Department of Civil and Environmental Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

12-100 Exploring CEE: Infrastructure and Environment in a Changing World

Fall and Spring: 12 units
Civil and Environmental Engineers (CEEs) engage in the planning, design, construction, operation, retrofit, demolition, and reuse of large-scale infrastructure that forms the backbone of all societies and economies. CEEs work at the dynamic interface of the built environment, information environment, and natural environment. Therefore, societal domains that require CEE expertise include smart cities and construction, sustainable energy and buildings, connected and automated transportation systems, resilient infrastructure, climate change mitigation and adaptation, and water management. Students will explore how sensing, data science, environmental science, life cycle systems and economic analysis, and infrastructure design are integrated to create a built environment that meets the needs of smart and connected communities while enhancing sustainability. Students work on team-based design-build projects that introduce principles from environmental, structural, construction engineering, and project management. Students learn technical skills as well as methods for management and design considerations that include uncertainty, economics, and ethics, for modern and future infrastructure.

12-200 CEE Challenges: Design in a Changing World

Fall: 9 units
Building upon design themes introduced in 12-100, in this course, students will be challenged to solve more complex problems related to conventional, cutting-edge, and emerging issues in Civil and Environmental Engineering and one or more of the areas of the built, natural, and information environments, such as smart cities. Students will gain an understanding of the effects of uncertainty, such as changing climate conditions. Through several team projects, students will explore the impact and management of tradeoffs, like constructability, sustainability, cost, and maintenance on design. They will learn to apply mathematics and science, advanced technologies, and computing to solve open-ended problems. Students will learn communication, project management, and design skills and practice the design process, from problem definition to constructed work.
Prerequisite: 12-100

12-201 Geology

Fall and Spring: 9 units
Introduction to physical geology; common rocks and rock-forming minerals and their chemical compositions/structure, physical properties, origins, and uses; geologic processes: surface and ground-water flow, volcanism, mountain-building, tectonics, glaciation, sedimentation, seismicity, and atmospheric and oceanic circulation.

12-212 Statics

Fall: 9 units
Introduction to vector mechanics; equivalent systems of forces; equilibrium of rigid bodies; free body diagram; distributed forces, hydrostatic forces, effective forces, centroids; applications to simple statically determinate trusses, beams, frames, cables and other physical systems; friction.

12-215 Introduction to Professional Writing in CEE

Fall: 9 units
The objective of the course is to prepare students for writing technical reports and essays assigned in CEE courses and laboratories, writing professional letters and reports for internships and professional positions, preparing documents in a team setting, delivering individual and team oral presentations, and transforming information for several types of audiences (scientific accommodation). The course focuses on document purpose, organization and style; basic editing techniques; scientific accommodation; plagiarism and proper paraphrasing and summarizing; evaluating, citing and referencing sources; team communication strategies; oral presentations; and proper use of tables, graphics, and other visual aids in documents and presentations. Course activities include in-class exercises, peer workshops, and homework assignments to illustrate examples of good and poor communication and to practice technical communication skills. Concurrent with lectures and class activities, students draft and revise individual and team technical reports and will give individual and team oral presentations.

12-221 Environmental Chemistry and Thermodynamics

Fall: 9 units
Environmental chemistry is foundational to the understanding of processes in natural and engineered systems. This course introduces environmental chemistry principles within the context of air and water systems. It focuses on the use of stoichiometry, thermodynamics, equilibrium, and kinetics to understand processes governing chemical and biological behaviors in natural and engineered systems. Topics in water include acid-base chemistry, the carbonate system, buffering, oxidation and reduction, mineral dissolution/precipitation, metal complexation, adsorption, and partitioning. Topics in air and climate to be discussed include atmospheric chemistry, air quality, combustion, aerosols, and climate science.
Prerequisites: 09-105 or 09-111

12-222 Environmental Chemistry Laboratory

Fall: 3 units
Students learn to conduct lab and field experiments relevant to environmental engineering and the understanding of natural and engineered systems. Exercises involve the collection and analysis of data from major domains of the environment (air, water, soil, sediments). Students learn to use state-of- the-art environmental analytical techniques. Students develop collaborative skills through team-based laboratory exercises and practice skills in written communication of laboratory results.

12-231 Solid Mechanics

Spring: 9 units
Understanding and calculating the deformation and eventual failure of solids is fundamental to the design of structures and materials for civil engineering applications ranging from structural analysis and design of buildings and bridges to the design of novel materials and structures optimized for specific functionality. This course provides students with an introduction to fundamental concepts and methods in solid mechanics. Topics covered include stress, strain, mechanical properties of materials, and geometric compatibility; response under axial loads, torsion, bending, transverse shear, and combined loadings; stress transformations and Mohr's circles, deflections of beams and shafts, and buckling of columns. Students will develop problem solving skills and apply these concepts to analyze deformable bodies.
Prerequisite: 12-212

12-233 CEE Infrastructure Systems in Action

Fall: 2 units
Civil and environmental engineering infrastructure is all around us. CEE infrastructure is integral to society's day-to-day operations, providing, for example, shelter, transportation, and clean drinking water. In this course, students will get a first-hand experience of civil and environmental engineering in action all around us. The course is comprised of lab sessions during which students will learn about and investigate infrastructure and phenomena in the built and natural environments on or near campus. Student coursework includes short assignments and reflections related to the lab experience.
Prerequisite: 12-100

12-234 Sensing and Data Acquisition for Engineering Systems

Spring: 4 units
Collecting and analyzing massive amounts of data is integral to understanding and managing the complexities of our infrastructure systems. Civil and environmental engineers need to select tools and to collect data to gain an understanding of the problems they are trying to solve. In this course, students will learn how to choose and use a range of measuring tools from simple hand tools to advanced sensors to collect data in laboratory-based and system-level studies, followed by data acquisition and processing. Experiment subjects will span the breadth of the fields including, for example, structural, geotechnical, environmental, and transportation engineering. The sensors and data will be used to assess not only an individual infrastructure component, but also infrastructure systems and networks. Students will complete planning activities for each of the experiments, conduct experiments, and acquire the resulting data from sensors and other measurements. Results and analysis will be submitted as part of a report or post-laboratory assignment.
Prerequisite: 12-212

12-271 Computation and Data Science for Civil & Environmental Engineering

Spring: 9 units
Computational science and computer applications play an important role in modern engineering practice and research. This course provides students with an introduction to the fundamentals of computation and data science using both deterministic and stochastic techniques. Topics include numerical methods for approximation, differentiation, integration, Monte Carlo simulation, quantifying error and uncertainty, regression, solving linear systems of equations and ordinary differential equations, root finding, and optimization; the use of several computing paradigms (numerical, symbolic, and spreadsheet) for enhancing engineering workflows with modeling and data, with an emphasis on identifying the appropriate tool for various engineering problems; the importance of and approaches for effective visual presentation of data; and the future of computer-based methods in engineering. Mathematical concepts from calculus, probability, and linear algebra are introduced as needed. Through application of these principles, students will develop the computational reasoning skills that are required to design and deploy computer-based solutions for a variety of problems in civil and environmental engineering.
Prerequisites: 21-120 Min. grade C and 33-141 and (15-110 or 15-112) and 21-122 Min. grade C

12-301 CEE Projects: Integrating the Built, Natural and Information Environments

Fall: 9 units
Civil and environmental engineers work at the interface of multiple disciplines, understanding and applying principles to evaluate and create. This course extends design skills from 12-100 and 12-200 to hands-on experiences with more integrated, interdisciplinary problem solving. Students explore the roles of diverse stakeholders, community engagement, and sustainability goals in CEE projects. Students integrate construction/structures, sensing, and sustainability through team-based projects, and apply communication, computation, and project management skills. Students develop an understanding of the professional, ethical, social, and economic aspects of engineering projects. The course combines formal instruction, field trips, teamwork, role-playing, and engagement with practicing experts involved with CEE projects.
Prerequisites: 12-271 and 12-200

12-333 Experimental & Sensing Systems Design and Computation for Infrastructure Systems

Spring: 4 units
Civil and environmental engineers must decide what information they need to collect, how to collect it, how to analyze the data and how to use that data to develop solutions for a changing world. Data are often incorporated into computational models to gain further insight and understanding of the problem and potential solutions. In this course, students will learn and develop different approaches to solve problems like field testing, laboratory experimentation, computer simulation, and data analytics. Students will design their own testing protocols and develop computer models to simulate situations that are difficult or expensive to sense in the real-world. Pre- and post-laboratory assignments or reports will be completed to document plans and to present an analysis of results.
Prerequisite: 12-356

12-335 Soil Mechanics

Fall: 9 units
Understanding the behavior of soils is essential for many applications within civil and environmental engineering from construction safety and structural integrity of buildings, to foundations, levees, groundwater remediation, landfill design, and erosion control. This course provides students with an introduction to fundamental concepts and methods in soil mechanics and geotechnical engineering. Topics covered in the course include physical, chemical and hydraulic characteristics and mineral composition of soils; stress-strain-strength relationships; permeability; consolidation; shear strength; and lateral earth pressure. Students will apply knowledge of these fundamentals to solve civil and environmental engineering problems related to soil deformation, stability, and groundwater flow.
Prerequisites: 12-231 and 33-142

12-351 Environmental Engineering

Spring: 9 units
Environmental engineering applies sustainability science, engineering principles, and systems approaches to protect the environment and human health. This includes protecting natural ecosystems and enhancing the quality of human life through environment-related policy development and technological innovation, and assessing the environmental impacts or benefits of infrastructure projects. This course provides a scientific and engineering basis for understanding and developing sustainable solutions for challenges in environmental and public health protection, especially in relation to urban water systems, with links to energy and climate. Topics covered include: sustainability; basic principles of water chemistry and microbiology; mass and energy balances; reactor theory and models; physical-chemical and biological processes; drinking water treatment; wastewater treatment; rivers, lakes, and ecosystems. Students will develop quantitative problem-solving skills for environmental engineering challenges. Students will also learn about and analyze current environmental and public health issues.
Prerequisites: 09-105 or 09-111

12-352 Environmental Engineering Lab

Spring: 3 units
Environmental engineering depends on many kinds of measurements as well as experimentation for monitoring and managing natural and engineered systems. In this course, students will design and conduct laboratory experiments that illustrate the fundamental principles of chemical, physical, and biological processes learned in environmental engineering. Topics include acid-base chemistry, carbonate chemistry, solids removal, and pathogen detection. Experiments include applications of methods to detect and quantify both inorganic and organic contaminants in water, and methods to remove contaminants from water. Students will also advance teamwork skills through group efforts and collaborative writing.

12-353 Environmental Biology and Ecology

Spring: 9 units
Profound changes are affecting our environment, including climate change, habitat loss, pollution, and invasive species. Understanding ecosystems and their inhabitants and functions is critical to engineering a sustainable future for humans. This course is an introduction to ecology and biology for environmental engineers. Ecology topics include the relationships among organisms and between organisms and their environment; and adaptations, populations, communities, and terrestrial and aquatic ecosystems. Biology subjects will focus on microbiology, as bacteria are an analog for more-complex species. Microbiology topics include biological molecules, biochemical reactions, energetics, diversity of microbial metabolism, physiology, biofilms, biogeochemical cycles, and the degradation of pollutants.
Prerequisite: 03-121

12-355 Fluid Mechanics

Fall: 9 units
The flow of fluids is important in many civil and environmental engineering applications ranging from water infrastructure and coastal engineering to bridge design. This course provides students with an introduction to fundamental concepts and methods in fluid mechanics. Topics covered in the course include fluid properties; pressure, hydrostatics, and buoyancy; open systems and control volume analysis; conservation of mass and momentum for moving fluids; viscous fluid flows and flow in conduits; dimensional analysis and similitude; open channel flows; lift and drag on immersed bodies; and differential analysis. Through application of these concepts, students will develop problem-solving skills and formulate models necessary to study, analyze, and design fluid systems essential to good engineering practice of fluid mechanics. Civil Engineering undergraduates register for section A. Environmental Engineering undergraduates register for section B. All graduate students register for section C.
Prerequisite: 21-260 Min. grade C

12-356 Fluid Mechanics Lab

Fall: 2 units
An understanding of fluid mechanics is greatly enhanced by hands-on experimentation and experience with the physical concepts of fluid flows. In this course, students will develop an ability to conduct experiments, take measurements, and analyze and interpret data in fluid mechanics. Topics covered include measurement of fluid properties; static forces on immersed surfaces; continuity and energy; viscous pipe flow; and open channel flow. Students will foster teamwork skills and an ability to creatively develop independent ideas around the description of fluid mechanics through small-group work with experimental apparatus and individual reports on the acquired data.

12-371 Advanced Computing and Problem Solving in Civil and Environmental Engineering

Spring: 9 units
Building upon the fundamentals developed in 12-271, this course introduces students to advanced topics in computational problem solving that are critical for implementing and interpreting computational solutions in civil and environmental engineering practice. These topics include numerical methods (both deterministic and stochastic) for approximation, differentiation, and integration in high dimensions; topics in numerical linear algebra for data science (including applications of QR factorization, singular-value decomposition, and Cholesky factorization); an introduction to clustering, regression, and classification; an introduction to statistical sampling; an introduction to graph and network theory; topics in deterministic and stochastic optimization; an introduction to scripting and automation; numerical solutions of ordinary differential equations (including finite differences and basic finite-element analysis); and practices for effective visualization of large data sets. Each topic is presented with real-world civil and environmental engineering problems, in areas such as smart cities, transportation, energy, buildings, and hydrology. An emphasis is placed on identifying the appropriate computational method for any specific problem; additional emphasis is placed on developing computational thinking. This course culminates in a project, which requires students to synthesize their computational reasoning skills in order to solve a challenging civil and environmental engineering problem.
Prerequisite: 12-271

12-401 CEE Design

Fall: 12 units
This capstone design experience integrates knowledge and experience from technical and professional skills acquired in the civil engineering and environmental engineering project course sequence. Students apply the design process and knowledge from the core curriculum to design engineering solutions to real engineering problems. Students work in teams in a pre-professional environment to meet the challenges with which they are presented. Oral, written, and graphic communications both within teams and with external audiences are essential to successful completion of the projects. Students manage the design process as they work with community partners to co-design solutions during the semester-long project. Student teams work with community partners to define the engineering problem, including requirements and performance criteria, and to imagine and evaluate potential solutions. Teams produce models and calculations to assess performance with respect to requirements and performance criteria and detailed design deliverables to convey the recommended solution.
Prerequisite: 12-301

12-411 Project Management for Engineering and Construction

Fall: 9 units
Through planning and management, and optimization and allocation of materials and labor under time and financial constraints, project managers lead teams to achieve project goals. This course is an introduction to project management of engineering, construction, and operations of building facilities and civil infrastructure. This course emphasizes design, construction, and operation as an integrated process and examines various topics related to four core aspects of project management - time, cost, quality, and safety. Engineering and management cases from civil, construction, and infrastructure engineering domains will be examined. Topics covered include contracting issues, legal structures, project planning and scheduling, cash flows, cost estimation and financing of constructed facilities, labor productivity, material management, equipment utilization, cost control, monitoring, and accounting for construction. The course will introduce various software tools useful for implementation of these topics, including project scheduling and management tools, software for optimization and economic analysis, field operation analysis tools, and digital design and modeling tools. Civil engineering undergraduates register for section A. Environmental Engineering undergraduates register for section B. All graduate students register for section C.
Prerequisite: 12-301

12-451 Advanced Environmental Engineering

Spring: 9 units
Building on fundamental concepts from 12-221, 12-351, and 12-353, this course focuses on the physical, chemical, and biological processes controlling the quality of water, soil, air and #8212; and ultimately human and ecosystem health. Students will learn how these processes regulate the cycling of contaminants and nutrients in the environment. Key topics include material and energy balances, advective-dispersive transport with reacting solutes, and partitioning of contaminants and nutrients across different media. Students will also gain familiarity with (1) how regulatory agencies and decision-makers account for these processes in environmental protection efforts and (2) related challenges and opportunities around climate change.
Prerequisites: 12-355 and 12-353 and 12-351 and 12-221

12-471 Applied Data Analytics for Civil and Environmental Systems

Spring: 9 units
Building upon the fundamentals developed in 12-271 and 12-371, this course empowers students to leverage computing tools for big data. Topics include design of experiments; advanced topics in statistics and uncertainty quantification; an introduction to signal processing and Fourier theory; an introduction to classification, clustering, and other concepts from machine learning; and an introduction to parallel and distributed computing and sensing. Each topic is presented in the context of a specific set of engineering problems. An emphasis is placed on identifying computationally appropriate and efficient solutions. This course culminates in a collaborative project, enabling students to synthesize their computational and data science skills to solve a significant problem in civil and environmental systems
Prerequisite: 12-371

12-600 AutoCAD

Fall and Spring: 3 units
AutoCAD is mostly held online. The course provides an introduction to the fundamentals of computer-aided design (CAD)software. Students learn how to set up CAD projects using Autodesk's AutoCAD software. Topics include coordinates, lines, circles, arcs, zooms, snaps and grids, text, views, layers, plines, blocks, reference files, dimensioning, isometrics, 3D commands, surfaces, solids, and more. CAD standards for layers, plotting, and symbol libraries are also covered. The course includes development of a CAD project by each student.

12-612 Intro to Sustainable Engineering

Fall: 9 units
This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems.

12-623 Molecular Simulation of Materials

Spring: 12 units
The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec.

12-631 Structural Design

Spring: 12 units
Design of structural members for bending moment, shear force, axial force, and combined axial force and bending. Reinforced concrete, structural steel, and composite beam construction are considered. Buckling effects in columns, beams and local plate segments are treated. Serviceability limits such as deflection and cracking are addressed. Design projects include the determination of loads and the selection of system geometry.
Prerequisite: 12-231

12-635 Structural Analysis

Fall: 12 units
Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.
Prerequisite: 12-231

12-636 Geotechnical Engineering

Spring: 9 units
Behavior of geotechnical structures; engineering design of geotechnical structures considering failure modes; uncertainties; economic issues, required design formats and relevant code provisions; performance requirements for foundations, subsurface investigations; allowable stress and LRFD design approaches; reliability-based design; shallow foundations; deep foundations; retaining structures; reinforced concrete foundations.
Prerequisite: 12-335

12-644 Intro to Transportation Systems Analysis

Fall: 6 units
This course covers fundamentals of planning, design, and operation of roadway transportation. Topics covered include basic traffic flow theory, traffic signal design and evaluation, transportation planning, pricing of transportation systems, and basic data analytics techniques. It also teaches the basics of the travel behavior model to understand planning of public transit services. The objective is to develop the capability to: 1) understand the principles of transportation planning, transportation economics and system management; 2) analyze transportation systems with emerging mobility data; and 3) apply methodologies to solve transportation system problems and develop management strategies/policies.

12-645 Smart Cities: Growth and Intelligent Transportation Systems

Fall: 6 units
Cities all around the world are being built and re-invented as smart cities utilizing information systems and innovative applications of data analytics. One major smart cities component is transportation. The Intelligent Transportation Systems (ITS) industry is expected to grow at a rate of 19% per year and reach $5.5 Billion in annual investment by 2020. This shifting dynamic provides great opportunity for improved transportation safety and efficiency but also poses challenging information systems and public policy challenges. Furthermore, there are new opportunities for professional-school graduates outside of engineering schools for employment in transportation planning and policy. This course is supported by CMU's Traffic21 Initiative and Technologies for Safe and Efficient Transportation (T-SET) University Transportation Center. Classes will feature guest lectures provided by T-SET faculty and industry and government ITS professionals.

12-648 CEE Research Project

Fall and Spring
This course is designed to give students the opportunity to work on a research project under the direction of a faculty member in Civil and Environmental Engineering. A student in this course must write a proposal and submit progress reports to the advisor. The student must also make a presentation of the project results and submit a final report. To register for this course, a student must have the approval of the faculty member for both the research topic and the number of units.

12-651 Air Quality Engineering

Fall: 9 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

12-657 Water Resource Systems Engineering

Spring: 9 units
Water Resource Systems Engineering combines hydrology, engineering, economics, and operations research to create tools and analyses that support decisions about large-scale water resource systems. The emphasis in this course will be on optimization methods, which are a core element of water systems analysis. Both water quantity and water quality problems will be covered.
Prerequisite: 12-355

12-659 Special Topics: Matlab

Fall: 6 units
This mini course is designed to be a practical introduction to engineering scientific computation. The topics of this class will include basic matrix computation, solving ordinary and partial differential equations, solving systems of linear equations, computing eigenvalues and eigenvectors, and basic signal processing and neural network techniques. Throughout the course, these scientific computation tools will be demonstrated using interactive scientific software called MATLAB.

12-690 CEE Independent Study

Fall and Spring
In-depth investigation of a special topic in Civil and Environmental Engineering under the direction of a faculty member. The subject of study is determined through discussion between the student and a faculty advisor. A student in this course must write a proposal about what they want to learn and how it can be evaluated. Approaches can include more in-depth examination of topics in the curriculum, study of topics not in the curriculum, a design project, or other investigation. To register for this course, a student must have the approval of the faculty member for both the subject and the number of units.

12-702 Fundamentals of Water Quality Engineering

Fall: 12 units
This course is a systematic overview of water quality engineering designed for students with no prior civil and environmental engineering background. Topics examined include physical, chemical, and biological characteristics of water; common water pollutants; basic water chemistry and micriobiology; mass and energy balances and their use in reactor analysis; physical, chemical and biological processes affecting natural water quality and the use of these processes in water supply and wastewater management systems; and selected problems in surface water and groundwater quality management. A background in college-level general chemistry, physics, calculus, and differential equations is assumed.

12-704 Probability and Estimation Methods for Engineering Systems

Fall: 12 units
Overview of rules of probability, random variables, probability distribution functions, and random processes. Techniques for estimating the parameters of probability models and related statistical inference. Application to the analysis and design of engineered systems under conditions of variability and uncertainty.

12-712 Sustainable Engineering Principles

Fall: 12 units
This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

12-714 Environmental Life Cycle Assessment

Spring: 12 units
Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.

12-720 Water Resources Chemistry

Fall: 12 units
This course provides a rigorous yet practical basis for applying the principles of physical chemistry to understanding the composition of natural waters and to the engineering of water and wastewater treatment processes. Topics covered include chemical equilibrium and kinetics; acid-base equilibria and buffering; solid precipitation and dissolution; oxidation and reduction reactions; adsorption on solids; and computer-aided problem solving. The primary objective of the course is to be able to formulate and solve chemical equilibrium models for complex aqueous systems. Knowledge of college-level general chemistry is assumed.

12-724 Biological Wastewater Treatment

Spring: 12 units
The exploitation of microbiological processes for environmental quality control is both historic and emergent. Engineered microbial systems have been used to treat wastewater for over 100 years, and they remain a critical component of modern operations. At the same time, new technologies are emerging to address modern challenges in the remediation and detoxification of hazardous chemicals and recovery of resources from waste. This course connects established principles of microbiology and engineering with empirical observations of complex microbial systems to develop quantitative tools for engineering biological systems. The course includes aerobic and anaerobic treatment perspectives as well as suspended growth and biofilm processes. Concepts are developed from a wastewater perspective but include applications in advanced, nutrient removal and resource recovery.

12-725 Fate, Transport & Physicochemical Processes of Orgnc Contaminants in Aqua Systms

Spring: 12 units
Examination of the major physical and chemical processes affecting the fate and treatment of organic compounds nanoparticles in aquatic systems. The emphasis is on anthropogenic organic compounds. The course will review some concepts from physical organic chemistry, and examine the relationships between chemical structure, properties, and environmental behavior of organic compounds. Chemical processes important to the fate, treatment, and biotransformation of specific organic compounds are addressed. Two laboratory sessions illustrate measurement techniques for organic compounds in water. 12-702 is a co- req for non environmental engineers or students who have not had and environmental engineering undergraduate course

12-726 Mathematical Modeling of Environmental Quality Systems

Spring: 12 units
Development and application of mathematical models for environmental systems. Material balance formulations and their solutions, computer implementation, model validation, uncertainty analysis, and use for projection and policy analysis. Applications to surface water, groundwater, atmospheric transport, indoor air pollution, and human exposure and risk.

12-740 Data Acquisition

Fall: 6 units
The intent of this course is to introduce students to the concepts, approaches and implementation issues associated with data acquisition for infrastructure systems. Students will be introduced to the types of data that is collected about infrastructure systems, excitation mechanisms, sensing technologies, data acquisition using sensors, signal pre-processing and post-processing techniques, and use of sensing in a variety of applications in construction and infrastructure management. Students will also gain experience with data acquisition hardware and software.

12-741 Data Management

Fall: 6 units
The intent of this course is to introduce students to database management systems and to knowledge discovery in database principles. Students will learn how to develop powerful tools for efficiently managing large amounts of civil engineering data so that it may persist safely over long periods of time. Students will be introduced to relational database systems and structured query languages. They will also be exposed to other existing data models. Students also will be introduced to data mining and analysis tools to discover patterns and knowledge from data.

12-746 Special Topics: Introduction to Python Prototyping for Infrastructure Systems

Fall: 6 units
This course uses the Python programming language to introduce fundamental programming approaches to students from civil and environmental engineering. No prerequisite required and students with no programming experience are recommended to take this course. This course will cover fundamental programming approaches, object-oriented programming concepts, graphical user interface design in Python, and file and database operation. Real-world examples from infrastructure management will be used in the class for demonstration and term project. Students will work individually and in teams to develop a series of applications that are potentially be used in real-world applications.

12-749 Climate Change Adaptation

Fall: 6 units
While the specific timing and magnitude of climate change impacts are uncertain, long-lived civil engineering infrastructure will need to be resilient to these potential impacts. Engineers designing for climate change adaptation require the tools to maximize resiliency and minimize cost for existing and proposed energy, transportation, water, urban and other types of infrastructure. Students successfully completing this course will understand how climate change affects civil infrastructure and how to quantitatively incorporate resilient designs and co-benefits under uncertainty. Students will use open data to examine current adaptation engineering challenges, quantify solutions, and communicate their technical recommendations through policy briefs. Prerequisites: Graduate standing or consent of instructor.

12-755 Finite Elements in Mechanics I

Fall: 12 units
The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow, and others. Introduction to advanced topics, including fourth-order equations, time dependence, and nonlinear problems.Prerequisite: Graduate standing or consent of instructor. Prerequisites: Graduate standing or consent of instructor.