Selection of topics will depend on particular qualifications of the staff, as well as on the interests of the students. Consent of department chair required.
Repeat Status: Course may be repeated.

CEE 468 Stability of Elastic Structures 3 Credits
Basic concepts of instability of a structure; bifurcation, energy increment, snap-through, dynamic instability. Analytical and numerical methods of finding buckling loads of columns. Postbuckling deformations of cantilever column. Dynamic buckling with nonconservative forces. Effects of initial imperfections. Inelastic buckling. Buckling by torsion and flexure. Variational methods. Buckling of frames. Instability problems of thin plates and shells.
Prerequisites: MATH 205

CEE 470 Reaction Kinetics in Environmental Engineering 3 Credits
Theory of reaction kinetics and its application to the design and operation of chemical, physico-chemical and biological reactors in water and wastewater treatment. Basic design equations for various types of reactors and migration of pollutants in the environment. Students cannot receive credit for both CEE 371 and CEE 470.

CEE 471 Environmental Risk Assessment 3 Credits
Effects of chemical releases on human health; ecological risks. Application of risk assessment methodology, including hazard identification, exposure assessment, toxicity assessment, and risk characterization. Accounting for uncertainty in data during risk management, risk reduction and implementation of regulations and environmental policy. Term project.

CEE 472 Water and Wastewater Treatment Facilities 3 Credits
Theory and design of water and wastewater treatment facilities. Physical, chemical, and biological treatment processes for water and wastewater treatment.
Prerequisites: CEE 375 or CHE 375

CEE 473 Environmental Separation and Control 3 Credits
Theory and application of adsorption, ion exchange, reverse osmosis, air stripping and chemical oxidation in water and wastewater treatment. Modeling engineered treatment processes. Students cannot receive credit for both CEE 473 and CEE 370.
Prerequisites: CEE 470

CEE 474 Aquatic Chemistry 3 Credits
Applying basic principles of aqueous chemistry for quantifying complex, environmental systems. Specific examples of air-water-soil interactions and consequent effects. Heterogeneous equilibria with more than one solid phase. Kinetics and thermodynamics of some important ionic and biological reactions.

CEE 475 Advanced Topics in Environmental Engineering 1-3 Credits
Advanced concentrated study of a selected topic in environmental engineering such as non-point source pollution control, water reuse systems, new concepts in treatment technology, toxic substance control, etc. The instructor and student select topic. s may include specialized laboratory research, literature review, and specialty conference attendance. Consent of department chair required.
Repeat Status: Course may be repeated.

CEE 476 Environmental Biotechnology 3 Credits
Fundamentals of microbiology and biochemistry applied to natural and engineered environmental systems. Systems ecology, energetics and kinetics of microbial growth, nutrition and toxicology, use of microorganisms for pollution monitoring and control. Pathogenicity and disease transmission, water quality using biological indices. Students cannot receive credit for both CEE 376 and 476.
Prerequisites: CEE 375 or CHE 375

CEE 477 Environmental Engineering Processes 3 Credits
Processed applied in environmental engineering for air pollution control, treatment of drinking water, municipal wastewater, industrial wastes and environmental remediation. Kinetics, reactor theory, mass balances, application of fundamental physical, chemical and biological principles to analysis and design. Students cannot receive credit for both CEE 375 and 477.
Prerequisites: CEE 170

CEE 478 Toxic and Hazardous Wastes 3 Credits
Regulations for collection, transportation, disposal and storage of hazardous wastes. Containment systems, monitoring, types of liners, new and available technologies to eliminate or recover the hazardous components of the wastes. Students cannot receive credit for both CEE 378 and CEE 478.
Prerequisites: CEE 274 or CEE 375 or CHE 375

CEE 479 Environmental Engineering Research 1-6 Credits
Individual research problems in environmental engineering with report.
Repeat Status: Course may be repeated.

CEE 480 Independent Study 1-3 Credits
An intensive study of one or more areas of civil and environmental engineering that is not normally covered in other courses. Consent of instructor is required. A written report may be required.
Repeat Status: Course may be repeated.

CEE 481 MS or MEng Project 1-6 Credits
A design project or focused study of a problem related to civil and environmental engineering. May be used in lieu of CEE 491. A written report is required. Consent of the instructor is required.
Repeat Status: Course may be repeated.

CEE 484 Advanced Environmental Chemistry 3 Credits
Environmental organic chemical classifications, chemical partitioning between phases (air-water, air-organic, and multi-phase partitioning), Linear Free Energy Relationships (LFER), sorption isotherms, organic chemical partitioning in living media, transformation reactions, and modeling of organic chemical transport with reactions. Graduate version of the course includes projects on advanced topics (e.g., dynamic properties of multidimensional models, photochemistry, reaction pathways, kinetics of redox reactions). Students cannot receive credit for both CEE 384 and CEE 484.

CEE 491 Thesis 1-6 Credits

CEE 499 Dissertation 1-15 Credits