Department of Civil, Environmental, and Architectural Engineering

Civil, Environmental, and Architectural Engineering

Civil engineering (CE) is the oldest engineering program at KU. The first graduating class in 1873 included a civil engineer. Civil engineers design roads, water systems, bridges, dams, and other structures, providing nearly all the infrastructure needed by modern society. Civil engineers were the first engineers to address environmental issues and are the lead engineering discipline in treating water supplies to protect public health. In recognition of the significant issues concerning the environment, the department name was changed in 1992 to civil and environmental engineering.

The environmental and water resources engineering (EWRE) and environmental and water resources science (EWRS) graduate programs were created in 2019 by combining existing programs in environmental engineering and science and water resources engineering. These programs dated back to the founding of the Environmental Health Sciences program in 1961. Environmental and water resources engineers and scientists address the safety and supply of water, the interactions of water and the hydrological cycle with the environment, and the use of physical, chemical, and biological processes to solve environmental and water problems.

Architectural engineering (ARCE) combines studies in architecture with engineering science and design courses in structures, illumination, power, mechanical, energy, and construction to prepare students for building design projects of all kinds. KU's B.S. degree program in architectural engineering was established in 1912. The first female graduate of the School of Engineering was an architectural engineering major. Architectural engineering merged with civil and environmental engineering in 2001 to form the Department of Civil, Environmental, and Architectural Engineering (CEAE).

Mission

CEAE’s mission is to provide students with an outstanding engineering education and be a leader in research and service. This mission is supported by the following three goals:

1. Prepare students for productive engineering careers
2. Maintain and grow strong research programs
3. Serve the profession

Undergraduate Programs

Civil, environmental, and architectural engineering offers undergraduate degree programs in both civil engineering and architectural engineering. The B.S. in civil engineering is a 4-year, 128-hour degree. The B.S. in architectural engineering is a 4-year, 128-hour program.

Students in civil engineering can identify either civil or environmental engineering as their concentration. Students in architectural engineering can specialize in one of four areas of emphasis: mechanical/energy systems, lighting/electrical systems, building structures, or construction, or a hybrid such as pre-architecture, sustainable buildings, acoustics, or fire protection.

Both degree programs require a student to take the Fundamentals of Engineering (FE) examination, which is part of the process toward registration as a Professional Engineer (P.E.), to graduate. To help students complete their degrees efficiently and to aid with professional development, all undergraduates in CEAE have individual faculty members as their Engineering Faculty Mentors.

Graduate Programs

The department offers graduate programs leading to the following degrees and certificates:

- Master of Science in Architectural Engineering
- Master of Science in Civil Engineering
- Master of Science in Environmental & Water Resources Engineering
- Master of Science in Environmental & Water Resources Science
- Master of Civil Engineering
- Master of Construction Management
- Doctor of Philosophy in Civil Engineering
- Doctor of Philosophy in Environmental & Water Resources Engineering
- Doctor of Philosophy in Environmental & Water Resources Science
- Graduate Certificate in Construction Management
- Graduate Certificate in Structural Analysis
- Graduate Certificate in Structural Design
- Graduate Certificate in Structural Forensics
- Graduate Certificate in Water Resources

An ABET-accredited baccalaureate degree in engineering, or the equivalent from abroad, is required for admission to the graduate degree programs in civil, environmental and architectural engineering. The graduate degree programs in environmental & water resources science and construction management are intended primarily for students with baccalaureate degrees in fields other than engineering.

Graduate students in the civil engineering degree programs can specialize in structural engineering, environmental engineering, water resources engineering, geotechnical engineering, transportation engineering, construction, or engineering mechanics. Students may be co-enrolled in a degree and certificate seeking program, and courses taken as a certificate seeking student may be counted towards a graduate degree.

Students in the **Master of Science** (M.S.) degree in architectural engineering program can specialize in mechanical/energy systems, lighting/electrical systems, building structures, or construction, or a hybrid such as sustainable buildings, acoustics, or fire protection. M.S. ARCE students often have bachelor degrees from other engineering disciplines.

The **M.S.** degree programs in civil and architectural engineering include a **Design Option**, which can be completed in 2 semesters of full-time study. Students in the Design Option take 4 regular academic courses each semester and work together as a consulting group on the design of a major engineering project. The Design Option is open to students in all areas of interest. Students in the Design Option must start in the fall semester and complete 15 credit hours, including the design project, in the fall and spring semesters. The M.S. degree programs also offer

a **Coursework-only Option** which requires the completion of 30 credit hours of coursework. This option does not require a thesis, special problem investigation, or a final oral examination.

The **Master of Civil Engineering** degree provides a coursework-only option for working professionals who do not need the research component of the M.S. degrees. The M.C.E. degree may be completed by taking courses offered during evening hours.

The interdisciplinary **Master of Science** degree in environmental & water resources science is intended primarily for students with baccalaureate degrees in fields other than engineering.

The **Master of Construction Management** is a professional non-thesis degree for part-time or full-time students. Graduate courses in construction management (CMGT) are taught in the evening.

The department's doctoral degrees are the **Doctor of Philosophy** degrees in civil engineering, environmental & water resources engineering, and environmental & water resources science. Most doctoral students hold M.S. degrees, but direct admission to a doctoral program is possible for especially well-qualified engineering B.S. holders.

Courses

ARCE 101. Introduction to Architectural Engineering. 2 Credits.
An introduction to the study of and careers in architectural engineering, including building structures, building mechanical systems, building electrical systems, and construction management. Topics include problem solving and study skills, the building design and construction process, design documents, and professional practice issues such as licensing requirements and ethics.

ARCE 217. Computer-Assisted Building Design. 3 Credits.
Introduction to computer-aided design (CAD) tools. The course covers 2D drafting and 3D modeling using Autodesk's AutoCAD® and building information modeling (BIM) software Revit®. Includes architectural and structural design; mechanical, electrical, and plumbing (MEP) design; and modeling using the Family Editor in Revit. Prerequisite: Must be eligible for MATH 125 or MATH 145, or consent of instructor.

ARCE 315. Electric Circuits and Machines. 3 Credits.
Introduction to DC and AC electrical circuit analysis techniques, AC power calculations, transformers, three-phase systems, magnetic circuits, and DC and AC machines with a focus on applications. Not open to electrical or computer engineering majors. Prerequisite: A course in differential equations and eight hours of physics.

ARCE 350. Building Materials Science. 3 Credits.
An introduction to the structural, thermal, electrical, and optical properties of building materials. Manufacturing, testing, integration, and specification of materials with emphasis on commercial, institutional, and industrial buildings. Prerequisite: PHSX 212 and CHEM 150 or CHEM 149, or consent of instructor.

ARCE 351. Building Materials Science, Honors. 3 Credits.
An introduction to the structural, thermal, electrical, and optical properties of building materials. Manufacturing, testing, integration, and specification of materials with emphasis on commercial, institutional, and industrial buildings with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, and presentations. Prerequisite: PHSX 212 and CHEM 150 or CHEM 149, or consent of instructor.

ARCE 460. Building Thermal Science. 3 Credits.
The fundamentals of moist air processes, air and moisture exchange, and building heat transfer. Determination of heating and cooling loads under steady-state and transient conditions. Prerequisite: ME 212. Corequisite: CE 330 OR ME 510 OR AE 345 OR C&PE 511; or consent of instructor

ARCE 462. Building Thermal Science, Honors. 3 Credits.
The fundamentals of moist air processes, air and moisture exchange, and building hear transfer. Determination of heating and cooling loads under steady-state and transient conditions with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, and presentations. Prerequisite: ME 212. Corequisite: CE 330 or ME 510 or AE 345 or C&PE 511; or consent of instructor.

ARCE 490. Special Problems. 1-3 Credits.
Special problems in architectural engineering. The study of a particular problem involving individual research and report. Prerequisite: Students must submit, in writing, a proposal including a statement of the problem the student wishes to pursue, the methodology the student plans to use in the program, and objectives of the special problems. The student must also have a signed agreement with the faculty member proposed as instructor for the course. Consent of the instructor.

ARCE 491. Honors Research. 3 Credits.
Research a particular architectural engineering problem. Research will involve defining the problem, developing a research methodology, applying the research methodology and gathering data, analyzing and interpreting the data, and presenting the results of the research. The student must have a faculty sponsor and submit a proposal in writing stating the objective of the research, the planned research method that will be used, and the method of reporting the results. Prerequisite: Participation in the University Honors Program, consent of instructor, and approval of the chair are required.

ARCE 520. Architectural Acoustics. 3 Credits.
An introduction to the physics of sound. Objective and subjective evaluation and control of sound as applied to architectural spaces. Room shaping, mechanical and electrical system noise and vibration control, and electro-acoustic sound reinforcement. May not be taken for credit by students with credit for ARCE 520, ARCE 720, or ARCH 720. (Same as ARCH 520.) Prerequisite: Junior or Senior students or consent of instructor.

ARCE 521. Electro-Acoustical Systems. 3 Credits.
A study of electro-acoustic sound reinforcement and reproduction systems for buildings. May not be taken for credit by students with credit for ARCE 521, ARCE 721, or ARCH 721. (Same as ARCH 521.) Prerequisite: Junior/Senior standing or consent of instructor.

ARCE 540. Power Systems Engineering I. 3 Credits.
This course introduces the design of commercial and industrial power systems. Emphasis is placed on the proper selection, specification, and installation of materials and equipment that comprise commercial and industrial power systems. This course covers the application of materials and equipment in accordance with industry standards, independent laboratory testing, and the National Electrical Code. Prerequisite: ARCE 315 or EECS 315 or consent of instructor.

ARCE 541. Power Systems Engineering II. 3 Credits.
A continuation of ARCE 540 that integrates system components into functional, safe, and reliable power distribution systems for commercial, industrial, and institutional (CII) facilities. Service entrance design, distribution system layout and reliability, emergency and standby power system design, medium-voltage distribution systems, symmetrical fault analysis, and special equipment and occupancies. (Same as EECS 441.) Prerequisite: ARCE 540 or EECS 212 and Upper-Level EECS Eligibility.

ARCE 542. Power System Protection. 3 Credits.

This course introduces techniques and methods used to analyze and predict the performance of commercial and industrial power systems and equipment under balanced and unbalanced fault conditions. Emphasis is placed on the selection, application, and coordination of protective devices to detect and clear power system faults in a safe and reliable manner. Prerequisite: ARCE 540 or EECS 212 or consent of instructor.

ARCE 545. Electric Energy Production and Storage. 3 Credits.
An introduction to the design of utility scale and small scale (distributed generation) electric energy production and storage systems. This course addresses the technical, operational, economic, and environmental characteristics associated with both traditional and nontraditional electric energy production systems along with associated grid integration, energy delivery, and regulatory issues. Traditional energy production systems covered include fossil fuel, hydroelectric, and nuclear power plants. Non-traditional energy productions systems covered include fuel cells, photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, and other emerging technologies. (Same as EECS 545.) Prerequisite: ARCE 540, or EECS 212 and Upper-Level EECS Eligibility.

ARCE 547. Power System Analysis. 3 Credits.
Introduction to the analysis of commercial, industrial, and utility power systems. Emphasis is placed on modeling system components which include transmission and distribution lines, transformers, induction machines, and synchronous machines and the development of a power system model for analysis from these components. System modeling will be applied to short-circuit studies and used to analyze symmetrical faults, to develop sequence networks using symmetrical components, and analyze unsymmetrical faults. (Same as EECS 547.) Prerequisite: ARCE 540, or EECS 212 and Upper-Level EECS Eligibility.

ARCE 550. Illumination Engineering. 3 Credits.
Students are introduced to lighting fundamentals, measurement, and technology and to their application in the analysis and design of architectural lighting systems. Prerequisite: PHSX 212 or consent of instructor.

ARCE 560. HVAC&R Systems Design. 3 Credits.
Analysis and design of heating, ventilating, air-conditioning, and refrigeration equipment and systems. Prerequisite: ARCE 460 or ARCE 462 or consent of the instructor.

ARCE 561. HVAC&R Systems Design, Honors. 3 Credits.
Analysis and design of heating, ventilating, air-conditioning, and refrigeration equipment and systems. The discussion section and its assignments are required. Not open for those with credit for ARCE 560. Prerequisite: ARCE 460 or ARCE 462, and either acceptance into the KU Honors Program or consent of the instructor.

ARCE 562. Water Systems Design. 3 Credits.
The analysis and design of hydronic systems for buildings including piping, plumbing, pumping, and the water-side of heating, ventilating, and air-conditioning (HVAC). Prerequisite: ME 510, AE 345, CE 330, or C&PE 511, or consent of the instructor.

ARCE 563. Energy Management. 3 Credits.
Energy usage in commercial buildings and industry, energy auditing methodology, utility analysis, management measures, and economic evaluation are covered. Includes fieldwork. Prerequisite: Corequisite: ARCE 460 or ARCE 462, or consent of instructor.

ARCE 565. Solar Energy Systems Design. 3 Credits.
A quantitative and qualitative study of active, passive, wind, and photovoltaic energy conversion systems for buildings. Solar radiation and system performance prediction. Prerequisite: ME 212 or C&PE 221, or consent of instructor.

ARCE 566. Fire Protection Engineering. 3 Credits.
An introduction to human response, fire science, combustion calculations, compartment fires, piping and sprinkler design, and smoke management. Analytical methods, experimental data, codes, case-studies, and videos are presented in this engineering design course. Prerequisite: ME 212 or C&PE 221, and ME 510, AE 345, CE 330, or C&PE 511, or consent of instructor.

ARCE 598. Comprehensive Design Project. 3 Credits.
Capstone architectural engineering design course that includes the analysis, design, and integration of a building's structural, mechanical, electrical, and lighting systems. Building codes, standards, performance, and sustainability are addressed, and BIM software utilized. Prerequisite: CMGT 457 or CMGT 500, or ARCE 520, or ARCE 540 and ARCE 550, or ARCE 460 or ARCE 462, or CE 562 or CE 563.

ARCE 720. Architectural Acoustics. 3 Credits.
An introduction to the physics of sound. Objective and subjective evaluation and control of sound as applied to architectural spaces. Room shaping, mechanical and electrical system noise and vibration control, and electro-acoustic sound reinforcement. May not be taken for credit by students with credit in ARCH 520/ARCE 520/ARCE 720. (Same as ARCH 720.)

ARCE 721. Electro-Acoustical Systems. 3 Credits.
A study of electro-acoustic sound reinforcement and reproduction systems for buildings. May not be taken for credit by students with credit in ARCH 521/ARCE 521/ARCE 721. (Same as ARCH 721.)

ARCE 740. Power Systems Engineering I. 3 Credits.
This course introduces the design of commercial and industrial power systems. Emphasis is placed on the proper selection, specification, and installation of materials and equipment that comprise commercial and industrial power systems. This course covers the application of materials and equipment in accordance with industry standards, independent laboratory testing, and the National Electrical Code. May not be taken for credit by students with credit for CE 540. Prerequisite: ARCE 315 or EECS 315 or equivalent, or consent of instructor.

ARCE 741. Power Systems Engineering II. 3 Credits.
A continuation of ARCE 740 that integrates system components into functional, safe, and reliable power distribution systems for commercial, industrial, and institutional (CII) facilities. Service entrance design, distribution system layout and reliability, emergency and standby power system design, medium-voltage distribution systems, symmetrical fault analysis, and special equipment and occupancies. May not be taken for credit by students with credit in ARCE 541. Prerequisite: ARCE 740, or consent of the instructor.

ARCE 742. Power System Protection. 3 Credits.
This course introduces techniques and methods used to analyze and predict the performance of commercial and industrial power systems and equipment under balanced and unbalanced fault conditions. Emphasis is placed on the selection, application, and coordination of protective devices to detect and clear power system faults in a safe and reliable manner. May not be taken for credit by students with credit in ARCE 542. Prerequisite: ARCE 740, or consent of instructor.

ARCE 745. Electric Energy Production and Storage. 3 Credits.
An introduction to the design of utility scale and small scale (distributed generation) electric energy production and storage systems. This course addresses the technical, operational, economic, and environmental characteristics associated with both traditional and nontraditional electric energy production systems along with associated grid integration, energy delivery, and regulatory issues. Traditional energy production systems covered include fossil fuel, hydroelectric, and nuclear power plants.

Non-traditional energy productions systems covered include fuel cells, photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, and other emerging technologies. May not be taken for credit by students with credit in ARCE 545. Prerequisite: ARCE 740, or consent of instructor.

ARCE 747. Power System Analysis. 3 Credits.
An introduction to the analysis of commercial, industrial, and utility power systems. Emphasis is placed on modeling system components which include transmission and distribution lines, transformers, induction machines, and synchronous machines and the development of a power system model for analysis from these components. System modeling will be applied to short-circuit studies and used to analyze symmetrical faults, to develop sequence networks using symmetrical components, and analyze unsymmetrical faults. May not be taken for credit by students with credit in ARCE 547. Prerequisite: ARCE 740, or consent of instructor.

ARCE 750. Daylighting. 3 Credits.
This course will cover daylighting design concepts, solar position, daylight availability, sky luminance distribution models, daylight delivery methods, integration of daylighting and electric lighting controls, physical modeling, and computer analysis techniques. Prerequisite: PHSX 212, or ARCH 531, or consent of instructor

ARCE 751. Advanced Lighting Design. 3 Credits.
Advanced analysis, design, and modeling of luminous environments. It covers impact of lighting on human perception and interaction with space, human factors in lighting, camera-aided light measurement technologies, advanced computer-aided lighting simulations, effective and efficient integration of natural and artificial lighting, modeling and analysis of light sources and spaces, simulation of lighting systems, and design of lighting control systems. Prerequisite: ARCE 217 and ARCE 650 or consent of instructor.

ARCE 752. Lighting Measurement and Design. 3 Credits.
This course will cover conventional lighting and solid-state lighting measurement, daylighting measurement, camera-aided lighting measurement technologies and applications, and design and development of custom luminaries in an LED workshop and innovative daylighting devices. Prerequisite: ARCE 650, or consent of instructor

ARCE 762. Water Systems Design. 3 Credits.
The analysis and design of hydronic systems for buildings including piping, plumbing, pumping, and the water-side of heating, ventilating, and air-conditioning (HVAC). May not be taken for credit by students with credit in ARCE 562. Prerequisite: ME 510, AE 345, CE 330, or C&PE 511, or equivalent, or consent of instructor.

ARCE 764. Advanced Thermal Analysis of Buildings. 3 Credits.
Manual and computational methods for determining steady-state and transient thermal loads in buildings. Advanced analysis of energy consumption given choices in building materials and mechanical systems. Prerequisite: ARCE 217 and ARCE 660 or ARCE 670; or consent of instructor.

ARCE 766. Fire Protection Engineering. 3 Credits.
An introduction to human response, fire science, combustion calculations, compartment fires, piping and sprinkler design, and smoke management. Analytical methods, experimental data, codes, case-studies, and videos are presented in this engineering design course. May not be taken for credit by students with credit in ARCE 566. Prerequisite: ME 212 or C&PE 331, and ME 510 or AE 345 or CE 330 or C&PE 511, or consent of instructor.

ARCE 767. Building Energy Modeling. 3 Credits.
This course introduces the basics and tools for building energy modeling. It covers the basic concepts and principles of building energy modeling, building energy analysis with whole building performance simulation tool EnergyPlus, and building energy systems and controls modeling with Modelica. Prerequisite: ARCE 560 or ARCE 561, or consent of instructor.

ARCE 891. Advanced Special Problems. 1-3 Credits.
A directed study of a particular complex problem in an area of architectural engineering or allied field. Prerequisite: Varies by topic, or with consent of instructor.

ARCE 895. Master's Project. 1-3 Credits.
Directed study and reporting of a specialized topic of interest to the architectural engineering profession. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

ARCE 899. Master's Thesis. 1-6 Credits.
Directed research and reporting of a specialized topic of interest to the architectural engineering profession. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

Courses

CE 101. Introduction to Civil and Environmental Engineering. 2 Credits.
An introduction to the study of and careers in civil and environmental engineering, including structural engineering, transportation engineering, geotechnical engineering, construction management, water resources engineering, and environmental design and sustainability. Topics include problem solving and study skills, the engineering design and construction process, design documents, and professional practice issues such as licensing requirements and ethics.

CE 191. Introduction to Civil Engineering. 2 Credits.
A discussion of engineering logic through examination of current concepts in engineering education, practice and professional development. Not open to juniors and seniors.

CE 201. Statics. 2 Credits.
The principles of statics, with particular attention to engineering applications. Prerequisite: EPHX 210 or PHSX 210 or PHSX 211 or PHSX 213 or PHSX 201, and MATH 125 or MATH 145 or MATH 116.

CE 240. Geomatics. 3 Credits.
This course introduces engineering applications of surveying and geographic information systems GIS) using surveying instruments and ArcGIS. The focus of this course is on practical application of geomatics to civil engineering problems. Two lectures periods and one lab period per week. Prerequisite: MATH 125 or MATH 145 or MATH 116; ARCE 217; or consent of instructor.

CE 250. Dynamics. 3 Credits.
The principles of kinematics and kinetics, with particular attention to engineering applications. Prerequisite: CE 201 or ME 201 or ME 211, and MATH 126 or MATH 146.

CE 260. Statics and Dynamics. 5 Credits.
A combination of statics and dynamics covered in CE 201 and CE 250. This course must be taken as a five-hour unit. Prerequisite: EPHX 210 OR PHSX 210 or PHSX 211 or PHSX 213 or PHSX 201, and MATH 126 or MATH 146.

CE 310. Strength of Materials. 3 Credits.
Principles of stress and deformation in solid objects. Prerequisite: CE 201 or CE 260 or ME 201 or ME 211. Corequisite: MATH 220 or MATH 221; or consent of instructor.

CE 312. Strength of Materials, Honors. 3 Credits.
Principles of stress and strain in solid objects with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects,

and presentations. Prerequisite: CE 201 or CE 260 or ME 201 or ME 211. Corequisite: MATH 220 or MATH 221; or consent of instructor.

CE 320. Numerical Methods for Civil Engineering. 3 Credits.
This course covers basic concepts of computational methods including; errors and accuracy; matrix operations; eigenvalues and vectors; numerical solution of non-linear equations; iterative methods for solving systems of linear algebraic equations; interpolation and numerical differentiation and integration. This is all done within a Python programming framework as students solve problems within a Civil Engineering context. Prerequisite: MATH 126 or MATH 146.

CE 330. Fluid Mechanics. 3 Credits.
This course covers the fundamentals of fluid mechanics and includes the topics fluid properties, hydrostatics, applications of conservation of mass, energy and momentum equations, pipe flow, dimensional analysis and open channel flow. Prerequisite: ENGL 101 or ENGL 102 or ENGL 105 or have an English ACT score of 27 or higher or a Verbal SAT score of 600 or higher and CE 250 or CE 260.

CE 331. Fluid Mechanics Lab. 1 Credits.
This is an experimental course that consists of several laboratory experiments intended to illustrate the concepts presented in CE 330, Fluid Mechanics. Prerequisite: ENGL 101 or ENGL 102 or ENGL 105 or have an English ACT score of 27 or higher or a Verbal SAT score of 600 or higher, and CE 250 or CE 260. Corequisite: CE 330.

CE 412. Structural Engineering Materials. 3 Credits.
Study of the engineering properties of structural materials and their control with emphasis on timber, concrete, and steel. Two one-hour lectures and one three-hour laboratory. Prerequisite: CE 310 or CE 312 and ENGL 102 or ENGL 105; or consent of instructor.

CE 413. Structural Engineering Materials, Honors. 3 Credits.
Study of the engineering properties of structural materials and their control with emphasis on timber, concrete, and steel. Two one-hour lectures and one three-hour laboratory. Prerequisite: CE 310 or CE 312 and ENGL 102 or ENGL 105. Open only to students admitted to the University Honors Program or by consent of instructor.

CE 455. Hydrology. 3 Credits.
An introduction to the fundamentals of hydrologic analysis. Subjects covered include collection and initial reduction of hydrologic data; rainfall-runoff relationships, hydrograph development; hydrologic routing, well equations and their application and hydrologic frequency analysis. Prerequisite: ENGL 101, ENGL 102 or ENGL 105. Co or pre-requisite: CE 330.

CE 461. Structural Analysis. 3 Credits.
Three one-hour lectures and one two-hour laboratory. Analysis of statically determinate and indeterminate beams, frames, and trusses using classical methods and introducing computer-based methods. Prerequisite: CE 310 or CE 312.

CE 477. Introduction to Environmental Engineering and Science. 3 Credits.
Application of fundamental scientific principles to the protection of atmospheric, aquatic, and terrestrial environments through the use of pollution abatement processes, with consideration also given to economic, social, political, and legal aspects of pollution control. Prerequisite: ENGL 102 or ENGL 105, MATH 101 or MATH 104, and CHEM 135 or CHEM 175 or CHEM 195 or CHEM 149 or CHEM 150.

CE 479. Introduction to Environmental Engineering and Science, Honors. 3 Credits.
Application of fundamental scientific principles to the protection of atmospheric, aquatic, and terrestrial environments through the use of pollution abatement processes, with consideration also given to economic, social, political, and legal aspects of pollution control. Open only to students admitted to the University Honors Program or by consent of instructor. Prerequisite: ENGL 102 or ENGL 105, MATH 101 or MATH 104, and CHEM 135 or CHEM 175 or CHEM 195 or CHEM 150 or CHEM 149.

CE 480. Introduction to Transportation Engineering. 3 Credits.
Students are provided with a solid introduction to the principles of highway engineering and traffic analysis. This course will present a large number of practical problems, and in sufficient depth, such that the student will be capable of solving real highway-related problems. Prerequisite: CE 240.

CE 484. Materials for Transportation Facilities. 3 Credits.
Principles involved in the testing, behavior, and selection of materials for use in the transportation field. Emphasis is on bituminous materials, aggregate, and soil stabilization. Prerequisite: CE 310 or CE 312.

CE 485. Materials for Transportation Facilities, Honors. 3 Credits.
Principles involved in the testing, behavior, and selection of materials for use in the transportation field. Emphasis is on bituminous materials, aggregate, and soil stabilization with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, presentations, and lab activities. Prerequisite: CE 310 or consent of instructor.

CE 487. Soil Mechanics. 4 Credits.
Three lecture periods and one laboratory period. Fundamental theories of soil mechanics and their applications in engineering. Prerequisite: CE 310 or CE 312, corequisite or prerequisite CE 330.

CE 490. Special Problems. 1-5 Credits.
An advanced study related to a special problem in the field of civil engineering or allied fields, for upper-division undergraduate students.

CE 495. Special Topics: _____. 1-3 Credits.
A course or colloquium to present topics of special interest. Prerequisite: Varies by topic.

CE 497. Extended Topics: _____. 1 Credits.
An extension of specific CE courses in order to meet transitional degree requirements. This course does not meet the CE technical elective requirements or the ARCE engineering science/engineering design elective. Prerequisite: Varies by topic or with consent of instructor.

CE 501. Engineering Ethics. 2 Credits. AE51
An examination of the ethical and social implications of being a professional engineer. Through the use of case studies, issues such as professional responsibility to clients, employers, and the public will be evaluated in light of professional codes of ethics. Prerequisite: Junior or Senior standing.

CE 525. Applied Probability and Statistics. 3 Credits.
Course topics include data description, measures of central tendency and dispersion, sampling and sampling designs, quality control, persistence, periodicity, sampling distributions, hypothesis testing, ANOVA, correlation, linear regression, multiple correlation, and multiple regression. Applications and real world problems are stressed. This course is offered at the 500 and 700 level with additional assignments at the 700 level. May not be taken for credit by students with credit in CE 725. Prerequisite: MATH 125 or MATH 145 or MATH 116.

CE 535. Engineering Applications of GIS. 3 Credits.
This course introduces engineering applications of geographic information system (GIS) using ArcGIS. The focus of this course is on practical application of GIS to civil engineering problems. Prerequisite: Junior or Senior standing, or consent of instructor.

CE 550. Life Cycle Assessment. 3 Credits.

Life cycle assessment (LCA) is a tool used across engineering fields to determine the life cycle, cradle-to-grave environmental impacts of a product or process. LCA practice helps develop a systems-thinking perspective and a deeper understanding of sustainability. Students will evaluate LCA methods and design appropriate LCA frameworks. Prerequisite: CE 477 or CE 479 or C&PE 211.

CE 552. Water Resources Engineering Design. 3 Credits.
Three one-hour lectures and one three-hour laboratory. Study of water resources structures and systems with design emphasis on the hydraulic features: dams, drainage, river engineering, pipelines, channels and hydraulic machinery. Prerequisite: CE 330 and CE 455.

CE 555. Open Channel Flow. 3 Credits.
Study of uniform and non-uniform steady flow of water in open channels, including backwater curves, the hydraulic jump, and the delivery of canals. Prerequisite: CE 330 or equivalent.

CE 562. Design of Steel Structures. 3 Credits. AE61 CAP
Two one-hour lectures and one three-hour laboratory. Fundamentals of structural design with steel. Prerequisite: CE 461.

CE 563. Design of Reinforced Concrete Structures. 3 Credits.
Fundamentals of structural design with reinforced concrete. Prerequisite: CE 461 and CE 412 or CE 413 or CE 484 or ARCE 350; or consent of the instructor.

CE 570. Concepts of Environmental Chemistry. 3 Credits.
The fundamentals of aquatic chemistry, with emphasis on application to water purification and wastewater treatment. Prerequisite: Undergraduate standing, CE 477 or CE 479, and MATH 115 or MATH 125 or MATH 145.

CE 571. Environmental Engineering Laboratory. 3 Credits.
A laboratory course introducing standard practices for measurement, analysis, and reporting of environmental data. Emphasis is placed on learning common analytical techniques used in environmental engineering and science. Prerequisite: Undergraduate standing, CE 477 or CE 479 or equivalent, and MATH 115 or MATH 125 or MATH 145.

CE 573. Biological Principles of Environmental Engineering. 3 Credits.
A basic study of the microorganisms of importance in environmental engineering. Emphasis is placed on the microbiology of dilute nutrient solutions. Microbial physiology, microbial ecology, and biochemistry will be discussed as they pertain to environmental engineering and science. Both biodegradation and public health aspects are included. Prerequisite: Undergraduate standing, CE 477 or CE 479 or equivalent, and MATH 115 or MATH 125 or MATH 145.

CE 574. Design of Air Pollution Control Systems. 3 Credits.
This course emphasizes understanding of air pollution problems and their solution through engineering design and science. Topics covered include: types of air pollutants; monitoring of air pollutants; transport of air pollutants in the atmosphere; and control of air pollution emissions from both stationary and mobile sources. Prerequisite: CE 330, CE 477 or CE 479, MATH 126 or MATH 146, PHSX 212; or consent of instructor.

CE 576. Municipal Water Supply and Wastewater Treatment. 3 Credits. AE61 CAP
The principles of public water supply design, including source selection, collection, purification, and distribution; for municipal wastewater, collection, treatment, and disposal. Prerequisite: CE 330 or C&PE 511, CE 477 or CE 479.

CE 582. Highway Engineering. 3 Credits.
A comprehensive study of the planning, design, construction, operations, and maintenance of highway systems with emphasis on the design aspects of a highway. Prerequisite: CE 455 and CE 480.

CE 588. Foundation Engineering. 3 Credits.
A study of the interaction of the characteristics of soil or rocks and structures. The estimation of settlement and bearing capacity of foundation elements. Principles governing the choice and design of footings, rafts, piers, and piles. Prerequisite: CE 487.

CE 677. Graduate Fundamentals of Environmental Engineering. 3 Credits.
Application of fundamental scientific principles to the protection of atmospheric, aquatic, and terrestrial environments through the use of pollution abatement processes, with consideration also given to economic, social, political, and legal aspects of pollution control. May not be taken for credit by students with credit in CE 477. Prerequisite: ENGL 102 or ENGL 105, MATH 101 or MATH 104, and CHEM 135 or CHEM 175 or CHEM 150.

CE 684. Materials for Transportation Facilities. 3 Credits.
Principles involved in the testing, behavior, and selection of materials for use in the transportation field. Emphasis is on bituminous materials, aggregate, and soil stabilization. Readings. Prerequisite: CE 310 and CE 487.

CE 701. Engineering Ethics. 3 Credits.
An examination of the ethical and social implications of being a professional engineer and doing engineering research. Through the use of case studies, issues such as professional responsibility to clients, employers, and the public will be evaluated in light of professional codes of ethics. May not be taken for credit by students with credit in CE 501. Prerequisite: Graduate standing.

CE 704. Dynamics and Vibrations. 3 Credits.
Problems in engineering dynamics and vibrations. Topics include applications of generalized forces and coordinates, Lagrange equations, and a study of the performance of single and multiple degree of freedom in vibrational systems. (Same as AE 704.) Prerequisite: AE 508 or AE 509 or CE 461 or ME 628.

CE 710. Structural Mechanics. 3 Credits.
Basic concepts in the analysis of stress and strain and the behavior of materials. Topics include elementary theory and problems in elasticity, theories of failure of materials including fracture mechanics and introduction to plasticity.

CE 711. Probabilistic Design and Reliability. 3 Credits.
Learn to evaluate statistical data and develop engineering design criteria for natural and man-made random phenomena. Develop and be able to use material or system fragility curves. Analyze complex systems or alternate system probabilities using Monte Carlo Simulation. Determine system reliability for statistically evaluated hazard probabilities. Techniques are applied to realistic design problems in Civil Engineering. Prerequisite: Graduate standing or permission of the instructor.

CE 712. Structural Engineering Materials. 3 Credits.
Study of the engineering properties of structural materials and their control with emphasis on timber, concrete, and steel. Two one-hour lectures and one three-hour laboratory. Not open for credit to students with credit in CE 412 or CE 413. Prerequisite: CE 310 or CE 312 or equivalent, and ENGL 102 or ENGL 105 or equivalent, or consent of instructor.

CE 713. Cold-formed Steel and Aluminum Design. 3 Credits.
Learn the principles of designing thin cold-formed and extruded materials. Focus is on cold-formed-steel with basic application to aluminum and concepts of curtainwall design. Load bearing and non-load bearing applications. Determine properties and strengths of columns and beams composed of arbitrary formed shapes. Learn to apply Direct Design.

Seismic and wind design of cold formed steel structures. Prerequisite: CE 562.

CE 714. Professional Practice. 3 Credits.
This course is the business of engineering. Topics include: case studies of design and construction litigation, proposals and contracts, managing risk and liability, principles of management and leadership, developing professional relationships, developing a quality culture, project and design accounting, errors and omissions, insurance, organizational structures, globalization, total quality management, and communications. Class participation is required. Prerequisite: Graduate standing or permission of the instructor.

CE 715. Corrosion Engineering. 3 Credits.
Electrochemical basis of corrosion. Estimating probability and rate of corrosion. Identifying different conditions likely to cause specific types of corrosion. Corrosion mitigation techniques. Prerequisite: CHEM 135, CHEM 150 or equivalent.

CE 721. Experimental Stress Analysis. 3 Credits.
Introduction to experimental stress-analysis techniques. Theory and application of mechanical strain gages, electrical strain gages, photoelastic techniques, and brittle coatings.

CE 725. Applied Probability and Statistics. 3 Credits.
Course topics include data description, measures of central tendency and dispersion, sampling and sampling designs, quality control, persistence, periodicity, sampling distributions, hypothesis testing, ANOVA, correlation, linear regression, multiple correlation, and multiple regression. Applications and real world problems are stressed. This course is offered at the 500 and 700 level with additional assignments at the 700 level. May not be taken for credit by students with credit in CE 525. Prerequisite: MATH 125 or MATH 145 or MATH 116.

CE 730. Intermediate Fluid Mechanics. 3 Credits.
Fall semester. Principles of steady and unsteady flows, theories of potential, viscous, and turbulent flows, and applications in water resources engineering. Prerequisite: CE 330 and MATH 320.

CE 731. Applied Groundwater Modeling. 3 Credits.
This course focuses on how to construct simple to complex computer models of groundwater systems and systems in which water flows between groundwater and surface water bodies such as springs, streams and lakes. We consider water flow, transport of solutes, and density effects (from saltwater or brines). We consider the conjunctive use of groundwater and surface water (demand-driven, supply-limited problems), and managed aquifer recharge (MAR). We consider three aspects of model development: (1) how to compare the computer models we construct to the systems modelers intend them to represent, (2) how accurate the models are likely to be and how uncertainty can be quantified, and (3) how useful the models are in practice. (Same as GEOL 758.) Prerequisite: GEOL 751 or CE 752, or approved by the professor.

CE 735. Engineering Applications of GIS. 3 Credits.
This course introduces engineering applications of geographic information system (GIS) using ArcGIS. The focus of this course is on practical application of GIS to civil engineering problems.

CE 736. Environmental Monitoring and Field Methods. 3 Credits.
A lecture-laboratory-field sampling course to familiarize students with environmental monitoring techniques and open source data availability. Dimensions of environmental monitoring will be considered for air, soil, and water measurements. The major emphasis will be on surface water monitoring techniques and their principles, utility, and limitations. Prerequisite: CE 330 or consent of instructor.

CE 747. Principles of Sustainability and Resilience. 3 Credits.
This course teaches the core competencies of sustainability and resilience regarding the built environment. The course focuses on fundamental concepts and how they can be applied in engineering and community planning practice. Prerequisite: Senior or graduate standing or permission of the instructor.

CE 749. Solid and Hazardous Wastes. 3 Credits.
Fundamental issues associated with solid and hazardous wastes are presented. Topics include government regulations, waste characteristics and quantities, the transport and attenuation of wastes in the environment, risk assessment, and handling, treatment and disposal techniques. Special emphasis is placed on hazardous waste remediation strategies in terrestrial systems. Prerequisite: Graduate standing in the Environmental Science and Engineering program, or consent of instructor.

CE 751. Physical Hydrology. 3 Credits.
In this course students will develop a land surface model based on the underlying physics and mechanisms of radiative transfer, precipitation, snow processes, evapotranspiration, infiltration and runoff generation. The course will also cover numerical and uncertainty issues associated with hydrologic modeling and its application to real world problems. Prerequisite: CE 455 or equivalent.

CE 752. Physical Hydrogeology. 3 Credits.
Study of fluid flow in subsurface hydrologic systems. Investigation of the ground water environment including porosity, and hydraulic conductivity and their relationship to typical geologic materials. Examination of Darcy's law and the continuity equation leading to the general flow equations. Discussion of typical hydraulic testing methods to estimate aquifer parameters in various situations and apply these to water resource problems. Study of the basic mechanisms that determine the behavior of typical regional flow systems. (Same as GEOL 751.)

CE 753. Chemical and Microbial Hydrogeology. 3 Credits.
Lecture and discussion of chemical and microbiological controls on groundwater chemistry. Topics include thermodynamic and microbiological controls on water-rock reactions; kinetics; and microbiological, chemical and isotopic tools for interpreting water chemistry with respect to chemical weathering and shallow diagenesis. Origins of water chemistry, changes along groundwater flow paths, and an introduction to contaminant biogeochemistry will be discussed through the processes of speciation, solubility, sorption, ion exchange, oxidation-reduction, elemental and isotopic partitioning, microbial metabolic processes and microbial ecology. An overview of the basics of environmental microbiology, including cell structure and function, microbial metabolism and respiration, microbial genetics and kinetics of microbial growth will be covered. (Same as GEOL 753.) Prerequisite: One year of chemistry, one year of calculus, one year of biology, an introductory course in hydrogeology, or consent of the instructors.

CE 754. Contaminant Transport. 3 Credits.
A study of the transport of conservative and non-conservative pollutants in subsurface waters. Case studies are used to illustrate and develop a conceptual understanding of such processes as diffusion, advection, dispersion, retardation, chemical reactions, and biodegradation. Computer models are developed and used to quantify these processes. (Same as GEOL 754.) Prerequisite: Introductory Hydrogeology or consent of instructor.

CE 755. Open Channel Flow. 3 Credits.
A study of uniform and non-uniform steady flow of water in open channels, including backwater curves, the hydraulic jump, and the delivery of canals. Prerequisite: CE 330.

CE 756. Wetlands Hydrology and Introduction to Management. 3 Credits.
A study of the basic structure and functions of wetlands; the physical, chemical, and biological processes involved; and an introduction to the management of wetlands. Also a brief introduction to the legal aspects of wetlands, the Section 404 permitting processes, and mitigation requirements. Prerequisite: Senior or graduate standing in engineering or a science area, or consent of instructor.

CE 757. Pipe-Flow Systems. 3 Credits.
Hydraulic analysis and design of pipelines, pipe networks, and pumping systems. Analysis and control of hydraulic transients. Engineering of water distribution systems. Prerequisite: CE 330 or equivalent.

CE 759. Water Quality Modeling. 3 Credits.
Analytical and numerical modeling of transport and transformation processes in the aquatic environment. Mass balance principles in multi-dimensional transport phenomena including advection, turbulent diffusion, and dispersion. Prerequisite: CE 330, MATH 127 or MATH 147, and MATH 220 or MATH 221 or equivalent.

CE 760. Stochastic Hydrology. 3 Credits.
This methods-based course includes probability models, parameter estimation, ensemble forecasting and verification, time series analysis, multivariate distributions, principal component analysis along with other stochastic methods imperative to hydrologic analysis and prediction. The application of these methods will be explored through examples in hydrology related to rainfall, streamflow, groundwater and land-atmosphere interactions. Prerequisite: CE 455, MATH 290 or MATH 291 or equivalent.

CE 761. Matrix Analysis of Framed Structures. 3 Credits.
Analysis of 2-D and 3-D frame and truss structures by the direct stiffness method. Computer techniques required to implement the analysis procedure.

CE 763. Design of Prestressed Concrete Structures. 3 Credits.
The theory and design of prestressed concrete structures based on service load and strength criteria. Prerequisite: CE 563.

CE 764. Advanced Design of Reinforced Concrete Structures. 3 Credits.
The theory and design of reinforced concrete members and structures with emphasis on frames and slabs. Introduction to bridge design and earthquake design. Prerequisite: CE 563.

CE 765. Advanced Steel Design - Building Structures. 3 Credits.
The theory and design of standard steel framed structures (primarily buildings). Design philosophies, stability, composite design, structural behavior, preliminary design, and connections. Prerequisite: CE 562 or equivalent.

CE 766. Advanced Steel Design - Bridge Structures. 3 Credits.
Introduction to simple plastic design principles. Analysis and design of steel bridges including composite and noncomposite plate girders, curved girders, box girders, and other specialized bridge types. Fatigue and connection design considered. Prerequisite: CE 562 or equivalent.

CE 767. Introduction to Fracture Mechanics. 3 Credits.
Theories and modes of structural failure as related to structural design. Application of fracture mechanics to failure analysis, fracture control plans, fatigue crack growth, and stress-corrosion crack growth. Prerequisite: CE 310 or CE 312 plus a structural or mechanical design course.

CE 768. Design of Timber Structures. 3 Credits.
Provide an introduction to behavior, analysis and design of timber components and systems. Prerequisite: CE 461.

CE 769. Design of Masonry Structures. 3 Credits.
Provide an introduction to behavior, analysis and design of masonry components and systems. Prerequisite: CE 461.

CE 770. Concepts of Environmental Chemistry. 3 Credits.
The fundamentals of aquatic chemistry, with emphasis on application to water purification and wastewater treatment. May not be taken for credit by students with credit in CE 570. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and five hours of chemistry.

CE 771. Environmental Engineering Laboratory. 3 Credits.
A laboratory course introducing standard practices for measurement, analysis, and reporting of environmental data. Emphasis is placed on learning common analytical techniques used in environmental engineering and science. May not be taken for credit by students with credit in CE 571. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and five hours of chemistry.

CE 772. Physical Principles of Environmental Engineering Processes. 3 Credits.
Physical principles of suspensions, kinetics, fluid flow, filtration, and gas transfer are applied to various environmental physical processes. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and four hours of physics.

CE 773. Biological Principles of Environmental Engineering. 3 Credits.
A basic study of the microorganisms of importance in environmental engineering. Emphasis is placed on the microbiology of dilute nutrient solutions. Microbial physiology, microbial ecology, and biochemistry will be discussed as they pertain to environmental engineering and science. Both biodegradation and public health aspects are included. May not be taken for credit by students with credit in CE 573. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and five hours of chemistry.

CE 774. Chemical Principles of Environmental Engineering Processes. 3 Credits.
Chemical principles of stoichiometry, thermodynamics, and kinetics are applied to various chemical processes having application in the field of environmental engineering and science, including adsorption, ion exchange, coagulation, oxidation, and precipitation. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and credit or registration in CE 570 or CE 770.

CE 775. Stormwater Treatment Systems Design. 3 Credits.
This course will address the design of stormwater treatment systems to provide hydrological control and water quality improvement. Specific topics include common stormwater pollutants, contaminant loading during storm events, design of structural BMPs (detention basins, traps, filters, and vegetated control systems) and low impact development practices. Prerequisite: CE 477 or CE 479, either CE 455 or C&PE 511 or consent of instructor.

CE 776. Water Reuse. 3 Credits.
This course addresses past and current water reclamation and reuse practices; health and environmental concerns associated with water reuse; technologies and systems for water treatment, reclamation, and reuse; water reuse applications, including agricultural reuse, direct and indirect potable reuse, landscape irrigation, industrial uses, urban non-irrigation applications, environmental and recreational uses, and groundwater recharge; and planning and implementation of water reuse systems. Prerequisite: CE 477 or CE 479 or equivalent.

CE 777. Industrial Water and Wastes. 3 Credits.
A review of the methods of industrial water treatment and the fundamentals of industrial wastewater pollution control. Topics include: water budgets, cooling tower and boiler treatment, corrosion control,

government regulations, wastewater characterization, waste minimization, pilot plants, pretreatment, final treatment, and site selection. May not be taken for credit by students with credit in CE 577. Prerequisite: CE 477 or CE 479 or equivalent.

CE 778. Air Quality. 3 Credits.
The course is intended to provide a working knowledge of pollutant sources, effects, meteorological factors, measurements, modeling approaches, legislation and controls associated with air quality problems. Students work on problems drawn from typical industrial situations, and use models to address specific air pollution scenarios. Prerequisite: CE 477 or CE 479 or equivalent, and MATH 115 or MATH 125 or MATH 145.

CE 781. Traffic Engineering Characteristics. 3 Credits.
A study of fundamental traits and behavior patterns of the road user and his or her vehicle in traffic. The major content involves techniques for obtaining data, analyzing data and interpreting data on traffic speed, volume, streamflow, parking and accidents. Capacity analyses using the most up to date procedures for major traffic facilities such as undivided highways, city streets, freeways, interchanges and intersections are also discussed at length. Prerequisite: CE 582 or equivalent.

CE 786. Highway Safety. 3 Credits.
Several topics dealing with highway safety are presented and discussed. Typical topics are railroad/highway crossings, accident reconstruction, distractions to the drivers, speed and crashes, elderly drivers, traffic control devices, roadside design, access management, traffic calming devices, and crash rates.

CE 787. Advanced Soil Mechanics. 3 Credits.
A comprehensive study of soil behavior. Topics include stress-strain behavior for soils under a variety of loading conditions, critical state soil mechanics theory, consolidation prediction, modeling subsurface water flow, and other topics. Prerequisite: CE 487 or equivalent.

CE 788. Geotechnical Engineering Testing. 3 Credits.
Three lectures. Field testing techniques, sampling methods, and laboratory testing procedures used to determine soil properties for engineering projects. Prerequisite: CE 487.

CE 790. Traffic Simulation Modeling and Analysis. 3 Credits.
This course introduces popular tools for modeling, analyzing and optimizing various transportation elements. Students will learn to formulate and apply basic principles of simulation modeling; use simulation and optimization techniques for improving traffic operations of a signalized intersection, an urban street network, and a freeway facility; and apply processes for developing simulation applications. Prerequisite: CE 781 or equivalent, or consent of instructor.

CE 799. Graduate Internship. 1-3 Credits.
An applied course intended to provide a practical educational opportunity which prepares students for professional practice in the fields of civil, environmental, and/or architectural engineering and any sub-discipline therein. Prerequisite: Graduate standing and department approval required to enroll.

CE 801. Energy Methods. 3 Credits.
The methods of analysis by energy methods of mechanics problems. Includes variational energy principles, calculus of variations, stationary energy and complementary energy principles, and the principle of virtual work. Applications. Prerequisite: CE 310 or CE 312 and MATH 320.

CE 804. Advanced Structural Dynamics. 3 Credits.
Advanced topics in structural dynamics, including experimental modal analysis, digital signal processing, data acquisition and analysis, random vibration concepts, system identification, structural health monitoring and damage detection, and introduction to smart structures technology (e.g. smart sensing, estimation, and control). This course provides practical laboratory experience through state-of-the-art commercial testing equipment and software. Prerequisite: CE 704 or consent of instructor.

CE 810. Theory of Elastic Stability. 3 Credits.
Buckling of columns in the elastic or hyperelastic region. Lateral and torsional buckling of straight and curved members. Buckling of plates and shells.

CE 815. Viscoelasticity of Solids. 3 Credits.
This course provides the basics of mechanical and mathematical modeling and characterization of linear viscoelastic materials. Topics include different viscoelastic models, experimental methods for characterization of viscoelastic materials, design methods for viscoelastic members, and introduction to temperature effects and nonlinear viscoelastic response of materials. Prerequisite: CE 310 or CE 312 or equivalent.

CE 850. Life Cycle Assessment. 3 Credits.
Life cycle assessment (LCA) is a tool used across engineering fields to determine the life cycle, cradle-to-grave environmental impacts of a product or process. LCA practice helps develop a systems-thinking perspective and a deeper understanding of sustainability. Students will evaluate LCA methods and design appropriate LCA frameworks. Prerequisite: CE 477 or CE 479 or C&PE 211 or equivalent.

CE 857. Sediment Transport. 3 Credits.
A study of the transport of sediment in alluvial channels. Specific topics include properties of sediment, mechanics of bed forms, particle entrainment, scour analysis, prediction of suspended load and bed load, design of stable channels and diversion works, and sedimentation of reservoirs. Prerequisite: CE 755 or consent of instructor.

CE 858. Urban Hydrology and Stormwater Management. 3 Credits.

Hydrology of urban watersheds; floodplain management; hydrologic modeling; storm drainage; stormwater detention; water quality improvement; geomorphology of urban streams; stream corridor management and stream restoration. Prerequisite: CE 751.

CE 859. Erosion and Sedimentation. 3 Credits.
A study of sediment erosion, transport, and deposition at the watershed scale with particular application to water quality degradation and reservoir infilling. Prerequisite: Graduate standing.

CE 861. Finite Element Methods for Solid Mechanics. 3 Credits.
Stress analysis of 2-D and 3-D solids, plates, and shells by the finite element method. Element formulations and behavior with emphasis on the isoparametric concept. Computer modeling and interpretation of results. Introduction to material and geometric nonlinear analysis of solids. Prerequisite: CE 761 or equivalent.

CE 862. Behavior of Reinforced Concrete Members. 3 Credits.
This mechanics course covers in detail the constitutive behavior of reinforced concrete members subjected to various types of loading and presents the basis for modeling the response of reinforced concrete structures in the nonlinear range of response. Topics covered include: stress-strain behavior of concrete under multi axial states of stress; moment-curvature analysis; advanced analysis of r/c members subjected to shear (variable angel truss models, modified compression field theory, strut-and-tie models); behavior of r/c members subjected to cyclic loading; modeling and effects of slip at the interface between reinforcing steel and concrete. Suggested prerequisite CE 764 or equivalent. Prerequisite: CE 563.

CE 864. Seismic Performance of Structures. 3 Credits.

This course builds on topics from structural dynamics to introduce principles of structural performance during earthquake events. Emphasis is placed on estimating the response of building structures as represented by simple and complex models. Topics covered include strong ground motion, response of simple systems to ground motion, nonlinear response of building systems, and performance-based earthquake engineering. Prerequisite: CE 704.

CE 874. Air Pollution Control. 3 Credits.
The design of control devices for the abatement of air pollutants, both gaseous and particulate, emitted from stationary sources. This includes the basic theory of control device operation and economic factors associated with each type of control device design. Prerequisite: CE 772 and CE 778 or equivalent.

CE 876. Wastewater Treatment Plant Design. 3 Credits.
Application of physical, chemical, and biological principles to the design of wastewater treatment systems for domestic and other wastewaters. Special emphasis is placed on biological treatment processes. Prerequisite: CE 576 or equivalent, or CE 573 or CE 773 or equivalent.

CE 877. Water Treatment Plant Design. 3 Credits.
Application of physical, chemical, and biological principles to the design of water treatment plants and processes for domestic water supply from surface and ground water sources. Prerequisite: CE 774, or concurrent enrollment.

CE 878. Air Quality Modeling. 3 Credits.
Fundamental physical and mathematical principles applied to air quality modeling; considered are factors that influence the choice and application of air quality models, as well as the interpretation of model output data. Practical applications are stressed using standard models. Prerequisite: CE 778 or equivalent and MATH 125 or MATH 145 or MATH 526 or CE 625.

CE 881. Traffic Engineering Operations. 3 Credits.
A study of theory and practical applications of a number of traffic operational and management tools to achieve the convenient, safe and efficient movement of people and goods in urban street networks. The major content involves signalized intersection capacity, design and operation; signalized intersection coordination; and modern roundabout design. Prerequisite: CE 582 or equivalent.

CE 882. Geometric Design of Traffic Facilities. 3 Credits.
A study of basic principles in the design of freeways, urban street systems, parking terminal and other traffic facilities with emphasis on capacity, safety, level of service, and dynamic design concept. Prerequisite: CE 781 or equivalent.

CE 884. Principles of Pavement Design. 3 Credits.
A study of the scientific principles of pavement design as applied to airfield and highway pavements, considering loading conditions, stress distribution, and the properties of the various pavement components, for both rigid and flexible pavements. Prerequisite: CE 487 or equivalent.

CE 885. Advanced Foundation Engineering. 3 Credits.
A study in the design, construction, and behavior of footings and rafts, piles and drilled shafts founded on soils and rocks. Prerequisite: CE 588 or equivalent.

CE 887. Earth Structures. 3 Credits.
Current theory and practice relating to the design of retaining walls, earth slopes, large embankments, and landslide mitigation. Application of geotextiles to the design of earth retaining structures and slope stabilization. Prerequisite: CE 588 or consent of instructor.

CE 888. Ground Improvement. 3 Credits.
Basic descriptions, classification, principles, advantages, and limitations of ground improvement techniques. Design, construction, and quality assurance/control of ground improvement techniques. Prerequisite: CE 588 or equivalent.

CE 889. Designing with Geosynthetics. 3 Credits.
Basic description and properties of geosynthetics including geotextiles, geogrids, geomembranes, geonets, geocomposites, and geosynthetic clay liners. Geosynthetic functions and mechanisms including separation, filtration, drainage, reinforcement, and containment. Design with geosynthetics for roadways, embankments/slopes, earth retaining structures, and landfills. Prerequisite: CE 588 or equivalent.

CE 890. Master's Project. 1-4 Credits.
Directed study and reporting of a specialized topic of interest in civil engineering or an allied field. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

CE 891. Advanced Special Problems. 1-3 Credits.
A directed study of a particular complex problem in an area of civil engineering or allied field. Prerequisite: Varies by topic, or with consent of instructor.

CE 892. Structural Engineering and Mechanics Seminar. 1 Credits.

Presentation and discussion of current research and design in structural engineering and engineering mechanics.

CE 895. Advanced Special Topics: _____. 1-3 Credits.
A graduate course or colloquium in a topic of civil engineering or an allied field. Prerequisite: Varies by topic, or with consent of instructor.

CE 899. Master's Thesis. 1-10 Credits.
Directed research and reporting of a specialize topic of interest in civil engineering or an allied field. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

CE 991. Research. 1-15 Credits.
An investigation of a special problem directly related to civil engineering. Graded on a satisfactory progress/limited progress/no progress basis.

CE 999. Ph.D. Dissertation. 1-15 Credits.
Restricted to Ph.D. candidates. Before candidacy, aspirants performing their research should enroll in CE 991. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

Courses

CMGT 457. Construction Project Management. 3 Credits.
An introduction to the management of construction projects with an emphasis on engineering economics. This course addresses time value of money, cash flow and interest, financial analysis of alternatives, and taxes and depreciation. Also included are projects management fundamentals, project scheduling, and project controls. Prerequisite: MATH 126 or MATH 146 or consent of the instructor.

CMGT 500. Construction Engineering. 3 Credits.
An introduction to the construction industry, construction project management, and construction operations. Topics include project participant roles and responsibilities; project delivery systems; procurement of construction services; sustainable construction; contracts, bonds, and insurance; equipment selection and use; constructability and value engineering; estimating and bidding; planning and scheduling; operations management; safety; and project commissioning and closeout. Prerequisite: Junior or Senior standing in the School of Engineering, or consent of the instructor.

CMGT 700. Construction Project Management. 3 Credits.

An introduction to the management of construction projects. This course addresses project delivery systems, project organization, estimating and bidding, planning and scheduling, legal and safety issues, among other topics. Prerequisite: Graduate standing or consent of instructor. Not open to those with credit in CMGT 500.

CMGT 701. Construction Planning and Scheduling. 3 Credits.
An introduction to the planning and scheduling of projects, for both construction and design. Emphasis is placed on the critical path method including network development, production of time schedules, time-cost considerations, and the efficient utilization of resources. Manual and computer techniques are covered. Prerequisite: Graduate standing or consent of instructor.

CMGT 702. Construction Equipment and Methods. 3 Credits.
This course introduces the student to the multitude of construction equipment employed in construction. The underlying technology and engineering principles are reviewed. Principles of equipment selection, equipment utilization, and equipment economic analysis are covered. Prerequisite: Graduate standing or consent of instructor.

CMGT 703. Construction Quality and Productivity. 3 Credits.
Operations analysis for work improvement in construction using process charts, work sampling, productivity tracking, and planning techniques. Quality control and quality assurance techniques are covered, including the measurement, collection, and interpretation of quality data. Prerequisite: CMGT 500 or CMGT 700, or consent of instructor.

CMGT 704. Construction Estimating and Bidding. 3 Credits.
A study of the quantity survey, cost estimating, scheduling and project controls; construction operations; and methods of building construction. Prerequisite: Graduate standing or consent of instructor.

CMGT 705. Construction Contracts, Bonds, and Insurance. 3 Credits.
Legal doctrines relating to owners, design professionals, and contractors. Sources of law, forms of association, and agency. Contract formation, rights and duties, interpretation, performance problems, disputes, and claims. Surety bonds and insurance. Prerequisite: Graduate standing or consent of instructor.

CMGT 706. Construction Alternative Project Delivery Methods. 3 Credits.
Learn the types of alternative project delivery methods that are increasingly used in the design and construction industry, including Design-Build (DB), Construction Manager at Risk (CMAR or CM/GC), Integrated Project Delivery (IPD), Public-Private-Partnerships (P3), and more. Within these methods, the course focuses on the industry's expanding scope of preconstruction services and increasing integration between design and construction professionals. Prerequisite: Graduate standing or consent of instructor.

CMGT 707. Engineering Risk and Decision Analysis. 3 Credits.
The course investigates the fundamental principles and techniques of risk and decision analysis. It applies these principles in project-level decisions in which risk or uncertainty play a central role. The course examines various risk and decision tools including Monte Carlo analyses, influence diagrams, and other types of multi-criteria decision analyses. In addition to teaching to the skills and techniques, the course will introduce students to new ideas and concepts regarding decision and risk analysis. Prerequisite: CMGT 500 or CMGT 700, CE 625 or MATH 526, or consent of instructor.

CMGT 711. Construction Safety. 3 Credits.
This course's primary purpose is to help students understand construction safety theories and practices. Methods used to improve construction safety are introduced. A class project is used to help students explore and identify opportunities to improve construction safety. Prerequisite: Graduate standing or consent of instructor.

CMGT 712. Construction Safety Solution Development. 3 Credits.
This course aims to help students develop solutions to improve construction safety. Solution development focuses on improving safety issues faced in the construction industry, including but not limited to software, hardware, processes, methods, and concepts. Prerequisite: Graduate standing or consent of instructor.

CMGT 713. Request for Proposals in Design and Construction. 3 Credits.
The design & construction industry is shifting away from low bid toward qualifications-based procurement methods. The course examines the most common Request for Proposal processes used by owners to select design & construction teams in a variety of delivery methods. The course will also introduce students to practical strategies to compete in these RFP scenarios. Prerequisite: Graduate standing or consent of instructor.

CMGT 801. Directed Readings in Construction Management. 1-3 Credits.
Graduate-level directed readings on a topic in construction management mutually agreed on by the student and instructor. Intended to build on one or more of the core course topics: project management; planning and scheduling; equipment and methods; quality; productivity and safety; estimating and bidding; contracts, bonds, and insurance. CMGT 801 may be repeated for credit to a maximum of three hours in the degree program. Mutually agreed course deliverable(s) required. Prerequisite: Approval of the course topic and deliverable(s) by the instructor, CMGT 500 or CMGT 700, CMGT 701, CMGT 702, CMGT 703, CMGT 704, and CMGT 705, or consent of instructor.

CMGT 891. Advanced Special Problems. 1-3 Credits.
A directed study of a particular complex problem in an area of construction management or allied field. Prerequisite: Varies by topic, or with consent of instructor.

CMGT 895. Construction Management Project. 1-3 Credits.
Graduate-level investigation and report on a construction management topic mutually agreed on by the student and project advisor. This is the capstone course in the Master of Construction Management (MCM) degree program. Successful completion of this project requires acceptance of the written report and oral presentation to the student's graduate committee. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Approval of project topic by project advisor, CMGT 500 or CMGT 700, CMGT 701, CMGT 702, CMGT 703, CMGT 704, CMGT 705, and nine elective credit hours, or consent of instructor.