# EN.570 (ENVIRONMENTAL HEALTH AND ENGINEERING)

## Courses

**EN.570.100. A Survey of Environmental Health and Engineering: Ask the Lorax. 1 Credit.**
This course is designed to introduce new students to Environmental Health and Engineering (EHE) as a discipline. There will be weekly seminars from different faculty members each sharing an overview of research and professional practice activities that they engage in. Students will get a broad perspective of the research and career options in environmental engineering
Distribution Area: Engineering, Natural Sciences

**EN.570.108. Introduction to Environmental Engineering and Design. 3 Credits.**
This course provides a broad overview of environmental engineering - what environmental engineering is and what environmental engineers do. Whenever possible, the topic areas listed herein will be presented in the context of real-world environmental problems. Specific topics include: Environmental engineering ethics and justice, professional engineering licensure, membership in professional societies and associations, environmental engineering design process and components, mass and energy balances, environmental chemistry, mathematics of growth and decay; risk assessment and management; water resources (quantity and quality), surface water pollutants, eutrophication; groundwater flow, contaminant transport, groundwater remediation; water quality control, municipal water and wastewater systems, drinking water standards; air pollution, national ambient air quality standards, toxic air pollutants, mobile and stationary source control technologies, indoor air quality; global atmospheric change, the greenhouse effect, global energy balance, carbon emissions, stratospheric ozone depletion, and issues pertaining to hazardous, solid, and medical waste management. Overviews of pertinent environmental laws and regulations will be presented where applicable. The course encompasses conceptual design projects for environmental systems and infrastructures. The ePortfolio tag(s) on this course signify that there are one or more assignments offered in the course that provide students with the opportunity to be assessed for proficiency in completion of the relevant ePortfolio requirement(s).
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)
EN Foundational Abilities: Ethical Reflection ePortfolio (FA5eP)

**EN.570.201. Environmental Biology and Ecology. 3 Credits.**
This course will cover basic topics in environmental biology and ecology for environmental engineering majors. The course will begin by describing the basic building blocks of life, cells and cellular components, which are common to all living things. We will then investigate factors that promote multicellularity, plant and animal physiology, and ecological principles that determine the distribution and function of organisms in the ecosystem.
Distribution Area: Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.222. Environment and Society. 3 Credits.**
Humans make their living in the environment. How we do that changes nature and changes us. This class explores human impacts on the environment, how we have thought about our relationship to nature over the millennia, and contemporary environmental discourses.
Distribution Area: Humanities, Social and Behavioral Sciences

**EN.570.239. Environmental Engineering Chemistry - Current and Emerging Topics. 3 Credits.**
Students will utilize their chemistry knowledge to understand contemporary environmental issues in various media. Lectures will discuss the chemical phenomena leading to and resulting from air and water pollution issues. Climate change impacts to air and water chemistry will also be covered.
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.303. Environmental Engineering Principles and Applications. 3 Credits.**
Fundamentals and applications of physical, chemical, and biological processes in the natural environment and engineered systems. The first part of this class will cover material balances, chemical equilibrium, chemical kinetics, vapor pressure, dissolution, sorption, acid-base reactions, transport phenomena, reactor design, and water quality. The second part of this class focuses on the principles and design of water and wastewater treatment processes, such as coagulation, sedimentation, filtration, biological treatment processes, and disinfection.
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.304. Environmental Engineering Laboratory. 4 Credits.**
Introduction to laboratory measurements relevant to water supply and wastewater discharge, including pH and alkalinity, inorganic and organic contaminants in water, reactor analysis, bench testing for water treatment, and measurement and control of disinfection by-products.
Recommended Course Background: EN.570.210 or Instructor Permission.
Prerequisite: EN.570.303.
**Prerequisite(s):** Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/);EN.570.303
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.305. Environmental Health and Engineering Systems Design. 4 Credits.**
Techniques from systems analysis applied to environmental engineering design and management problems: reservoir management, power plant siting, nuclear waste management, air pollution control, and transportation planning. Design projects are required.
Distribution Area: Engineering, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.320. Case Studies in Climate Change - A Field Course. 4 Credits.**
In this interdisciplinary seminar class, we will discuss past, present, and future climate change. We will do so through several case studies on California; Eastern California is a hub of research on past climate change, and arguably few states are being more heavily impacted by current climate change than California. Throughout the first half of the course, we will learn how climate has changed in the past, the magnitude of those changes, the possible causes, and the physical and ecological impacts of past climate change. In the second half of the course, we will contrast past climate change with the impacts and severity of contemporary climate change. We will explore how climate change is stressing water resources, air quality, and ecological resilience across California, and we will critically evaluate how the state's recent policy initiatives are ameliorating (or exacerbating) these stresses. The course will include a week-long spring break field trip to Eastern California where we will explore how climate change is stressing water resources, air quality, and ecological resilience across the state. Do not hesitate to email the instructor (smill191@jhu.edu) for more information about the field trip.
Distribution Area: Engineering, Natural Sciences

**EN.570.321. Case Studies in Climate Change - A Field Course. 2 Credits.**
This is the 2 credit co-requisite course for EN.570.320 Case Studies in Climate Change offered in fall. In this course we will travel to Eastern California for a week-long field trip to explore how climate change is stressing water resources, air quality, and ecological resilience across California. We will critically evaluate how the state's recent policy initiatives are ameliorating (or exacerbating) these stresses. Please email the instructor if you are interested in this course (smill191@jhu.edu) for more details on the co-requisite.
**Prerequisite(s):** EN.570.320

**EN.570.333. Water and energy in the terrestrial biosphere. 3 Credits.**
How does water move through the landscape? How do we make predictions about how streamflow, groundwater, and soil moisture will respond to climate change and landscape change? In this course we will examine the processes controlling the movement of water, and the use of models to make hydrologic predictions. In particular the course covers the water balance, radiation balance and energy balance at the terrestrial earth surface; evaporation, transpiration, and their relationship to plant physiology and ecology; snow and ice; shallow groundwater, recharge, and base flow; runoff generation processes, and the role of surface and subsurface landscape structure. We will use simple model codes to gain an appreciation for the structure, calibration/validation, uncertainty, and post-processing of hydrologic models. Although the course is intended as a follow-on from Hydrology 570.353/653, it can be taken by any student with sufficient background, and with the consent of the instructor. Major assessment is a term paper (no exam).
Distribution Area: Engineering, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.334. Engineering Microeconomics. 3 Credits.**
The course introduces the principles of microeconomics and engineering economics, and applications of those principles to environmental engineering and public policy analysis. The financial and economic implications of engineering designs and control policies are critical to their success. We introduce principles of engineering economics and microeconomics (demand and production theory) and their uses in engineering decision making.
Distribution Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.349. Water quality of rivers, lakes, and estuaries. 3 Credits.**
Sustainably managing aquatic environments for ecosystem and public health in a changing climate requires us to understand the combined effect of multiple physical, chemical, and biological processes. This class will equip students to apply their understanding of environmental engineering principles to real-world water quality issues using computer simulation models. Emphasis will be placed on gaining insight by understanding fundamental assumptions and equations, and application to classical problems of oxygen demand and eutrophication. Advanced topics including pathogen and toxin dynamics will also be introduced.
**Prerequisite(s):** EN.570.303
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.350. Environmental Hazards and Health Risks. 3 Credits.**
This course explores the concepts, assessment, and control of exposure to biological, physical and chemical hazards in the environment, the risk of adverse health outcomes resulting from such exposures, and the relationship between the exposures and health outcomes. These are placed in the context of the multi-disciplinary scientific field of environmental health as an essential component of the wider field of public health. The course is comprised of lectures, examples, group discussions, and group presentations. The proposed course will fill a gap in content and skill development in the issues and techniques relating to human health risk assessment. This course is targeted toward undergraduates who may not have had any exposure to environmental health science, and provides an introduction to environmental health using the framework of health risk assessment. The course first introduces the concepts of exposure to environmental hazards and biological dose, routes of exposure, statistical characterization of exposure variability in populations, and monitoring networks. The next set of concepts relate to hazard characterization, i.e., adverse health outcomes resulting from such exposures using a variety of types of data including in vitro and in vivo studies, and human epidemiological studies and their strengths and weaknesses. The next segment will deal with the quantitative characterization of the relationship between exposure/dose and the adverse health outcomes, i.e., the dose-response relationships, the metrics used for this, and quantitatively characterizing the health risks of a population. The course will introduce students to several tools including mathematical modeling of exposures and risk, and uncertainty analysis.
**Prerequisite(s):** (AS.171.101 ) AND (AS.030.101 AND AS.030.102) AND (AS.110.108 AND AS.110.109)
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.351. Introduction to Fluid Mechanics. 3 Credits.**
Introduction to the use of the principles of continuity, momentum, and energy to fluid motion. Topics include hydrostatics, ideal-fluid flow, laminar flow, turbulent flow. Recommended Course Background: Statics, Dynamics, and AS.110.302
**Prerequisite(s):** Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter Laboratory Safety Introductory Course in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/)
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.353. Hydrology. 3 Credits.**
The occurrence, distribution, movement, and properties of the waters of the Earth. Topics include precipitation, infiltration, evaporation, transpiration, groundwater, and streamflow. Analyzes include the frequency of floods and droughts, time-series analyzes, flood routing, and hydrologic synthesis and simulation. Recommended Course Background: AS.110.302, EN.570.351
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.367. Sustainability Science and Policy: The Threat of Climate Change. 3 Credits.**
The challenge of sustainability is simultaneously promoting human well-being while protecting the environment. Advancing a transition toward sustainability hinges on applying what we know to what we should do, including undergirding public policies with knowledge—especially knowledge gleaned from science, technology, and engineering. This course examines sustainability science, communications, and public policy through the lens of climate—what is known about climate change and impacts, what motivates public understanding, and what actions through mitigation and adaptation make progress toward sustainability.

**EN.570.406. Environmental History. 3 Credits.**
Environmental history explores the interactions between social change and environmental transformation, or the ways in which societies modify landscapes and are themselves affected by geological, climatological and changing ecological conditions. Topics include the relationship between climate change and human evolution, the environmental impacts of market-based commodity production and regional economic specialization; the relationship between urbanization and environmental change; how warfare affects and is affected by environmental conditions.
Distribution Area: Humanities, Social and Behavioral Sciences
Writing Intensive

**EN.570.411. Engineering Microbiology. 3 Credits.**
Fundamental aspects of microbiology and biochemistry as related to environmental pollution and water quality control processes, biogeochemical cycles, microbiological ecology, energetics and kinetics of microbial growth, and biological fate of pollutants.
Distribution Area: Engineering, Natural Sciences

**EN.570.415. Current Trends in Environmental Microbiology. 3 Credits.**
This course will highlight recent discoveries and advances in environmental microbiology such as the identification of novel microbes, changing paradigms in nitrogen cycling, single-cell activity methods and novel methods in microbial community analysis. We will explore these topics by reading and discussing the current literature, supported by short lectures and in class activities related to the topics. Background in microbiology or microbial ecology is recommended. This course will meet with EN.570.615.
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.416. Data Analytics in Environmental Health and Engineering. 3 Credits.**
Data analytics is a field of study involving computational statistics, data mining and machine learning, to explore data sets, explain phenomena and build predictive models. The course begins with an overview of some traditional analysis approaches including ordinary least squares regression and related topics, notably diagnostic testing, detection of outliers and methods to impute missing data. More recent developments are presented, including ridge regression. Generalized linear models follow, emphasizing logistic regression and including models for polytomous data. Variable subsetting is addressed through stepwise procedures and the LASSO. Supervised machine learning topics include the basic concepts of boosting and bagging and several techniques: Decision Trees, Classification and Regression Trees, Random Forests, Conditional Random Forests, Adaptive Boosting, Support Vector Machines and Neural Networks. Unsupervised machine learning approaches are addressed through applications using k-means Clustering, Partitioning Around Medoids and Association Rule Mining. Methods for assessing model predictive performance are introduced including Confusion Matrices, k-fold Cross-Validation and Receiver Operating Characteristic Curves. Public health and environmental applications are emphasized, with modeling techniques and analysis tools implemented in R.
Distribution Area: Engineering, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.419. Environmental Engineering Design I. 2 Credits.**
Through general lectures and case study examples, this course will expose students to some of the non-technical professional issues that they will face as professional engineers and in their second-semester senior design project.
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.420. Air Pollution. 3 Credits.**
The course consists of an introduction to the fundamental concepts of air pollution. Major topics of concern are aspects of atmospheric motion near the earth's surface; basic thermodynamics of the atmosphere; atomospheric stability and turbulence; equations of mean motion in turbulent flow, mean flow in the surface boundary layer; mean flow, turbulence in the friction layer; diffusion in the atmosphere; statistical theory of turbulence; plume rise. Emphasis is place upon the role and utility of such topics in a systems analysis context, e.g., development of large and mesoscale air pollution abatement strategies. Comparisons of the fundamental concepts common to both air and water pollution are discussed. This course meets with EN.570.657, Air Pollution.
Distribution Area: Engineering, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.421. Environmental Engineering Design II. 3 Credits.**
Engineering design process from problem definition to final design. Team projects include written/oral presentations. Students will form small teams that work with local companies or government agencies in executing the project. Recommended Course Background: EN.570.303, EN.570.352, and EN.570.419
**Prerequisite(s):** EN.570.419
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.422. Resilience of Ecological Systems. 3 Credits.**
The ability of ecosystems to recover from natural events and human actions is increasingly being threatened by climate change. This course is a study of ecosystems using mathematical models, with a particular focus on quantifying their resilience. We will model a number of ecosystems, including rainforests, lakes, temperate forests, savannas, and grasslands. We will analyze ecological phenomena that impact public health and commerce. These include lake eutrophication and anoxia, forest fires, and insect outbreaks. We will study whole-earth mathematical models, biodiversity, and models to study the spread and control of pandemics. New this semester will be game theory applications, urban ecosystems and environmental justice. In all cases, potential pro-active and reactive management and control approaches will be evaluated. Mathematical techniques will be introduced and developed in a context-sensitive manner. Undergraduate and graduate students are welcome to enroll. Recommended course background (i.e. potentially useful but not required): EN.553.291 or AS.110.302, or equivalent.
Distribution Area: Engineering, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.423. Environmental Impacts of Climate Change. 3 Credits.**
This course will begin with a brief review of the climate system and climate change projections for the 21st Century and beyond. We will then study the impact of atmospheric carbon dioxide and other greenhouse gases on the earth's energy budget and understand the effect of these gases on radiative forcing on the earth's surface. Topics will include the impacts of rising temperatures and changing precipitation patterns, Arctic amplification, climate tipping points and the Atlantic Meridional Overturning Circulation (AMOC), sources and impacts of rising sea levels, heat waves, droughts, and forest fires. We will study the impact of rising temperatures on energy needs, public health, vulnerable populations, and spread of infectious diseases. The course will emphasize use of simple physics-based models of the underlying processes to develop an understanding of the observations and projections. We will learn the workflow of retrieving climate change projections from reliable databases and sources, and using GIS tools for spatial analysis, we will quantify the impacts of climate change as predicted under different representative concentration and shared socioeconomic pathways. The course will also cover preparedness and potential adaptation solutions to mitigate the impacts of climate change in the near term and in the long term. The course will include in-class discussions on relevant topics brought forward by students. Students will employ the tools and skills learned in the course to conduct a project (possibly in groups) focused on projected climate change impacts on a specific environmental or health issue and adaptation measures for a chosen location.Background recommended but not required: AS110.109 or equivalent; some background in climate studies is desirable but not essential.
Distribution Area: Engineering

**EN.570.425. Environmental Physics and Engineering. 3 Credits.**
In this course we will develop mechanistic models for several of the phenomena in nature that impact our environment. The course will begin with a brief review of commonly used mechanics-based techniques and continue with a study of dynamics of moving objects, systems of particles, inertial and rotating reference frames, tidal, centrifugal, and Coriolis forces, and large-scale flows. One focus area will be the dynamics of phenomena such as rockslides, avalanches, and flow of debris; the structural mechanics and propagation of seismic waves; and tsunamis. We will study atmospheric and deep ocean thermodynamics models and understand the heat transfer processes causing large-scale flows including large-scale oceanic and atmospheric waves. Related other topics will include coastal oceans, currents, and waves. We will also discuss molecular vibrations and radiation, motion of microscopic particles, random walks and diffusion, and self-propulsion of small organisms. As part of the course, students will work on a semester-long, application-focused project. Recommended prior coursework: AS.171.101, 110.108/109

**EN.570.426. Groundwater, Porous Media, and Hydrogeology. 3 Credits.**
Fundamentals of groundwater flow and transport emphasizing groundwater as a major water resource, role of groundwater in the hydrologic cycle and as an agent of geologic processes, groundwater management, and groundwater contamination and its protection. Specific topics include the Darcy equation, storage of water in a porous medium, mass conservation and the groundwater flow equation, solutions to the groundwater flow equation, well hydraulics, unsaturated flow and vadose zone processes, contaminant transport, dispersion and adsorption. Assignments will include quantitative exercises requiring simple computer codes.
**Prerequisite(s):** EN.570.351 or Equivalent

**EN.570.428. Problems in Applied Economics. 3 Credits.**
This course focuses on a monetary approach to national income determination and the balance of payments. Money and banking, as well as commodity and financial markets, are dealt with under both central banking, as well as alternative monetary regimes. Particular emphasis is placed on currency board systems. Students learn how to properly conduct substantive economic research, utilizing primary data sources, statistical techniques and lessons from economic history. Findings are presented in the form of either memoranda or working papers of publishable quality. Exceptional work may be suitable for publication through the Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise. Advanced excel programming skills are required and students are expected to be pre-screened for research at the Library of Congress in Washington, D.C.. Bloomberg certification is a pre-requisite.
**Prerequisite(s):** EN.660.203 AND AS.180.101 AND AS.180.102
Distribution Area: Social and Behavioral Sciences
Writing Intensive

**EN.570.429. Methods in Microbial Community Analysis. 3 Credits.**
This course will provide a practical knowledge of molecular methods used to identify microorganisms present with a sample and gain insight into their function and dynamics. It will provide theoretical background into how to identify microorganisms and infer functional capabilities from genetic material, practical knowledge of common molecular methods and computational skills needed to analyze the resulting sequence data. No background in molecular biology, computation or microbiology is necessary. Course objectives include (1) understanding key aspects of microbial community composition from literature reports; (2) recognizing major microbial taxonomic groups and understanding phylogenetic relationships; (3) developing molecular biology lab skills required to create gene amplicon libraries from an aquatic samples; (4) working knowledge of statistical methods used to associate taxonomic and functional gene information with specific environmental conditions. Recommended Course Background: Microeconomics, Introductory Statistics, Optimization.Open to undergraduates. Co-listed with EN.570.619
Distribution Area: Engineering, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.441. Environmental Inorganic Chemistry. 3 Credits.**
Advanced undergraduate/graduate course that explores the chemical transformations of elements of the periodic table. Thermodynamic, kinetic, and mechanistic tools needed to address the multiple chemical species and interfaces that are present in natural waters and water-based technological processes are emphasized. Ligand exchange, metal ion exchange, adsorption/desorption, precipitation/dissolution, electron and group transfer reactions, and other concepts from coordination chemistry will be covered. Applications include elemental sources and sinks in ocean waters, reactive transport in porous media, weathering and soil genesis, nutrient and toxic element uptake by organisms, water treatment chemistry, and rational design of synthetic chemicals.Co-listed with EN.570.641
**Prerequisite(s):** AS.030.101 AND AS.030.102
Distribution Area: Natural Sciences, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.442. Environmental and Analytical Organic Chemistry. 3 Credits.**
This course examines the major physical and chemical attributes and processes affecting the behavior of organic compounds in the environment. Emphasis is on anthropogenic hydrophobic organic compounds (e.g. halogenated organic compounds) and less hydrophobic emerging contaminants of concern (e.g. pharmaceuticals, explosives, etc). The course will also address (bio)analytical and computational approaches that are used to to detect organic compounds in the environment and assess their potential environmental and human health risks.
**Prerequisite(s):** EN.570.239 AND EN.570.303
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.443. Aquatic and Biofluid Chemistry. 3 Credits.**
Equilibrium speciation of natural waters, biofluids, and engineered systems. Topics include acids, bases, pH, and buffering; the precipitation and dissolution of solids; complexation and chelation; oxidation and reduction reactions; regulation and design. Intended for students from a variety of backgrounds. Recommended Course Background: One year of both Chemistry and Calculus. Meets with EN.570.643 (Aquatic and Biofluid Chemistry).
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.445. Physical and Chemical Processes I. 3 Credits.**
The application of basic physical and chemical concepts to the analysis of environmental engineering problems. Principles of chemical equilibrium and reaction, reaction engineering, interphase mass transfer, and adsorption are presented in the context of process design for unit operations in common use for water and wastewater treatment. Topics addressed include mass balances, hydraulic characteristics of reactors, reaction kinetics and reactor design, gas transfer processes (including both fundamentals of mass transfer and design analysis), and adsorption processes (including both fundamentals of adsorption and design analysis).
**Prerequisite(s):** EN.570.303 or permission of instructor.
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.446. Biological Process of Wastewater Treatment. 3 Credits.**
This course focuses on the fundamentals and applications of aerobic and anaerobic biological unit processes for the treatment of municipal wastewater, resource recovery from waste streams, and biological processes for drinking water production. The principles of activated sludge treatment, suspended and biofilm growth, biological nutrient removal, anaerobic treatment, solids handling and treatment, land treatment, and nutrient removal are presented. This course uses concepts from microbiology and the basic principles of stoichiometry, energetics, and microbial kinetics to support the design of biological unit processes. This course will meet with EN.570.646.
**Prerequisite(s):** Students who are currently enrolled in or have taken EN.570.646 are not eligible to take EN.570.446.
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.448. Physical and Chemical Processes II. 3 Credits.**
Fundamentals and applications of physical and chemical processes used in water and wastewater treatment. This class will cover particle interactions, coagulation, flocculation, granular media filtration, membrane processes, and emerging water treatment processes. Recommended Course Background: EN.570.445 or Permission Required.
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.449. Social Theory for Engineers. 3 Credits.**
Engineers work in a social context. This course addresses a number of questions about that social context. How should we understand how societies come about, how they evolve,and why the rules of the game are what they are? What is the relationship between the individual and society, what does it mean to be 'modern,' are there different forms of rationality? How might all this impinge on what it means to be an engineer?
Distribution Area: Humanities, Social and Behavioral Sciences
Writing Intensive

**EN.570.456. Environmental Electrochemistry. 3 Credits.**
This course focuses on the positive role that electrochemical science and engineering can play in the protection of the environment. Topics will include environmental electrochemical analyses, electrochemical methods for pollution abatement and control, water/air disinfection approaches, sensors, material recycling (metals) and green energy. The overarching goal of the course is to introduce students to the field of environmental electrochemistry through the study of electrochemical techniques and principles to environmental engineering and science. Prerequisites: One year of both Chemistry and Calculus.
**Prerequisite(s):** AS.030.101 AND AS.030.102
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.463. Analytical Chemistry and Product Design. An Environmental Perspective. 3 Credits.**
This course offers a holistic framework for evaluating the efficacy, chemical transformations, and environmental footprint of manufactured chemicals. Applications range from consumer products and reactor ingredients to pesticides and other chemicals intentionally added to farmlands and other environmental media. Analytical chemistry is a central feature of this course. Analytical instrumentation enables product purity to be tested, offers the means of monitoring reaction pathways and rates, and makes it possible to track dispersion and ultimate fate.
**Prerequisite(s):** Students who have taken, or are currently enrolled in, EN.570.663 are not eligible to take EN.570.463.
Distribution Area: Natural Sciences, Quantitative and Mathematical Sciences

**EN.570.470. Applied Economics & Finance. 3 Credits.**
This course focuses on company valuations, using a Probabilistic Discounted Cash Flow Model. Students use the model and primary data from financial statements filed with the Securities and Exchange Commission to calculate the value of publically-traded companies. Using Monte Carlo simulations, students also generate forecast scenarios, project likely share-price ranges and assess potential gains/losses. Stress is placed on using these simulations to diagnose the subjective market expectations contained in current objective market prices, and the robustness of these expectations. During the weekly seminar, students company valuations are reviewed and critiqued. A heavy emphasis is placed on research and writing. Exceptional work may be suitable for publication through the Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise. Advanced excel programming skills are required and students are expected to be pre-screened for research at the Library of Congress in Washington, D.C.. Bloomberg certification is a pre-requisite.
**Prerequisite(s):** EN.660.203 AND (EN.570.428 OR AS.360.528)
Distribution Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences
AS Foundational Abilities: Science and Data (FA2)
Writing Intensive

**EN.570.480. Energy Use, Climate Change, and Our Engineered Infrastructure. 3 Credits.**
The world needs to change from a fossil fuel energy infrastructure to one based on renewable energy to decrease CO2 emissions and minimize the impacts of climate change. This switch will require massive changes to our existing infrastructure as well as how we consume energy in our daily lives. Understanding and quantifying energy use is important for making effective changes in our daily energy use. In this course we will quantify energy use, study how much energy and water we use in our daily lives, and determine how much CO2 gets emitted from our homes and through our activities, as well as by components of our infrastructure (electric power industries, food systems, building materials such as concrete and steel, and transportation). We will calculate energy consumed by electric vehicles versus cars with internal combustion engines and compare that energy to that used by other forms of transportation. We will evaluate how our homes and buildings, and food and transportation infrastructure can be modified to reduce energy consumption and carbon emissions. Greenhouse gases that cause climate change include more than just carbon from fossil fuels. We will therefore also discuss sources of other greenhouse gases and methods to mitigate and reduce their emissions. Other topics include modeling rates of renewable energy growth, energy storage, climate science, and environmental and climate justice. This course is most appropriate for Engineering students, but it can be taken by any student interested in the topic. Prerequisites are Math and Chem.

**EN.570.490. Solid Waste Engineering and Management. 3 Credits.**
This course covers advanced engineering and scientific concepts and principles applied to the management of municipal solid waste (MSW) to protect human health and the environment and the conservation of limited resources through resource recovery and recycling of waste material. Topics include regulatory aspects and hierarchy of integrated solid waste management; characterization and properties of MSW; municipal wastewater sludge utilization; hazardous waste found in MSW; collection, transfer, and transport of solid waste; separation, processing, composting, and recycling of waste material; the landfill method of solid waste disposal which encompasses guidelines for design, construction, operation, siting, monitoring, remedial actions, and closure of MSW landfills. Permitting and public participation processes, current issues, and inventive approaches are also addressed.
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.491. Hazardous Waste Engineering and Management. 3 Credits.**
The course addresses traditional and innovative technologies, concepts, and principles applied to the management of hazardous waste to protect human health and the environment. Topics include regulatory requirements; fate and transport of contaminants; physical, chemical, and biological treatment; land disposal restrictions; guidelines for design, construction, and closure of hazardous waste landfills; environmental monitoring systems; management of medical waste and treatment options; management of underground and above-ground storage tanks; toxicology and risk assessment; pollution prevention and waste minimization; hazardous waste generators and transporters; permitting and enforcement of hazardous waste facilities; closure and financial assurance requirements; and RCRA Subtitle C Corrective Action and CERCLA/Superfund remediation processes.
Distribution Area: Engineering
AS Foundational Abilities: Science and Data (FA2)

**EN.570.497. Risk and Decision Analysis. 3 Credits.**
This class introduces the decision analysis approach to making decisions under risk and uncertainty. Topics covered include decision trees, Bayes law, value of information analysis, elicitation of subjective probabilities, multiattribute utility, and their applications to environmental and energy problems. Textbook: R.T. Clemen, Making Hard Decisions, 2014. Recommended Course Background: introductory statistics and probability.
Distribution Area: Engineering, Quantitative and Mathematical Sciences
AS Foundational Abilities: Science and Data (FA2)

**EN.570.498. Pursuing Sustainability Policy. 2 Credits.**
This seminar examines the pursuit of sustainability policy. Students will explore whether the complex systems approach to sustainability and sustainable development leads to different priorities, strategies, and methods compared to conventional approaches and analytical tools that are used in environmental policy. The seminar will draw from case studies related to energy and climate change, water sustainability, and land use change, as well as theoretical materials. Invited speakers will include technical experts and practitioners.

**EN.570.499. Pursuing Sustainability Policy: Knowledge to Action. 1 Credit.**
This seminar examines the pursuit of sustainability policy. Students will explore whether the complex systems approach to sustainability and sustainable development leads to different priorities, strategies, and methods compared to conventional approaches and analytical tools that are used in environmental policy. The seminar will draw from case studies related to energy and climate change, water sustainability, and land use change, as well as theoretical materials. Invited speakers will include technical experts and practitioners. This course is a continuation of EN.570.498, which is recommended but not required.

**EN.570.501. Undergraduate Research. 1 - 3 Credits.**
This course is open to EHE undergraduate majors only who are conducting an investigation of an environmental engineering problem under the supervision of the faculty instructor.
**Prerequisite(s):** You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

**EN.570.502. Undergraduate Research. 1 - 3 Credits.**
This course is open to EHE undergraduate majors only who are conducting an investigation of an environmental engineering problem under the supervision of the faculty instructor.
**Prerequisite(s):** You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

**EN.570.504. Financial Market Research. 3 Credits.**
This course investigates the workings of financial, foreign exchange, and commodity futures markets. Research is focused on price behavior, speculation, and hedging in these markets. Extensive research and writing of publishable quality are required. Exceptional work may be suitable for publication through the Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise. An approved research proposal is a pre-requisite.
**Prerequisite(s):** You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

**EN.570.505. Undergraduate Independent Study. 3 Credits.**
This course is open to EHE undergraduate majors only who are conducting an investigation of an environmental engineering problem and preparing a project deliverable under the supervision of the faculty instructor.
**Prerequisite(s):** You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

**EN.570.511. Group Undergraduate Research. 3 Credits.**
Students pursue research problems individually or in pairs. Although the research is under the direct supervision of a faculty member, students are encouraged to pursue the research as independently as possible. The professor and students will meet weekly in required meetings.
**Prerequisite(s):** You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

**EN.570.597. Undergraduate Research-Summer. 3 Credits.**
Investigation of an environmental engineering problem under faculty instructor supervision during summer session.
**Prerequisite(s):** You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

**EN.570.607. Energy Policy and Planning Models. 3 Credits.**
Methods for optimizing operation and design of energy systems and for analyzing market impacts of energy and environmental policies are reviewed, emphasizing both theory and solution of actual models. Review of linear and nonlinear programming and complementarity methods for market simulation. Recommended Course Background: EN.570.493 and EN.570.495 or equivalent.
Distribution Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.610. Engineering Microbiology. 3 Credits.**
Fundamental aspects of microbiology and biochemistry as related to environmental pollution and water quality control processes, biogeochemical cycles, microbiological ecology, energetics and kinetics of microbial growth, and biological fate of pollutants.
Distribution Area: Engineering, Natural Sciences

**EN.570.615. Current Trends in Environmental Microbiology. 3 Credits.**
This course will highlight recent discoveries and advances in environmental microbiology such as the identification of novel microbes, changing paradigms in nitrogen cycling, single-cell activity methods and novel methods in microbial community analysis. We will explore these topics by reading and discussing the current literature, supported by short lectures and in class activities related to the topics. Background in microbiology or microbial ecology is recommended. This course will meet with EN.570.415
Distribution Area: Engineering, Natural Sciences

**EN.570.616. Data Analytics in Environmental Health and Engineering. 3 Credits.**
Data analytics is a field of study involving computational statistics, data mining and machinelearning, to explore data sets, explain phenomena and build predictive models. The coursebegins with an overview of some traditional analysis approaches including ordinary leastsquares regression and related topics, notably diagnostic testing, detection of outliers andmethods to impute missing data. More recent developments are presented, including ridgeregression. Generalized linear models follow, emphasizing logistic regression and includingmodels for polytomous data. Variable subsetting is addressed through stepwise procedures andthe LASSO. Supervised machine learning topics include the basic concepts of boosting andbagging and several techniques: Decision Trees, Classification and Regression Trees, RandomForests, Conditional Random Forests, Adaptive Boosting, Support Vector Machines and NeuralNetworks. Unsupervised machine learning approaches are addressed through applications usingk-means Clustering, Partitioning Around Medoids and Association Rule Mining. Methods forassessing model predictive performance are introduced including Confusion Matrices, k-foldCross-Validation and Receiver Operating Characteristic Curves. Public health andenvironmental applications are emphasized, with modeling techniques and analysis toolsimplemented in R. EN.570 616 meets with EN.570.416. Undergraduate (usually Senior) students should sign up for 416 with permission of instructor only.
Distribution Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.619. Methods in Microbial Community Analysis. 3 Credits.**
This graduate level course will provide a practical knowledge of molecular methods used to identify microorganisms present with a sample and gain insight into their function and dynamics. It will provide theoretical background into how to identify microorganisms and infer functional capabilities from genetic material, practical knowledge of common molecular methods and computational skills needed to analyze the resulting sequence data. No background in molecular biology, computation or microbiology is necessary. Course objectives include (1) understanding key aspects of microbial community composition from literature reports; (2) recognizing major microbial taxonomic groups and understanding phylogenetic relationships; (3) developing molecular biology lab skills required to create gene amplicon libraries from an aquatic samples; (4) working knowledge of statistical methods used to associate taxonomic and functional gene information with specific environmental conditions. Recommended Course Background: Microeconomics, Introductory Statistics, Optimization.Co-listed with EN.570.429

**EN.570.623. Environmental Impacts of Climate Change. 3 Credits.**
This course will begin with a brief review of the climate system and climate change projections for the 21st Century and beyond. We will then study the impact of atmospheric carbon dioxide and other greenhouse gases on the earth's energy budget and understand the effect of these gases on radiative forcing on the earth's surface. Topics will include the impacts of rising temperatures and changing precipitation patterns, Arctic amplification, climate tipping points and the Atlantic Meridional Overturning Circulation (AMOC), sources and impacts of rising sea levels, heat waves, droughts, and forest fires. We will study the impact of rising temperatures on energy needs, public health, vulnerable populations, and spread of infectious diseases. The course will emphasize use of simple physics-based models of the underlying processes to develop an understanding of the observations and projections. We will learn the workflow of retrieving climate change projections from reliable databases and sources, and using GIS tools for spatial analysis, we will quantify the impacts of climate change as predicted under different representative concentration and shared socioeconomic pathways. The course will also cover preparedness and potential adaptation solutions to mitigate the impacts of climate change in the near term and in the long term. The course will include in-class discussions on relevant topics brought forward by students. Students will employ the tools and skills learned in the course to conduct a project (possibly in groups) focused on projected climate change impacts on a specific environmental or health issue and adaptation measures for a chosen location.Background recommended but not required: AS110.109 or equivalent; some background in climate studies is desirable but not essential.
Distribution Area: Engineering

**EN.570.625. Environmental Physics and Engineering. 3 Credits.**
In this course we will develop mechanistic models for several of the phenomena in nature that impact our environment. The course will begin with a brief review of commonly used mechanics-based techniques and continue with a study of dynamics of moving objects, systems of particles, inertial and rotating reference frames, tidal, centrifugal, and Coriolis forces, and large-scale flows. One focus area will be the dynamics of phenomena such as rockslides, avalanches, and flow of debris; the structural mechanics and propagation of seismic waves; and tsunamis. We will study atmospheric and deep ocean thermodynamics models and understand the heat transfer processes causing large-scale flows including large-scale oceanic and atmospheric waves. Related other topics will include coastal oceans, currents, and waves. We will also discuss molecular vibrations and radiation, motion of microscopic particles, random walks and diffusion, and self-propulsion of small organisms. As part of the course, students will work on a semester-long, application-focused project. Recommended prior coursework: AS.171.101, 110.108/109

**EN.570.626. Groundwater, Porous Media, and Hydrogeology. 3 Credits.**
Fundamentals of groundwater flow and transport emphasizing groundwater as a major water resource, role of groundwater in the hydrologic cycle and as an agent of geologic processes, groundwater management, and groundwater contamination and its protection. Specific topics include the Darcy equation, storage of water in a porous medium, mass conservation and the groundwater flow equation, solutions to the groundwater flow equation, well hydraulics, unsaturated flow and vadose zone processes, contaminant transport, dispersion and adsorption. Assignments will include quantitative exercises requiring simple computer codes. Recommended Course Background: A course in Differential Equations or Consent of Instructor.

**EN.570.633. Water and energy in the terrestrial biosphere. 3 Credits.**
How does water move through the landscape? How do we make predictions about how streamflow, groundwater, and soil moisture will respond to climate change and landscape change? In this course we will examine the processes controlling the movement of water, and the use of models to make hydrologic predictions. In particular the course covers the water balance, radiation balance and energy balance at the terrestrial earth surface; evaporation, transpiration, and their relationship to plant physiology and ecology; snow and ice; shallow groundwater, recharge, and base flow; runoff generation processes, and the role of surface and subsurface landscape structure. We will use simple model codes to gain an appreciation for the structure, calibration/validation, uncertainty, and post-processing of hydrologic models. Although the course is intended as a follow-on from Hydrology 570.353/653, it can be taken by any student with sufficient background, and with the consent of the instructor. Major assessment is a term paper (no exam).
Distribution Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.641. Environmental Inorganic Chemistry. 3 Credits.**
Advanced undergraduate/graduate course that explores the chemical transformations of elements of the periodic table. Thermodynamic, kinetic, and mechanistic tools needed to address the multiple chemical species and interfaces that are present in natural waters and water-based technological processes are emphasized. Ligand exchange, metal ion exchange, adsorption/desorption, precipitation/dissolution, electron and group transfer reactions, and other concepts from coordination chemistry will be covered. Applications include elemental sources and sinks in ocean waters, reactive transport in porous media, weathering and soil genesis, nutrient and toxic element uptake by organisms, water treatment chemistry, and rational design of synthetic chemicals. Co-listed with EN.570.441
Distribution Area: Engineering, Natural Sciences

**EN.570.642. Environmental and Analytical Organic Chemistry. 4 Credits.**
This course examines the major physical and chemical attributes and processes affecting the behavior of organic compounds in the environment. Emphasis is on anthropogenic hydrophobic organic compounds (e.g. halogenated organic compounds) and less hydrophobic emerging contaminants of concern (e.g. pharmaceuticals, explosives, etc). The course will also address (bio)analytical and computational approaches that are used to to detect organic compounds in the environment and assess their potential environmental and human health risks.
Distribution Area: Engineering, Natural Sciences

**EN.570.643. Aquatic and Biofluid Chemistry. 3 Credits.**
Equilibrium speciation of natural waters, biofluids, and engineered systems. Topics include acids, bases, pH, and buffering; the precipitation and dissolution of solids; complexation and chelation; oxidation and reduction reactions; regulation and design. Intended for students from a variety of backgrounds. Recommended Course Background: One year of both Chemistry and Calculus. Meets with EN.570.443 (Aquatic and Biofluid Chemistry)
Distribution Area: Engineering, Natural Sciences

**EN.570.644. Physical and Chemical Processes. 3 Credits.**
The application of basic physical and chemical concepts to the analysis of environmental engineering problems. Principles of chemical equilibrium and reaction, reaction engineering, interphase mass transfer, and adsorption are presented in the context of process design for unit operations in common use for water and wastewater treatment. Topics addressed include mass balances, hydraulic characteristics of reactors, reaction kinetics and reactor design, gas transfer processes (including both fundamentals of mass transfer and design analysis), and adsorption processes (including both fundamentals of adsorption and design analysis).
Distribution Area: Engineering

**EN.570.646. Biological Processes of Wastewater Treatment. 3 Credits.**
Fundamentals and application of aerobic and anaerobic biological unit processes for the treatment of municipal and industrial wastewater.
**Prerequisite(s):** Students who have taken or are enrolled in EN.570.446 are not eligible to enroll in EN.570.646.
Distribution Area: Engineering, Natural Sciences

**EN.570.648. Physical and Chemical Processes II. 3 Credits.**
Fundamentals and applications of physical and chemical processes used in water and wastewater treatment. This class will cover particle interactions, coagulation, flocculation, granular media filtration, membrane processes, and emerging water treatment processes.
Recommended Course Background: EN.570.445 or Permission Required.
Distribution Area: Engineering

**EN.570.649. Water quality of rivers, lakes, and estuaries. 3 Credits.**
Sustainably managing aquatic environments for ecosystem and public health in a changing climate requires us to understand the combined effect of multiple physical, chemical, and biological processes. This class will equip students to apply their understanding of environmental engineering principles to real-world water quality issues using computer simulation models. Emphasis will be placed on gaining insight by understanding fundamental assumptions and equations, and application to classical problems of oxygen demand and eutrophication. Advanced topics including pathogen and toxin dynamics will also be introduced. Students should have taken EN.570.303 (or equivalent).

**EN.570.652. Experimental Methods in Environmental Engineering and Chemistry. 4 Credits.**
An advanced laboratory covering principles of modern analytical techniques and their applications to problems in environmental sciences. Topics include electrochemistry, spectrometry, gas and liquid chromatography. The course is directed to graduate students and advanced undergraduates in engineering and natural sciences. Co-listed with EN.570.452
**Prerequisite(s):** Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.570.443 OR EN.570.643 OR permission of instructor.
Distribution Area: Engineering, Natural Sciences
Writing Intensive

**EN.570.653. Hydrology. 3 Credits.**
The occurrence, distribution, movement, and properties of the waters of the Earth. Topics include precipitation, infiltration, evaporation, transpiration, groundwater, and streamflow. Analyzes include the frequency of floods and droughts, time-series analyzes, flood routing, and hydrologic synthesis and simulation. Recommended Course Background: AS.110.302, EN.570.351
Distribution Area: Engineering

**EN.570.656. Environmental Electrochemistry. 3 Credits.**
This course focuses on the positive role that electrochemical science and engineering can play in the protection of the environment. Topics will include environmental electrochemical analyses, electrochemical methods for pollution abatement and control, water/air disinfection approaches, sensors, material recycling (metals) and green energy. The overarching goal of the course is to introduce students to the field of environmental electrochemistry through the study of electrochemical techniques and principles to environmental engineering and science.
Prerequisites: One year of both Chemistry and Calculus.
Distribution Area: Engineering

**EN.570.657. Air Pollution. 3 Credits.**
The course consists of an introduction to the fundamental concepts of air pollution. Major topics of concern are aspects of atmospheric motion near the earth's surface; basic thermodynamics of the atmosphere; atomospheric stability and turbulence; equations of mean motion in turbulent flow, mean flow in the surface boundary layer; mean flow, turbulence in the friction layer; diffusion in the atmosphere; statistical theory of turbulence; plume rise. Emphasis is place upon the role and utility of such topics in a systems analysis context, e.g., development of large and mesoscale air pollution abatement strategies. Comparisons of the fundamental concepts common to both air and water pollution are discussed.
Distribution Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.663. Analytical Chemistry and Product Design: An Environmental Perspective. 3 Credits.**
This course offers a holistic framework for evaluating the efficacy, chemical transformations, and environmental footprint of manufactured chemicals. Applications range from consumer products and reactor ingredients to pesticides and other chemicals intentionally added to farmlands and other environmental media. Analytical chemistry is a central feature of this course. Analytical instrumentation enables product purity to be tested, offers the means of monitoring reaction pathways and rates, and makes it possible to track dispersion and ultimate fate. Also offered as EN.570.453 for undergraduates.
Distribution Area: Natural Sciences, Quantitative and Mathematical Sciences

**EN.570.667. Sustainability Science and Policy: The Threat of Climate Change. 3 Credits.**
The challenge of sustainability is simultaneously promoting human well-being while protecting the environment. Advancing a transition toward sustainability hinges on applying what we know to what we should do, including undergirding public policies with knowledge—especially knowledge gleaned from science, technology, and engineering. This course examines sustainability science, communications, and public policy through the lens of climate—what is known about climate change and impacts, what motivates public understanding, and what actions through mitigation and adaptation make progress toward sustainability.

**EN.570.680. Energy Use, Climate Change, and Our Engineered Infrastructure. 3 Credits.**
The world needs to change from a fossil fuel energy infrastructure to one based on renewable energy to decrease CO2 emissions and minimize the impacts of climate change. This switch will require massive changes to our existing infrastructure as well as how we consume energy in our daily lives. Understanding and quantifying energy use is important for making effective changes in our daily energy use. In this course we will quantify energy use, study how much energy and water we use in our daily lives, and determine how much CO2 gets emitted from our homes and through our activities, as well as by components of our infrastructure (electric power industries, food systems, building materials such as concrete and steel, and transportation). We will calculate energy consumed by electric vehicles versus cars with internal combustion engines and compare that energy to that used by other forms of transportation. We will evaluate how our homes and buildings, and food and transportation infrastructure can be modified to reduce energy consumption and carbon emissions. Greenhouse gases that cause climate change include more than just carbon from fossil fuels. We will therefore also discuss sources of other greenhouse gases and methods to mitigate and reduce their emissions. Other topics include modeling rates of renewable energy growth, energy storage, climate science, and environmental and climate justice. This course is most appropriate for Engineering students, but it can be taken by any student interested in the topic. Prerequisites are Math and Chem.

**EN.570.690. Solid Waste Engineering and Management. 3 Credits.**
This course covers advanced engineering and scientific concepts and principles applied to the management of municipal solid waste (MSW) to protect human health and the environment and the conservation of limited resources through resource recovery and recycling of waste material. Topics include regulatory aspects and hierarchy of integrated solid waste management; characterization and properties of MSW; municipal wastewater sludge utilization; hazardous waste found in MSW; collection, transfer, and transport of solid waste; separation, processing, composting, and recycling of waste material; the landfill method of solid waste disposal which encompasses guidelines for design, construction, operation, siting, monitoring, remedial actions, and closure of MSW landfills. Permitting and public participation processes, current issues, and inventive approaches are also addressed.
Distribution Area: Engineering

**EN.570.691. Hazardous Waste Engineering and Management. 3 Credits.**
The course addresses traditional and innovative technologies, concepts, and principles applied to the management of hazardous waste to protect human health and the environment. Topics include regulatory requirements; fate and transport of contaminants; physical, chemical, and biological treatment; land disposal restrictions; guidelines for design, construction, and closure of hazardous waste landfills; environmental monitoring systems; management of medical waste and treatment options; management of underground and above-ground storage tanks; toxicology and risk assessment; pollution prevention and waste minimization; hazardous waste generators and transporters; permitting and enforcement of hazardous waste facilities; closure and financial assurance requirements; and RCRA Subtitle C Corrective Action and CERCLA/Superfund remediation processes.
Distribution Area: Engineering

**EN.570.695. Environmental Health and Engineering Systems Design. 3 Credits.**
A collection of systems analytic techniques which are frequently used in the study of public decision making is presented. Emphasis is on mathematical programming techniques. Primarily linear programming, integer and mixed-integer programming, and multiobjective programming. Recommended Course Background: AS.110.106-AS.110.107/AS.110.109
Distribution Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.697. Risk and Decision Analysis. 3 Credits.**
This class introduces the decision analysis approach to making decisions under risk and uncertainty. Topics covered include decision trees, Bayes law, value of information analysis, elicitation of subjective probabilities, multiattribute utility, and their applications to environmental and energy problems. Textbook: R.T. Clemen, Making Hard Decisions, 2014. Recommended Course Background: introductory statistics and probability.
Distribution Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.698. Pursuing Sustainability Policy. 2 Credits.**
This seminar examines the pursuit of sustainability policy. Students will explore whether the complex systems approach to sustainability and sustainable development leads to different priorities, strategies, and methods compared to conventional approaches and analytical tools that are used in environmental policy. The seminar will draw from case studies related to energy and climate change, water sustainability, and land use change, as well as theoretical materials. Invited speakers will include technical experts and practitioners.

**EN.570.699. Pursuing Sustainability Policy: Knowledge to Action. 1 Credit.**
This seminar examines the pursuit of sustainability policy. Students will explore whether the complex systems approach to sustainability and sustainable development leads to different priorities, strategies, and methods compared to conventional approaches and analytical tools that are used in environmental policy. The seminar will draw from case studies related to energy and climate change, water sustainability, and land use change, as well as theoretical materials. Invited speakers will include technical experts and practitioners. This course is a continuation of EN.570.698, which is recommended but not required.

**EN.570.800. Graduate Independent Study. 1 - 3 Credits.**
Investigation of an environmental engineering problem and preparation of project deliverable under supervision of faculty instructor.

**EN.570.801. Doctoral Research. 3 - 20 Credits.**
This course is intended for Ph.D. students continuing their doctoral research and thesis. Students should register for the section taught by their faculty advisor.
Distribution Area: Engineering, Natural Sciences

**EN.570.803. Master's Research. 3 - 10 Credits.**
Investigation of an environmental engineering problem and preparation of project report.
Distribution Area: Engineering

**EN.570.805. Jensen Internship. 3 Credits.**
The Jensen Fellowship/Internship is intended to support, through financial assistance and workplace experience, an Environmental Health and Engineering (EHE) graduate student seeking a terminal degree in environmental science or engineering. In honor of Loren D. Jensen, Ph.D., EA's founder and former faculty member of the Department of Geography and Environmental Engineering, the Fellowship is awarded to the applicant who best represents potential to develop into a consultant in the environmental consulting and engineering field.

**EN.570.841. Wolman Seminar- Graduates. 1 Credit.**
This course features a set of guest lectures from prominent faculty in environmental science and engineering. Each week, faculty in the department invite speakers from academic, government, or industrial institutions doing exciting work in their field. Students will be required to attend the seminar each week and are invited to ask questions of the speaker and interact with them before or after each seminar to learn about research and job opportunities in the field.

**EN.570.873. Environmental Science & Management Seminar. 1 Credit.**
A weekly meeting of students interested in systems analysis applications in the energy and environmental fields, which often involve multiple objectives, risks, public policy, and technological, economic, and natural environmental systems. There will be weekly visiting speakers or presentations by the students themselves on topical issues and methods for simulating, controlling, and designing energy and environmental systems.

**EN.570.881. Environmental Engineering Seminar. 1 Credit.**
A weekly meeting of students interested in environmental engineering, environmental chemistry, and engineering microbiology. Visiting speakers and the students themselves present their work and receive in-depth feedback from other participants.