

# ENVIRONMENTAL HEALTH AND ENGINEERING

<https://ehe.jhu.edu/>

Housed in both the Whiting School of Engineering and Bloomberg School of Public Health, the Department of Environmental Health and Engineering is the only program of its kind, bringing environmental engineering and public health faculty into a single, collaborative department. The overarching goal of the program is to prepare students to tackle the environmental challenges of the 21<sup>st</sup> century by both identifying existing and emerging environmental issues and developing innovative policy and technical solutions to address these threats to our environment and mankind.

EHE offers three programs of study, within the Whiting School of Engineering, to prepare students for a future in interdisciplinary scientific collaboration:

- an undergraduate program (Bachelor of Science in Engineering),
- a Master's program with varied tracks, concentrations, and research opportunities, and
- a doctoral degree program.

Drawing from a number of cross-divisional disciplines and approaches, EHE is concerned with identifying, exploring, and ultimately solving environmental problems including (but certainly not limited to):

- air pollution assessment, management and health outcomes
- aquatic chemistry
- bioinformatics
- climate and health
- drinking water, water reuse, and wastewater treatment
- environmental and economic policy, law, and management
- environmental nanotechnology
- energy and water systems
- epidemiology and epigenetics
- microbiology and microbial ecology
- toxicology, physiology, and metabolomics
- evaluation of environmental program impacts
- hazardous and solid waste engineering and management
- hydrology, transport and earth systems
- occupational exposure assessment and health impacts
- particle interaction
- pollutant fate and transport

Interdisciplinary, collaborative practices within our academic programs are necessary in order to most effectively identify and address long-standing, environmental questions and problems. Because of its diversity of interests and association with other departments within the university, EHE is able to offer a broad range of study and research opportunities for both undergraduate and graduate students.

## Facilities

Our state of the art labs and facilities are well-equipped for research and study within a vast array of interdisciplinary areas of study. On the Homewood campus, EHE offices and laboratories are located in Ames Hall and at the Stieff Building. In addition to computers for scientific

modelling laboratories, EHE has two undergraduate teaching labs and many individual laboratories for environmental engineering and health research. Each lab is equipped with a broad array of state-of-the-art analytical equipment for assessment of biologics and chemicals in water, waste water, and soil.

Extensive computer facilities and high speed computing are available both in the department and the university as a whole for computational and modeling studies.

On the Bloomberg campus, EHE offices and laboratories are located on the 6<sup>th</sup> and 7<sup>th</sup> floors of the Public Health building. Laboratories include state-of-the-art equipment and facilities for assessment of hazardous environmental chemicals/toxicants (airborne, waterborne, or foodborne) on human health and the exploration of the physiological, immune, genetic, and/or epigenetic origins of these effects.

Students have access to a broad range of core facilities on both campuses including: Mass Spectrometry and Proteomics, Biostatistics, and Data Management, Computational Biology, Genetics Resource Core, High Throughput Chemical Screening Core, Deep Sequencing and Microarray Cores.

Working with faculty on both campuses, students conduct research in our local, regional, national, and global laboratories and field sites.

## Undergraduate Programs

The Department of Environmental Health and Engineering offers:

- an undergraduate Bachelor of Science (B.S.) degree in Environmental Engineering
- five focus areas within the environmental engineering major:
  - Environmental Management and Economics
  - Environmental Engineering and Science
  - Land Air and Water Resources
  - Environmental Health Engineering
  - Energy Systems Analysis
- three minors:
  - a minor in environmental engineering
  - a minor in environmental sciences
  - a minor in engineering for sustainable development
- a five-year combined (B.S./M.S. or B.S./M.S.E.) program.

As part of these minor programs, or as part of other programs of the student's own design, the department offers electives in such areas as ecology, geomorphology, water and wastewater pollution treatment processes, environmental systems analysis, and environmental policy studies.

## Program Objectives

The B.S. in Environmental Engineering degree program is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org> (<http://www.abet.org/>).

## ABET Program Educational Objectives

The BSEE Program Educational Objectives focus on objectives that our graduates are expected to attain within a few years of graduation. The objectives were reviewed and approved by our external advisory committee in January 2022. The objectives are stated as follows:

The Program in Environment Engineering educates students to think critically, communicate clearly, and collaborate effectively in the rigorous application of engineering and scientific principles for solving environmental problems. We emphasize the importance of intellectual growth, professional ethics, service to society, and environmental stewardship, equity, and justice. Our graduates are prepared to be successful

- engineering professionals in private and governmental organizations, and
- students in the best graduate programs.

Students graduating with a B.S. in Environmental Engineering will have demonstrated:

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

## Annual Student Enrollment and Graduation Data

Academic Year	Total Enrolled	Total Graduated
2016-17	49	12
2017-18	49	10
2018-19	44	11
2019-20	44	4
2020-21	43	11
2021-22	49	

## Continuous Improvement

The Department of Environmental Health and Engineering strives to continuously improve its curriculum by using performance criteria to regularly assess its program educational objectives (what skills it expects its students to demonstrate). The environmental engineering program uses the results of each assessment to continuously improve upon its curriculum and thus ensure that it is meeting the needs of its students.

Our department is noted for our students' exceptionally high pass rate of the "Fundamentals of Engineering" (FE) exam offered by the National Council of Examiners for Engineering and Surveying (NCEES).

## Graduate Programs

Because of the department's unique cross-divisional affiliation, EHE is able to offer a wide array of masters and doctoral programs at the intersection of public health and engineering. With programs based both on the Bloomberg School of Public Health's East Baltimore campus and on the Whiting School of Engineering's Homewood campus, our graduate students benefit from expertise that is deep and broad in areas that include the science of chemical, biological and physical processes relevant to environment and health, environmental engineering, environmental and health policy, and data analytics.

Graduates of the department have found jobs in university departments of civil and environmental engineering, economics, biology, chemistry, geography, and geology; in federal, state, and municipal government; in private industry; and in private research and consulting organizations.

## Financial Aid

Financial aid is granted on the basis of merit and availability. Criteria for consideration for these awards include academic excellence, professional or research experience, and career commitment to the field. Ph.D. students receive full financial support while in fulltime, resident status. Partial tuition fellowships are offered to qualified master's students.

Furthermore, many students within the department have been awarded graduate research fellowships available to Ph.D. and Masters students through programs administered by the National Science Foundation and the Environmental Protection Agency.

## Programs

- Engineering for Sustainable Development, Minor (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/engineering-sustainable-development-minor/>)
- Environmental Engineering, Bachelor of Science (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/environmental-engineering-bachelor-science/>)
- Environmental Engineering, Minor (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/environmental-engineering-minor/>)
- Environmental Sciences, Minor (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/environmental-sciences-minor/>)
- Geography and Environmental Engineering, Master of Arts (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/environmental-health-engineering-master-arts/>)
- Geography and Environmental Engineering, Master of Science (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/environmental-health-engineering-master-science/>)
- Geography and Environmental Engineering, Master of Science in Engineering (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/environmental-health-master-science-engineering/>)
- Geography and Environmental Engineering, PhD (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/environmental-health-engineering-phd/>)

- Occupational and Environmental Hygiene, Master of Science (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/environmental-health-engineering/occupational-environmental-hygiene-master-sience/>)

For current course information and registration go to <https://sis.jhu.edu/classes/>

## Courses

### **EN.570.108. Introduction to Environmental Engineering and Design. 3 Credits.**

Overview of environmental engineering including water/air quality issues, water supply/ wastewater treatment, hazardous/solid waste management, pollution prevention, global environmental issues, public health considerations/environmental laws, regulations and ethics. Cross-listed with Public Health Studies.

Area: Engineering

### **EN.570.110. Introduction to Engineering for Sustainable Development. 3 Credits.**

Area: Humanities, Social and Behavioral Sciences

### **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.

Area: Natural Sciences

### **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.

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.

Area: Engineering, Natural Sciences

### **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.

Area: Engineering, Natural Sciences

### **EN.570.304. Environmental Engineering Laboratory. 3 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 458083 in the Search box to locate the appropriate module.;EN.570.303

Area: Engineering, Natural Sciences

### **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.

Area: Engineering, Quantitative and Mathematical Sciences

### **EN.570.320. Case Studies in Climate Change - A Field Course. 2 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. This course has a 2-credit co-requisite in the spring semester where we will travel to Eastern California for a week-long field trip. Please email the instructor if you are interested in this course ([smill191@jhu.edu](mailto:smill191@jhu.edu)) for more details on the co-requisite spring field trip.

### **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](mailto:smill191@jhu.edu)) for more details on the co-requisite.

**Prerequisite(s):** EN.570.320

### **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.

Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences

**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

Area: Engineering, Natural Sciences

**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)

Area: Engineering, Natural Sciences

**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 458083 in the Search box to locate the appropriate module.

Area: Engineering

**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

Area: Engineering

**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.

Area: Humanities, Social and Behavioral Sciences  
Writing Intensive

**EN.570.411. Engineering Microbiology. 4 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.

**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.

Area: Engineering, Natural Sciences

**EN.570.412. Landscape Hydrology and Watershed Analysis. 3 Credits.**

The purpose of this class is to understand the landscape-scale controls on the fluxes of water and waterborne materials through watersheds. This class differs from the Hydrology and Hydrologic Modeling classes in its focus on data analysis, and its embrace of the complexity of real landscapes. There will be significant quantitative components to the material taught, but emphasis will be on developing a greater sense of the way that landscapes "function", and how this function is related to real-world issues of water resources and pollution. Students will gain an understanding of how climate, geologic and ecologic setting, and human impacts control the partitioning of water between different fates, the flowpaths through the landscape and the storage and residence time of water. They will also learn conceptual and practical tools for analyzing hydrologic and other landscape data, and integrating this data in a holistic approach to watershed analysis. The class will be of interest for students intending to go into watershed or landscape management, and anyone wishing to pursue research in hydrology, geomorphology or ecology at landscape and watershed scales. The class will include at least one field trip to an instrumented watershed. GIS skills will be an advantage but are not required.

**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.

Area: Engineering, Natural Sciences

**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.

Area: Engineering, Quantitative and Mathematical Sciences

**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.

Area: Engineering

**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; atmospheric 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 placed 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.

Area: Engineering, Quantitative and Mathematical Sciences

**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

Area: Engineering

**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.

Area: Engineering, Quantitative and Mathematical Sciences

**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

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

Area: Engineering, Quantitative and Mathematical Sciences

**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

Area: Natural Sciences

**EN.570.442. Environmental Organic Chemistry. 3 Credits.**

Advanced undergraduate/graduate course focusing on processes that affect the behavior and fate of anthropogenic organic contaminants in aquatic environments. Students learn to predict chemical properties influencing transfers of organic chemicals between air, water, sediments, soil, and biota, based on a fundamental understanding of intermolecular interactions and thermodynamic principles.

**Prerequisite(s):** AS.030.101 AND AS.030.102. Course in organic chemistry preferred.

Area: Engineering, Natural Sciences

**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).

Area: Engineering, Natural Sciences

**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.

Area: Engineering

**EN.570.446. Biological Process of Wastewater Treatment. 3 Credits.**

Fundamentals and application of aerobic and anaerobic biological unit processes for the treatment of municipal and industrial wastewater.

Recommended Course Background: EN.570.411

Area: Engineering, Natural Sciences

**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.

Area: Engineering

**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?

Area: Humanities, Social and Behavioral Sciences

Writing Intensive

**EN.570.451. Environmental Dispersion and Transport. 3 Credits.**

The course will provide an overview of the basic foundations of transport and dispersion phenomena in the environment (surface water, groundwater, ocean and atmosphere). The emphasis will be on mathematical formulation of transport equations, analytical solutions, physical insights, methods of analysis of concentration data. The course will cover classical advection-diffusion concepts, shear dispersion phenomena, and transport in random velocity fields with applications to turbulent diffusion and macrodispersion in groundwater. Although numerical modeling is not the primary objective of the course, we will build a simple computational toolbox using random-walk particle tracking to visualize and quantify transport processes. Computation of analytical solutions will require MATLAB or python (or equivalent programming, although EXCEL may also suffice with macros). If time permits, we will touch upon reactive transport and non-Fickian transport formulations. Recommended course background in EN.553.291 Linear Algebra and Differential Equations and EN.570.351 Fluid Mechanics.

Area: Engineering, Natural Sciences

**EN.570.452. 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.570.652

**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

Area: Engineering, Natural Sciences  
Writing Intensive

**EN.570.454. Geostatistics: Understanding Spatial Data. 3 Credits.**

Spatial and geographic datasets are becoming increasingly common with improvements in data collection technologies. For example, satellites are able to collect more and more types of earth/environmental data, and web technologies (e.g., social media and e-commerce) provide vast new datasets on social, economic, and public health phenomena. However, many common statistical tools are ill-suited to spatial datasets; these datasets often exhibit complex spatial (and temporal) dependencies that require a special set of tools. In this course, students will learn how to quantitatively analyze, model, and predict spatial and spatiotemporal phenomena. Topics will include quantifying the spatial and temporal properties of data, interpolation and prediction, multivariate models, modeling uncertainty, measurement design, and strategies for very large datasets. We will draw examples from a wide variety of academic disciplines, including environmental engineering, earth science, public health, and political science. Pre-requisites: An introductory course in statistics is recommended. Knowledge of a scientific programming language (e.g., Matlab, R, or Python) will also be helpful.

Area: Engineering, 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)  
Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences  
Writing Intensive

**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.

Area: Engineering

**EN.570.491. Hazardous Waste Engineering and Management. 3 Credits.**

This course addresses traditional and innovative technologies, concepts, and principles applied to the management of hazardous waste and site remediation to protect human health and the environment. Co-listed with EN.570.691

Area: Engineering

**EN.570.492. Wolman Seminar - Undergraduates. 1 Credit.**

Undergraduates only with permission of instructor.

**EN.570.496. Urban and Environmental Systems. 3 Credits.**

The mathematical techniques learned in EN.570.305 and EN.570.495 are applied to realistic problems in urban and environmental planning and management. Examples of such problems include the siting of public-sector and emergency facilities; natural areas management, protection and restoration; solid waste collection, disposal, and recycling; public health; the planning and design of energy and transportation systems; and cost allocation in environmental infrastructure development.

Area: Engineering, Quantitative and Mathematical Sciences

**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.

Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.501. Undergraduate Research. 1 - 3 Credits.**

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration &gt; Online Forms.

**EN.570.502. Undergraduate Research. 1 - 3 Credits.**

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration &gt; 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 Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration &gt; Online Forms.  
Writing Intensive

**EN.570.505. Undergraduate Independent Study. 3 Credits.**

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration &gt; Online Forms.

**EN.570.590. Internship - Summer. 1 Credit.**

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration &gt; Online Forms.

**EN.570.597. Undergraduate Research-Summer. 3 Credits.**

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration &gt; 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.

**EN.570.610. Engineering Microbiology. 4 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.

**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. 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

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 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. EN.570.616 meets with EN.570.416. Undergraduate (usually Senior) students should sign up for 416 with permission of instructor only.

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.570.626. 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.570.631. Collaborative Modeling for Resolving Water Resources Disputes. 3 Credits.**

Overview of collaborative modeling in water resources, Economic issues in water resources disputes, Legal issues in water resources disputes, Biological/Environmental issues in water resources disputes, Water management in the Delaware Basin, Understanding and using the Delaware River Basin Commission's water management tool (an OASIS based model of the Delaware, Multi-objective water management, Understanding management trade-offs, Collaborative processes, Reality based negotiation skills, and Consensus building. Recommended Course Background: A strong interest in utilizing scientific tools to help resolve real-world disputes. A background in general science – with at least two of the following disciplines: Biology, chemistry, physics, earth science, economics.

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

Area: Natural Sciences



**EN.570.642. Environmental Organic Chemistry. 3 Credits.**

Advanced undergraduate/graduate course focusing on processes that affect the behavior and fate of anthropogenic organic contaminants in aquatic environments. Students learn to predict chemical properties influencing transfers of organic chemicals between air, water, sediments, soil, and biota, based on a fundamental understanding of intermolecular interactions and thermodynamic principles. New prerequisites (grad students only): at least one year of undergraduate general chemistry, a course in organic chemistry preferred.

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)

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).

Area: Engineering

**EN.570.647. Hydrologic Transport in the Environment. 3 Credits.**

This course considers the transport of solutes and sediments by water through terrestrial landscapes, with an emphasis on the movement of nutrients and contaminants from the landscape into receiving water bodies like rivers, lakes and estuaries. The course will cover the theoretical approaches (advection-diffusion/dispersion, transit time distributions), the use of active and passive tracers to infer transport processes, analysis of water quality time series, runoff generation and flow pathways in watersheds, and the effect of climate variability on transport. Assessment is based on a semester project and in-class presentations. Seniors interested in joining the class must have Hydrology 570.353 and should contact the instructor.

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.

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.570.650. Seminar on Critical Zone Science. 1 Credit.**

Seminar class covering foundational literature and current research in soils, geomorphology, hydrology, ecology, geochemistry, biogeochemistry, and related topics. Each semester will focus on a particular theme. The course is pass-fail, with attendance and engagement required, as well as minimal writing assignments intended to encourage critical thinking.

Area: Engineering, Natural Sciences

**EN.570.651. Environmental Transport and Dispersion. 3 Credits.**

The course will provide an overview of the basic foundations of transport and dispersion phenomena in the environment (surface water, groundwater, ocean and atmosphere). The emphasis will be on mathematical formulation of transport equations, analytical solutions, physical insights, methods of analysis of concentration data. The course will cover classical advection-diffusion concepts, shear dispersion phenomena, and transport in random velocity fields with applications to turbulent diffusion and macrodispersion in groundwater. Although numerical modeling is not the primary objective of the course, we will build a simple computational toolbox using random-walk particle tracking to visualize and quantify transport processes. Computation of analytical solutions will require MATLAB or python (or equivalent programming, although EXCEL may also suffice with macros). If time permits, we will touch upon reactive transport and non-Fickian transport formulations. Recommended course background in EN.553.291 Linear Algebra and Differential Equations and EN.570.351 Fluid Mechanics.

Area: Engineering, Quantitative and Mathematical Sciences

**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):** EN.570.443 OR EN.570.643 OR permission of instructor.; 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.

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

Area: Engineering

**EN.570.654. Geostatistics: Understanding Spatial Data. 3 Credits.**

Spatial and geographic datasets are becoming increasingly common with improvements in data collection technologies. For example, satellites are able to collect more and more types of earth/environmental data, and web technologies (e.g., social media and e-commerce) provide vast new datasets on social, economic, and public health phenomena. However, many common statistical tools are ill-suited to spatial datasets; these datasets often exhibit complex spatial (and temporal) dependencies that require a special set of tools. In this course, students will learn how to quantitatively analyze, model, and predict spatial and spatiotemporal phenomena. Topics will include quantifying the spatial and temporal properties of data, interpolation and prediction, multivariate models, modeling uncertainty, measurement design, and strategies for very large datasets. We will draw examples from a wide variety of academic disciplines, including environmental engineering, earth science, public health, and political science. Pre-requisites: An introductory course in statistics is recommended. Knowledge of a scientific programming language (e.g., Matlab, R, or Python) will also be helpful.

Area: Engineering, Quantitative and Mathematical Sciences

**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; atmospheric 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 placed 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.

Area: Engineering, Quantitative and Mathematical Sciences

**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.

Area: Engineering

**EN.570.691. Hazardous Waste Engineering and Management. 3 Credits.**

This course addresses traditional and innovative technologies, concepts, and principles applied to the management of hazardous waste and site remediation to protect human health and the environment.

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

Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.696. Urban and Environmental Systems. 3 Credits.**

The mathematical techniques learned in EN.570.305 and EN.570.495 are applied to realistic problems in urban and environmental planning and management. Examples of such problems include the siting of public-sector and emergency facilities; natural areas management, protection and restoration; solid waste collection, disposal, and recycling; public health; the planning and design of energy and transportation systems; and cost allocation in environmental infrastructure development.

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.

Area: Engineering, Quantitative and Mathematical Sciences

**EN.570.800. Graduate Independent Study. 1 - 3 Credits.****EN.570.801. Doctoral Research. 3 - 20 Credits.**

Area: Engineering, Natural Sciences

**EN.570.803. Master's Research. 3 - 10 Credits.**

Area: Engineering

**EN.570.805. Jensen Internship. 3 Credits.**

Restricted internship; reserved for students who have received the Jensen Fellowship.

**EN.570.841. Wolman Seminar- Graduates. 1 Credit.****EN.570.873. Environmental Science & Management Seminar. 1 Credit.****EN.570.881. Environmental Engineering Seminar. 1 Credit.****Cross Listed Courses****Center for Leadership Education****EN.660.345. Multidisciplinary Engineering Design 1. 3 Credits.**

This course number was formally EN.500.308. Students will work on teams with colleagues from different engineering disciplines to tackle a challenge for a clinical, community, or industry project partner. Through practicing a creative, human-centered design process, teams will understand the essential need behind the problem, prototype solutions, and test and refine their prototypes. In addition to project work, students will learn healthy team dynamics and how to collaborate among different working styles. Students will work on teams with colleagues from different engineering disciplines to tackle a challenge for a clinical, community, or industry project partner. Through practicing a creative, human-centered design process, teams will understand the essential need behind the problem, prototype solutions, and test and refine their prototypes. In addition to project work, students will learn healthy team dynamics and how to collaborate among different working styles. Students may choose to move their projects forward towards implementation in Multidisciplinary Engineering Design 2 in spring 2023.

Area: Engineering

**General Engineering****EN.500.113. Gateway Computing: Python. 3 Credits.**

This course introduces fundamental programming concepts and techniques, and is intended for all who plan to develop computational artifacts or intelligently deploy computational tools in their studies and careers. Topics covered include the design and implementation of algorithms using variables, control structures, arrays, functions, files, testing, debugging, and structured program design. Elements of object-oriented programming, algorithmic efficiency and data visualization are also introduced. Students deploy programming to develop working solutions that address problems in engineering, science and other areas of contemporary interest that vary from section to section. Course homework involves significant programming. Attendance and participation in class sessions are expected.

**Prerequisite(s):** Students may not have earned credit in: EN.500.112 OR EN.500.114 OR EN.510.202 OR EN.530.112 OR EN.580.200 OR EN.601.107 OR EN.500.132 OR EN.500.133 OR EN.500.134.

Area: Engineering