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 21st 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 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
- landscape hydrology and transport
- 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.

Undergraduate Programs

The Department of Environmental Health and Engineering offers:

- an undergraduate Bachelor of Science (B.S.E.) degree in Environmental Engineering
- four focus areas within the environmental engineering major:
  - Environmental Management and Economics
  - Environmental Engineering Science
  - Environmental Transport
  - Environmental Health Engineering
- 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.

Major in Environmental Engineering

The mission of our undergraduate program is to provide students with a broadly based yet rigorous education in the fundamental subjects central to the field, in a milieu that fosters development of a spirit of intellectual inquiry and the problem-solving skills required to address the open-ended issues characteristic of the real world.

Our B.S. program provides a strong foundation in the physical, chemical, and biological sciences, as well as in mathematics, engineering science, and engineering design. It is broad and flexible enough to accommodate students with a variety of interests in environmental engineering. This training should provide an ideal preparation for future employment in business or industry or for subsequent training at the graduate level.
either in environmental engineering or in a field such as environmental law, public health, or medicine.

Program Objectives
The B.S. in Environmental Engineering degree program is accredited by the Engineering Accreditation Commission of ABET, 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 May 2015. The objectives are stated as follows:

- The Program in Environment Engineering educates students to think critically, communicate clearly, and collaborate effectively as they apply the fundamental scientific principles of engineering to environmental problems. We emphasize the importance of intellectual growth, professional ethics, and service to society. 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:

- (a) an ability to apply knowledge of mathematics, science, and engineering
- (b) an ability to design and conduct experiments, as well as to analyze and interpret data
- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (d) an ability to function on multidisciplinary teams
- (e) an ability to identify, formulate, and solve engineering problems
- (f) an understanding of professional and ethical responsibility
- (g) an ability to communicate effectively
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- (i) a recognition of the need for, and an ability to engage in life-long learning
- (j) a knowledge of contemporary issues
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice;

and, the following specific Environmental Engineering outcomes:

- EE(1a) Understand and apply the principles upon which engineering practice is based: physical, chemical, and biological science
- EE(1b) Understand and apply the principles upon which engineering practice is based: mathematics and scientific computation
- EE(1c) Understand and apply the principles upon which engineering practice is based: economics
- EE(1d) Understand and apply the principles upon which engineering practice is based: engineering science
- EE(2) – Have the knowledge and skills to design, conduct, and evaluate experiments

- EE(3) – Understand the cross-media (air, water, earth) nature of environmental problems and the need for multidisciplinary approaches to their solution.
- EE(4) – Be able to design systems, components, or processes that provide engineering solutions to environmental problems given realistic economic, social, political, ethical, health, safety, and sustainability constraints
- EE(5) – Demonstrate critical thinking skills and ability for independent study needed to engage in life-long learning
- EE(6) – Possess the knowledge and skills to identify, formulate, and implement solutions to engineering problems using modern engineering tools and synthesizing different fields of knowledge
- EE(7) – Can communicate both orally and in writing, and effectively function in multidisciplinary teams
- EE(8) – Understand contemporary issues, the social nature of environmental problems, and the context in which environmental engineering is practiced in modern society
- EE(9) – Have access to specialized training through coursework and research
- EE(10) – Understand professional ethics and the value of service through participation in technical activities and in professional organizations

Annual Student Enrollment and Graduation Data
Academic Year/ Total Enrolled/ Total Graduated

2015-16/ 61/ 18
2016-17/ 56/ 13
2017-18/ 45/ 9

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).

Focus Areas within the Environmental Engineering (EE) Major
Students must select among four different focus areas:

- Environmental Management and Economics
- Environmental Engineering Science
- Environmental Transport
- Environmental Health Engineering

With the assistance of a faculty advisor, each student will plan a curriculum suited to his or her ultimate career goals. The program also encourages and supports individual study and research. Program requirements total 125 credits.

Mathematics with a focus on applications (19 credits)

Required Courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
<td>4</td>
</tr>
</tbody>
</table>
Environmental Health and Engineering

AS.110.109  Calculus II (For Physical Sciences and Engineering)  4
AS.110.202  Calculus III  4
or AS.110.302  Honors Multivariable Calculus
EN.553.291  Linear Algebra and Differential Equations  4
or AS.110.302  Differential Equations and Applications

An advanced course (300-level or higher) in probability and statistics. The Department of Applied Mathematics and Statistics offers a number of suitable courses. 4

Total Credits 19

Basic Science (BS) (24-25 credits)
Required courses:
AS.171.101  General Physics: Physical Science Major I  4
or AS.171.107  General Physics for Physical Sciences Majors (AL)
AS.171.102  General Physics: Physical Science Major II  4
or AS.171.108  General Physics for Physical Sciences Majors (AL)
AS.173.111  General Physics Laboratory I  1
AS.173.112  General Physics Laboratory II  1
One year of introductory chemistry (i.e. AS.030.101 Introductory Chemistry I and AS.030.102 Introductory Chemistry II)
AS.030.105  Introductory Chemistry Laboratory I  1
AS.030.106  Introductory Chemistry Laboratory II  1
EN.570.205  Ecology  3

An additional course in the biological sciences such as: AS.020.151 General Biology I, or EN.570.328 Geography & Ecology of Plants

Note: Premedical Students could substitute:
AS.020.305  Biochemistry  3
AS.020.306  Cell Biology  3
AS.020.315  Biochemistry Project lab  3
AS.020.316  Cell Biology Lab  3

Premedical students should also take additional chemistry courses as electives, such as:
AS.030.205  Introductory Organic Chemistry I  3
AS.030.206  Organic Chemistry II  3
AS.030.225  Introductory Organic Chemistry Laboratory  3

Total Credits 24

Humanities and Social Sciences (HS) (18 credits)
A minimum of six courses totaling 18 credits in Humanities or Social Sciences. The six courses must include:

1. one advisor-approved course that specifically develops writing skills (e.g., a how to write class),
2. EN.570.334 Engineering Microeconomics, and
3. four additional Humanities and Social Sciences courses with at least two at the 300-level or higher. EN.570.406 Environmental History can be taken as part of these requirements.

Please note that the writing course will fulfill one of the two writing intensive courses required by the university.

Note: most medical schools require a year of English literature and/or composition.

Required course:
EN.570.334  Engineering Microeconomics  3

Elective examples for EHE:
EN.570.406  Environmental History

Writing course examples:
AS.220.105  Fiction/Poetry Writing I  3
or AS.220.106  Fiction/Poetry Writing II
AS.220.146  Introduction to Science Writing  3
Either AS.060.113 or AS.060.114; both cannot be counted for H/S credit.
AS.060.113  Expository Writing  3
or AS.060.114  Expository Writing

Total Credits 15

General Engineering (GE) (16 credits)
Required courses:
EN.570.108  Introduction Environmental Engineering  3
An introductory course in computing, such as:
EN.570.210  Computation/Math Modeling  3
A course in thermodynamics, such as:
EN.540.203  Engineering Thermodynamics & EN.510.312 and Thermodynamics/Materials
or EN.530.231  Mechanical Engineering Thermodynamics
A course in Statics, such as:
EN.560.201  Statics & Mechanics of Materials  4
or EN.530.201  Statics and Mechanics of Materials
EN.570.351  Introduction to Fluid Mechanics  3

Total Credits 16

Design Experience and Engineering Laboratory (Senior Design) (D) (9 credits)
Required courses:
EN.570.305  Environmental Health and Engineering Systems Design  4
EN.570.419  Environmental Engineering Design I  2
EN.570.421  Environmental Engineering Design II  3

Total Credits 9

The Design and Synthesis sequence is a five-credit project course (2 credits fall semester, 3 credits spring semester) and involves a comprehensive study of the engineering design process from problem definition to final design. The course involves team projects that include written and oral presentations. Students will form small teams that will work with local companies or government agencies in executing the project. Prerequisite: senior standing in the Environmental Engineering major.

Environmental Engineering Requirements (23 credits)
Required courses: (15 credits)
EN.570.239  Emerging Environmental Issues  3
EN.570.303  Environmental Engineering Principles and Applications  3
EN.570.304  Environmental Engineering Laboratory  3
EN.570.353  Hydrology  3

Total Credits 12

Environmental Engineering Electives (15 credits):
Students take at least two courses from one of the following focus areas, and at least one course from two of the other focus areas, and one more
course from any focus area. Courses to be selected in consultation with advisor. Changes in courses must be accompanied by a Waiver/Substitution Form.

Environmental Management and Economics

- EN.570.418/618 Multiobjective Programming and Planning 3
- EN.570.496 Urban and Environmental Systems 3
- EN.570.497 Risk and Decision Analysis 3
- EN.570.490 Solid Waste Engineering and Management 3
- EN.570.491 Hazardous Waste Engineering and Management 3

Environmental Engineering Science

- EN.570.411 Engineering Microbiology 4
- EN.570.442 Environmental Organic Chemistry 3
- EN.570.443 Aquatic and Biofluid Chemistry 3
- EN.570.490 Solid Waste Engineering and Management 3
- EN.570.491 Hazardous Waste Engineering and Management 3

Environmental Transport

- EN.570.657 Air Pollution 3

Environmental Health Engineering

- AS.280.350 Fundamentals of Epidemiology 4
- PH.221.624 *
- PH.182.638 *
- PH.182.626 *
- PH.182.640 *
- PH.182.627 *
- PH.182.615 *
- PH.182.622 *
- PH.188.680 *
- PH.182.625 *

* Note: 600-level courses require permission of instructor

These courses are offered on the Bloomberg School of Public Health campus. For more information: http://www.jhsphs.edu/courses

Technical Electives (TE) (minimum of 12 credits)

(selected in consultation with an advisor)

At least three Engineering, Quantitative Studies, or Natural Sciences at or above the 300-level, subject to approval by the department totaling at least 12 credits.

Technical electives must fulfill the following requirements:

1. TEs must total 12 credits of advanced 300-level Engineering, Quantitative Studies, or Natural Sciences courses, and
2. TEs must be approved by the department. (For ABET requirements at least one from: Solid Waste; Hazardous Waste; Air Pollution; Environmental Health Engineering, if not satisfied as part of the Environmental Engineering electives.) Up to six credits of independent study or research may be applied toward engineering requirements (e.g., EN.570.501 Undergraduate Research/EN.570.502 Undergraduate Research, EN.570.505 Undergraduate Independent Study, or Senior Thesis). Note earlier comments for premedical majors.

It is strongly recommended that students take additional advanced classes in computing and numerical methods. EE students are strongly encouraged to take at least one course in organic chemistry (e.g., AS.030.205 Introductory Organic Chemistry I). The organic chemistry course will meet the TE requirement.

Guidance for Technical Electives for the EE Major

Technical electives are intended to provide students with courses with technical content and extend mastery in appropriate subject matter.

- TEs require use of fundamental science or mathematics, have appropriate prerequisites (e.g., university-level calculus, physics, chemistry, or other N or Q courses) and generally at a 300-level or higher.
- TEs must have the appropriate level of rigor which is defined as encompassing both of the following requirements:
  - 5-10 homework assignments; and
  - a culminating project (final project, group project, paper) or final examination. Lecture-only classes (no homework or exams) will not qualify as a TE for the EE major.
- TEs require accumulation and depth of analytical skill or knowledge. In general, this precludes survey courses or courses that have no technical prerequisites that are taught by multiple professors or a series of guest lecturers, or cover a broad spectrum of a topic instead of building mastery in one area.

Exceptions are possible only with the approval of either the Departmental Chair or Director of Undergraduate Studies.

Sample EE Program (Focus Area: Environmental Engineering Science)

Note: This program is based on the assumption that students have not previously completed A.P. courses in calculus, physics, chemistry, etc.

### First Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>AS.110.108 Calculus I (Physical Sciences and Engineering (M))</td>
<td>4</td>
<td>AS.110.109 Calculus II (For Physical Sciences and Engineering (M))</td>
<td>4</td>
</tr>
<tr>
<td>AS.030.101 Introductory Chemistry I (BS)</td>
<td>3</td>
<td>AS.030.102 Introductory Chemistry II (BS)</td>
<td>3</td>
</tr>
<tr>
<td>AS.030.105 Introductory Chemistry Laboratory I (BS)</td>
<td>1</td>
<td>AS.030.106 Introductory Chemistry Laboratory II (BS)</td>
<td>1</td>
</tr>
<tr>
<td>EN.570.108 Introduction Environmental Engineering (GE)</td>
<td>3</td>
<td>AS.171.101 General Physics: Physical Science Major I (BS)</td>
<td>4</td>
</tr>
<tr>
<td>HS Elective</td>
<td>3</td>
<td>AS.173.111 General Physics Laboratory I (BS)</td>
<td>1</td>
</tr>
<tr>
<td>EN.570.210 Computation/Math Modeling (GE)</td>
<td>3</td>
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</tbody>
</table>

14 16
## Minor in Environmental Engineering

Environmental engineers play particularly pivotal roles as professionals who bridge the gap between understanding complex scientific concepts and helping to formulate public policies that affect the environment. Environmental engineering has become an important aspect of engineering practice in most engineering fields, and the discipline spans the professional spectrum from the private sector through governmental agencies to academia. An undergraduate minor in environmental engineering allows engineering students to pursue an interest in this field and to incorporate aspects of environmental engineering into careers in other engineering disciplines.

Students in any undergraduate major in the Whiting School of Engineering are eligible for admission to the environmental engineering minor program. Students will work with an advisor in the Department of Environmental Health and Engineering to develop a program that meets the requirements for the minor and is consistent with the educational requirements of their major field of engineering study.

Requirements of the EE minor program consist of:

- a set of required core science and mathematics courses, already common to civil and chemical engineering majors;
- four required courses in environmental engineering (total of 12 credits, listed below); and
- two elective courses, one taken at the freshman or sophomore level, and the other taken at the junior or senior level.

### Core Courses (EE Minor)

Advanced placement credits and/or equivalent courses in other schools or departments are acceptable, subject to advisor approval.

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
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<tbody>
<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
<td>4</td>
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<tr>
<td>AS.110.109</td>
<td>Calculus II (For Physical Sciences and Engineering)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>AS.110.202</td>
<td>Calculus III or AS.110.211 Honors Multivariable Calculus</td>
<td>4</td>
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<tr>
<td>AS.030.101</td>
<td>Introductory Chemistry I</td>
<td>3</td>
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<tr>
<td>EN.553.291</td>
<td>Linear Algebra and Differential Equations</td>
<td>4</td>
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<tr>
<td>AS.030.102</td>
<td>Introductory Chemistry II</td>
<td>3</td>
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<tr>
<td>AS.030.105</td>
<td>Introductory Chemistry Laboratory I</td>
<td>1</td>
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<tr>
<td>AS.030.106</td>
<td>Introductory Chemistry Laboratory II</td>
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</tr>
<tr>
<td>AS.171.101</td>
<td>General Physics:Physical Science Major I or AS.171.107 General Physics for Physical Sciences Majors (AL)</td>
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<tr>
<td>AS.173.111</td>
<td>General Physics Laboratory I</td>
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<tr>
<td>AS.173.112</td>
<td>General Physics Laboratory II</td>
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</tbody>
</table>

### Required Courses (total of 12 credits)

Math (M) = 19 credits; Humanities and Social Sciences (HS) = 18 credits; Basic Science (BS) = 24 credits; General Engineering (GE) = 16 credits; Environmental Engineering Requirement (EER) = 15 credits; Environmental Engineering Electives (EEE) = 12 credits; Technical Electives (TE) = 12 credits; Design (D) = 9 credits

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EN.570.205</td>
<td>Ecology (BS)</td>
<td>3</td>
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<tr>
<td></td>
<td>HS Elective 3</td>
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<thead>
<tr>
<th>Second Year</th>
<th>Fall Credits</th>
<th>Spring Credits</th>
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<tbody>
<tr>
<td>AS.171.102</td>
<td>General Physics: Physical Science Major II</td>
<td>4</td>
</tr>
<tr>
<td>EN.553.291</td>
<td>Linear Algebra and Differential Equations</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.112</td>
<td>General Physics Laboratory II (BS)</td>
<td>1</td>
</tr>
<tr>
<td>EN.560.201</td>
<td>Statics Mechanics of Materials (GE)</td>
<td>4</td>
</tr>
<tr>
<td>EN.570.205</td>
<td>Ecology (BS)</td>
<td>3</td>
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<td></td>
<td></td>
<td>16</td>
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</table>

<table>
<thead>
<tr>
<th>Third Year</th>
<th>Fall Credits</th>
<th>Spring Credits</th>
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</thead>
<tbody>
<tr>
<td>EN.570.301</td>
<td>Environmental Engineering Fundamentals I (EER)</td>
<td>3</td>
</tr>
<tr>
<td>EN.570.305</td>
<td>Environmental Health and Engineering Systems Design (D)</td>
<td>4</td>
</tr>
<tr>
<td>EN.570.334</td>
<td>Engineering Microeconomics (HS Elective 4)</td>
<td>3</td>
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<tr>
<td>EN.570.351</td>
<td>Introduction to Fluid Mechanics (GE)</td>
<td>3</td>
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<tr>
<td>Environmental Engineering or Technical Elective (EEE or TE)</td>
<td>3</td>
<td>HS Elective 5</td>
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<tr>
<td>Environmental Engineering or Technical Elective (EEE or TE)</td>
<td>3</td>
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<td>16</td>
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</tbody>
</table>
Required Courses (EE Minor)
A total of 18 credits are required in addition to the previously specified core.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN.570.301</td>
<td>Environmental Engineering Fundamentals I</td>
<td>3</td>
</tr>
<tr>
<td>EN.570.302</td>
<td>Water &amp; Wastewater Treatment</td>
<td>3</td>
</tr>
<tr>
<td>EN.570.304</td>
<td>Environmental Engineering Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>EN.570.305</td>
<td>Environmental Health and Engineering Systems Design</td>
<td>4</td>
</tr>
</tbody>
</table>

Elective Courses
(Total of 6 credits) one course from each of two groups is required. Double counting of these courses with specified required courses in the student’s major is not allowed. Substitution for one required course may be possible under special circumstances, with explicit approval of the environmental engineering minor advisor. Additional course electives are possible but require approval of the environmental engineering minor advisor.

Group A
Introductory courses at the freshman and sophomore level. One course required.*

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>EN.570.108</td>
<td>Introduction Environmental Engineering</td>
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</tr>
<tr>
<td>EN.570.205</td>
<td>Ecology</td>
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<tr>
<td>EN.570.239</td>
<td>Emerging Environmental Issues</td>
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<tr>
<td>EN.570.328</td>
<td>Geography &amp; Ecology of Plants</td>
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<tr>
<td>AS.020.151</td>
<td>General Biology I</td>
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<tr>
<td>AS.270.220</td>
<td>The Dynamic Earth: An Introduction to Geology</td>
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Group B *

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>EN.570.353</td>
<td>Hydrology</td>
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<tr>
<td>EN.570.411</td>
<td>Engineering Microbiology</td>
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<tr>
<td>EN.570.442</td>
<td>Environmental Organic Chemistry</td>
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<tr>
<td>EN.570.443</td>
<td>Aquatic and Biofluid Chemistry</td>
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<tr>
<td>EN.570.445</td>
<td>Physical and Chemical Processes I</td>
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<tr>
<td>EN.570.490</td>
<td>Solid Waste Engineering and Management</td>
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<tr>
<td>EN.570.491</td>
<td>Hazardous Waste Engineering and Management</td>
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</tr>
<tr>
<td>AS.030.204</td>
<td>Chemical Structure and Bonding w/Lab</td>
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</tr>
<tr>
<td>AS.030.205</td>
<td>Introductory Organic Chemistry I</td>
<td></td>
</tr>
<tr>
<td>AS.030.301</td>
<td>Physical Chemistry I</td>
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<tr>
<td>AS.270.369</td>
<td>Geochem Earth/Environment</td>
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<tr>
<td>EN.540.301</td>
<td>Kinetic Processes</td>
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<tr>
<td>EN.540.303</td>
<td>Transport Phenomena I</td>
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</tbody>
</table>

Total Credits 6

* Engineering science courses that are developed for juniors and seniors and also introductory graduate-level courses. One course is required.

For further information, contact Dr. William P. Ball, EE Minor Coordinator, 410-516-5434, bball@jhu.edu, or Adena Rojas, Senior Academic Program Coordinator, 410-516-5533, arojas@jhu.edu.

Minor in Environmental Sciences
The environmental sciences minor has been developed to encourage and facilitate studies in environmental sciences by students completing degrees in the other science and engineering disciplines. The environmental sciences (ES) minor requires:

- completion of a set of courses in the core sciences,
- two introductory courses dealing with the environment, and
- three or more upper-level environmental sciences courses, as described.

Core Sciences (ES Minor)
Because of the interdisciplinary nature of environmental science, it is important that professionals from various areas of expertise acquire a common language and set of core concepts to make discussion and cooperation possible. The following courses represent the minimum set of requirements:

Mathematics (12 credits)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.109</td>
<td>Calculus II (For Physical Sciences and Engineering)</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.201</td>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.211</td>
<td>Honors Linear Algebra</td>
<td></td>
</tr>
<tr>
<td>AS.110.202</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.211</td>
<td>Honors Multivariable Calculus</td>
<td></td>
</tr>
<tr>
<td>AS.110.302</td>
<td>Differential Equations and Applications</td>
<td></td>
</tr>
</tbody>
</table>

Biology (3 credits)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.020.151</td>
<td>General Biology I</td>
<td>3</td>
</tr>
</tbody>
</table>

Physics (10 credits)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.171.101</td>
<td>General Physics: Physical Science Major I</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.107</td>
<td>General Physics for Physical Sciences Majors (AL)</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.102</td>
<td>General Physics: Physical Science Major II</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.108</td>
<td>General Physics for Physical Sciences Majors (AL)</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.111</td>
<td>General Physics Laboratory I</td>
<td>1</td>
</tr>
<tr>
<td>AS.173.112</td>
<td>General Physics Laboratory II</td>
<td>1</td>
</tr>
</tbody>
</table>

Chemistry (13 credits)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.030.101</td>
<td>Introductory Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>AS.030.105</td>
<td>Introductory Chemistry Laboratory I</td>
<td>1</td>
</tr>
<tr>
<td>AS.030.106</td>
<td>Introductory Chemistry Laboratory II</td>
<td>1</td>
</tr>
</tbody>
</table>

Total Credits 30

Environmental Sciences
Students must take two introductory courses dealing with the environment and three or more of the upper-level environmental science courses on the following lists:

Introductory Courses (6 credits)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN.570.110</td>
<td>Introduction to Engineering for Sustainable Development</td>
<td></td>
</tr>
<tr>
<td>EN.570.205</td>
<td>Ecology</td>
<td></td>
</tr>
<tr>
<td>EN.570.239</td>
<td>Emerging Environmental Issues</td>
<td></td>
</tr>
<tr>
<td>AS.270.110</td>
<td>Freshman Seminar: Sustainable + Non-Sustainable Resources</td>
<td></td>
</tr>
<tr>
<td>AS.270.220</td>
<td>The Dynamic Earth: An Introduction to Geology</td>
<td></td>
</tr>
<tr>
<td>AS.270.221</td>
<td>The Dynamic Earth Laboratory</td>
<td></td>
</tr>
</tbody>
</table>

Upper-Level Courses (9 credits)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN.570.239</td>
<td>Emerging Environmental Issues</td>
<td></td>
</tr>
<tr>
<td>EN.570.301</td>
<td>Environmental Engineering Fundamentals I</td>
<td></td>
</tr>
<tr>
<td>EN.570.302</td>
<td>Water &amp; Wastewater Treatment</td>
<td></td>
</tr>
</tbody>
</table>
century. Working as an engineer in this context involves negotiating environmental dislocation that afflict major parts of the globe in the 21st century. Engineers will be increasingly called upon to help devise solutions to the tremendous problems of poverty, inequality, and social and environmental dislocation that afflict major parts of the globe in the 21st century. Working as an engineer in this context involves negotiating highly complex social, economic, and political realities and dealing with a wide range of institutions and actors, including national and local governments, multilateral lenders such as the World Bank, diverse non-governmental organizations (NGOs), and local communities. It also increasingly involves working in interdisciplinary teams with social scientists, public health and medical workers, humanitarian aid workers, bankers, politicians, and the like. “Sustainable” development implies a development path that is socially equitable, culturally sensitive, and environmentally appropriate over a multi-generational time frame. The minor in Engineering for Sustainable Development exposes engineering students to some of the key issues related to development, methods of information-gathering in diverse and difficult settings, and working effectively with non-engineers on complex problems.

The minor encompasses seven courses. The core course is EN.570.110 Introduction to Engineering for Sustainable Development. Five additional courses will be selected in a program devised in consultation with the minor advisor.

**Of the Five Additional Courses**
- Three must be grouped around a specific theme, region or within a specific discipline. Themes might include, for example, public health, environment, or economic development. Regions include Africa, Latin America, or Asia. Disciplinary concentrations might be in Anthropology, Economics, Geography, History, Political Science, Public Health, or Sociology.
- Three of the courses must be at the 300-level or above.
- One of the courses must cover methods for gathering and evaluating information in a development context.

**Examples include:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.070.347</td>
<td>Anthropology and Public Action</td>
<td>3</td>
</tr>
<tr>
<td>AS.280.345</td>
<td>Public Health Biostatistics</td>
<td>4</td>
</tr>
<tr>
<td>AS.280.350</td>
<td>Fundamentals of Epidemiology</td>
<td>4</td>
</tr>
<tr>
<td>AS.230.202</td>
<td>Research Methods for the Social Sciences</td>
<td>3</td>
</tr>
</tbody>
</table>

**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 everything from the science of biological processes and environmental engineering to 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.

**Ph.D. Degree**

The goals for students in our Ph.D. program are:

- to develop reasoning skills that can be applied to new and unanticipated issues;
- learn how to pose questions and answer them in a logical manner;
- acquire a depth of understanding and technical knowledge in a particular study area, on par with others worldwide; and
• make a significant contribution to our understanding in this particular study area. The emphasis in the Ph.D. degree is upon a sound foundation in the fundamentals required in a given area with considerable flexibility in course selection determined by the interests and background of each graduate student. The doctoral student must take the equivalent of about two full academic years of formal course work. Roughly half of this is done in the principal subject, and the rest is chosen from allied fields. Students may request to move to non-resident status in their final semester, with the approval of the department and Dean’s Office once they have completed all exams and a defense date has been scheduled.

All students must pass departmental and Graduate Board oral examinations for the doctorate. Usually these examinations are taken after two years of academic work. Research leading to the dissertation should make an original contribution to the chosen field of specialization, and the result must be worthy of publication. A final dissertation defense that involves an open seminar and a closed oral examination is required of all EHE doctoral students. More information can be found in the departmental advising manual.

**Master of Science (M.S.) Degree**

The M.S. degree is open to students with undergraduate degrees in engineering, mathematics, biology, chemistry, physics, geology, and other scientific disciplines. The M.S. degree program includes the following requirements:

- A minimum of 30 graduate credits including no more than 1 credit of seminar, 1 credit of intersession course work or 1.5 credits from CLE (with advisor approval), and 6 credits of independent research counting toward the 30 credits.
- At least 50% of the required 30 credits must come from courses within the department.
- Students are permitted to apply up to two classes with a grade of “C” toward their degree.
- Up to two courses from AAP or EP may be taken and counted to receive a master’s degree as long as there is sufficient rigor and prior approval as deemed by the advisor. Students must have written consent from advisor (an email will suffice) prior to signing up for the course.

M.S. students have the option to complete an independent research project, submitted as a formal essay. A minimum of two semesters is required to complete the M.S. degree without the research project option. Three to four semesters are typically required to complete the degree with a research project.

M.S. students are strongly recommended to take mathematics-specifically differential equations and computing skills-as prerequisites for the M.S. program. Additionally, M.S. students who choose to follow Contaminant Fate and Transport, Environmental Process Engineering, and Water Resources Engineering concentrations are encouraged to take an introductory fluid mechanics course. Whether introductory fluid mechanics will count towards an M.S. student’s graduation credits is decided on a case-by-case basis by the department. Each individual’s program of study is planned by the student in consultation with department faculty and must be approved by the faculty advisor.

**Concentrations for the M.S. Degree**

**Environmental Science**

This concentration provides a broad yet rigorous background for environmental professionals. Using the department’s areas of interest, study, and research as guides and in consultation with their advisors, M.S. students can construct their own concentration that complements and expands their interests and professional goals. Additionally, M.S. students can choose to follow or pull from the M.S.E. concentration tracks: Contaminant Fate & Transport, Environmental Management and Economics, Environmental Process Engineering, and Water Resources Engineering.

**Environmental Science and Policy**

This concentration is similar to Environmental Science but includes economics and systems courses.

**Master of Science in Engineering (M.S.E.) Degree**

The M.S.E. degree is open to students with an ABET-accredited undergraduate engineering degree or demonstrated equivalent (as determined by the department). The M.S.E. degree program includes the following requirements:

- A minimum of 30 graduate credits including no more than 1 credit of seminar, 1 credit of intersession course work or 1.5 credits from CLE (with advisor approval), and 6 credits of independent research counting toward the 30 credits.
- At least 50% of the required 30 credits must come from courses within the department.
- Students are permitted to apply up to two classes with a grade of “C” toward their degree.
- 5-6 required courses and 4-5 recommended elective courses depending on concentration (Note: In order to substitute an alternate course for a recommended elective, students must receive written approval from their advisor).
- Prerequisites (required) for the M.S.E. program include mathematics: differential equations and computing skills.
- Up to two courses from AAP or EP may be taken and counted to receive a master’s degree as long as there is sufficient rigor and prior approval as deemed by the advisor. Students must have written consent from advisor (an email will suffice) prior to signing up for the course.

The M.S.E. program is typically a two semester program based on course work alone. However, M.S.E. students have the option to complete an independent research project, submitted as a formal essay or group project report. An M.S.E. degree with significant research components will usually require three to four semesters for completion and is generally intended for those students planning to work in engineering practice. Each individual’s program of study is planned by the student in consultation with department faculty and must be approved by the faculty advisor. M.S.E. students select from the concentrations below.

**Concentrations for the M.S.E. Degree**

**Contaminant Fate and Transport**

This concentration emphasizes understanding of physical, chemical, and biological phenomena that affect the movement and transformation of pollutants in the environment.

**Environmental Process Engineering**

This concentration involves the analysis and design of processes of water treatment, waste treatment, and environmental remediation, and includes a solid grounding in the chemical, biological, and physical principles underlying treatment and remediation technologies.
Water Resources Engineering
This concentration combines a solid grounding in environmental fluid mechanics and hydrology with electives in modeling, water development planning, policy, and contaminant fate and transport.

Environmental Management and Economics
This concentration focuses on using models of physical and economic systems to analyze and improve the design of public policies and environmental control systems.

M.A. Degree
The M.A. degree is open to students with undergraduate degrees in social sciences or the humanities. It requires:

- a minimum of 30 graduate credits including no more than 1 credit of seminar, 1 credit of intersession course work or 1.5 credits from CLE (with advisor approval), and 6 credits of independent research counting toward the 30 credits.
- at least 50% of the required 30 credits must come from courses within the department.
- students are permitted to apply up to two classes with a grade of “C” toward their degree.
- up to two courses from AAP or EP may be taken and counted to receive a master’s degree as long as there is sufficient rigor and prior approval as deemed by the advisor. Students must have written consent from advisor (an email will suffice) prior to signing up for the course.

M.A. students have the option to complete an independent research project, submitted as a formal essay. Students can focus on one of the department’s areas of interest, study, or research or construct their own program that complements and expands their undergraduate experience; three semesters are typically required to complete the degree. Each program of study is planned by the student in consultation with department faculty and must be approved by the faculty advisor.

For more detailed information about our Graduate programs, including course requirements and research opportunities, visit our website at ehe.jhu.edu

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. 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.

Faculty
Chair
Marsha Wills-Karp
Anna M. Baetjer Professor in Environmental Health and Engineering: allergy, asthma, immunology, pulmonary biology, environmental health, air pollution, genetics of asthma, microbiome

Professors
Jacqueline Agnew
aging workers, occupational health, environmental health, occupational stress, musculoskeletal disorders, ergonomics, neurotoxins
Shyam S. Biswal
electronic cigarettes, cigarette smoke, lung diseases, inflammation, cancer, COPD, emphysema, asthma
Edward J. Bouwer
Abel Wolman Professor of Environmental Engineering: environmental microbiology, waste treatment
Patrick N. Breysse,
industrial hygiene, exposure assessment, pollution, childhood asthma, environmental epidemiology
Grace S. Brush
ecology, paleoecology, plant geography
Srinivasan Chandrasegaran
restriction enzymes, methylases, chimeric nucleases, targeted recombination, zinc finger nucleases, targeted gene correction, targeted gene disruption, homologous recombination
Arthur Dannenberg
tuberculosis, BCG, sulfur mustard, cytokines, adhesion molecules, allergic dermatitis, macrophages and lymphocytes cell mediated immunity, CMI delayed-type hypersensitivity DTH
J. Hugh Ellis
environmental systems
Paul Ferraro
Bloomberg Distinguished Professor of Water and Environmental Economics: evaluation of environmental program impacts, behavioral economics
Robert Fitzgerald,
carotid body, chemotransduction, cardiopulmonary control, acetylcholine, catecholamines, gene-based differences in ventilatory response to hypoxia and in morphology/function of the carotid body

Alan Goldberg
toxicology, humane science, in vitro, Center for Alternatives to Animal Testing
John Groopman
chemical carcinogenesis, environmental carcinogenesis, chemoprevention, cancer prevention and control
Steve H. Hanke
applied micro- and macroeconomics and finance
Thomas Hartung
Benjamin F. Hobbs
Theodore K. and Kay W. Schad Professor of Environmental Management: environmental, energy, and water systems, economics
Thomas Inglesby
public health preparedness, global health security, biosecurity and biosafety, emerging infections, pandemic influenza, medicine and vaccine development policy, science diplomacy, preparedness indices, exercises, national policy
Thomas Kensler
chemical carcinogenesis, chemoprevention, hepatocarcinogenesis, reactive oxygen, antioxidants, enzyme induction, aflatoxin, oltipraz, chlorophyllin, sulforaphane, Keap1, Nrf2, triterpenoids

Peter Lees
industrial hygiene, occupational and environmental hygiene, exposure assessment, retrospective exposure assessment, surface contamination, dermal exposure, synthetic vitreous fibers, chromium

Jonathan Links
imaging, dosimetry, radiation, dirty bombs, nuclear medicine, radiological terror, public health preparedness

Wayne Mitzner
the structural basis of physiologic lung function, how this normal structure manifests itself in pathologic situations and environmental exposures

Gurumurthy Ramachandran
exposure assessment, occupational health, exposure models air pollution, Bayesian applications in exposure assessment, nanoparticles, occupational exposures, indoor air pollution, cookstove emissions, exposome

A. Lynn Roberts
environmental chemistry

Erica J. Schoenberger
economic geography, environmental history, environmental politics and policy, history of mining, history of the automobile, interdisciplinary scientific collaboration

Kellogg J. Schwab
Abel Wolman Professor in Water and Public Health: environmental microbiology, microbial fate and transport, water quality, drinking water treatment, disinfection, groundwater, wastewater, sewage, water and wastewater distribution systems, gastroenteritis, diarrhea, enteric pathogens, parasites (cryptosporidium, toxoplasma, giardia), viruses (norovirus, norwalk-like viruses, hepatitis A virus, rotavirus), bacterial indicators of water quality, bacteriophage, antibiotic resistant bacteria, molecular detection of microorganisms (PCR, RT-PCR, microarrays, hybridization), infectious diseases, microbial risk assessment, food borne and waterborne outbreak investigations, urban environmental pollution, airborne microorganisms, concentrated animal feeding operations (CAFO), Chesapeake Bay research

Brian Schwartz
biological markers, cognitive functioning, gene-environment interaction, genetic susceptibility, lead intoxication, molecular epidemiology, neurobehavioral testing, occupational epidemiology, occupational safety and health, retrospective assessment of exposure, solvents, chemicals, global warming, global environmental change, the built environment, unconventional fossil fuels, fracking, environmental epidemiology

Ellen Silbergeld
industrial farming, food safety, molecular devices for pathogen detection, disease modeling, antibiotic-resistant bacteria, heavy metals, environmental and occupational health

Alan T. Stone
environmental and aquatic chemistry

Paul Strickland
environmental and occupational health, molecular biomonitoring, genotoxic agents, carcinogens, genetic polymorphisms, carcinogen

James D. Yager
estrogens, estrogen, estradiol, estrogen metabolism, catechol-O-methyltransferase (COMT), catechols, estrogen receptor, estrogen receptors, carcinogenesis, liver cancer, breast cancer, genetic polymorphisms, environmental disease: molecular mechanisms, pathophysiology molecular, translational toxicology, training program in environmental health sciences

Associate Professors
Steven S. An
exposome and cellular engineering

Daniel Barnett J.
public health practice, preparedness, emergency response, training, exercises, evaluation, terrorism preparedness, all-hazards readiness, mental health, organizational change, public health workforce *

Joseph P Bressler
neurodevelopmental disorders, epigenetics, biomarkers, environmental toxicology

Gigi Kwik Gronvall
biosecurity, biodefense, biosafety, synthetic biology, emerging biotechnologies, national security, international security, medical countermeasure research and development, science policy

Christopher D. Heaney
environmental epidemiology, occupational and environmental health, Infectious diseases Water and health, global climate change, community-based participatory research

Paul A. Locke
environmental law, environmental policy, risk assessment, risk management, radon, radiation, alternatives to animal testing, regulation, uranium mining, space radiation

Norma F. Kanarek
environmental health sciences, public health practice, public health performance, surveillance tracking, community health, community health assessment, applied epidemiology, cancer

Jennifer Nuzzo
public health preparedness, emerging infectious disease, tuberculosis, water security, quarantine, biosurveillance, infectious disease diagnostics, International health regulations, global health security, Affordable Care Act, epidemiology, outbreak detection, outbreak response

Winnie Wan-yee
epigenetic reprogramming in development and disease, epigenetic epidemiology, DNA methylation, DNA hydroxymethylation, transgenerational inheritance, house dust mite, airborne PAHs, arsenic, endocrine disrupting chemicals, asthma, cardiovascular disease, cancer

Assistant Professors
Jessie Buckley P.
biomarkers, children's environmental health, developmental origins of health and disease, endocrine disruptors, environmental epidemiology, environmental phenols, epidemiologic methods, exposure assessment, exposure mixtures, obesity, occupational epidemiology, perinatal and pediatric epidemiology, phthalates

Meghan Frost Davis
antimicrobial resistance, asthma, environmental epidemiology, environmental microbiology, microbial ecology, microbiome, MRSA, MRSP, one health, staphylococci, veterinary medicine

Ciaran Harman
Russell Croft Faculty Scholar: landscape hydrology and transport

Kirsten Koehler
exposure assessment, aerosols, air quality, spatial statistics

Mark J. Kohr
cardiovascular disease, cardiac physiology, electrophysiology, proteomics, reactive nitrogen species, nitric oxide, s-nitrosylation, reactive oxygen species, nitroso-redox balance, oxidative stress, sex differences

Scot Miller
greenhouse gases, air pollution, atmospheric science

Keeve E. Nachman
arsenic, food systems, risk science, risk assessment, environmental epidemiology, industrial food animal production, animal waste, animal feed, foraging, urban gardens, agriculture, biosolids, veterinary drugs, Chesapeake Bay watershed protection, antimicrobial resistance, exposure assessment, regulatory toxicology, regulatory policy, chemical residues in food

Roni A. Neff
food system, food waste, meat, climate change, agriculture, policy, communication, sustainability, health disparities, Baltimore, history, occupational injury and illness, resilience

Carsten Prasse
environmental chemistry, exposome science, water treatment, environmental health

Sarah Preheim
environmental microbiology, microbial ecology, bioinformatics

Caitlin Rivers
epidemiology, infectious disease modeling, outbreak science, public health preparedness, public health response, open data, biosecurity, biodefense, public health policy, national security

Tara Kirk Sell
biosecurity, biodefense, public health preparedness, emerging infectious disease, federal funding, nuclear consequence management, Zika, Ebola, communication, risk, public health policy, emergency response

Fenna Sillé
immunology, immunotoxicology, arsenic, infectious disease, tuberculosis, early-life exposures, metabolomics

Genee S. Smith
climate change, environmental epidemiology, infectious disease, air pollution, extreme weather events

Zhibin Wang
human epigenome, epigenetic code, establishment mechanism of histone codes/patterns, environmental disease, next-generation sequencing, histone acetylation, HATs and HDACs, transcriptional regulation, DNA methylation, asthma, cancer, autoimmune diseases, HIV/AIDS

Crystal Watson
public health and medical preparedness, risk assessment and management, crisis decision making, emergency response, CBRN events, global catastrophic biological risk, terrorism preparedness, emerging infectious diseases, policy and funding analysis

Professor Emeritus
John J. Boland
environmental economics and policy

Research Professor
William P. Ball
environmental engineering, physical and chemical processes, water quality

Associate Teaching Professor
Hedy V. Alavi
Associate Teaching Professor: hazardous and solid waste engineering and management

Senior Research Associate
Katya Tsaioun
mechanisms of toxicity, integration of different streams of Evidence in toxicology and nutrition, determination of risk of bias of toxicological and nutrition studies, grading the evidence, food safety, developing public policy to change consumer behavior

Research Associates
Mary L. Doyle
ERC professional continuing education hearing conservation spirometry CE occupational health COHN-S CME continuing medical education

Helena Therese Hogberg
developmental neurotoxicity, 3D organotypic cell models and omics approaches

Andre Kleensang
metabolomics, transcriptomics, analytical chemistry, bioinformatics, biometry, genetic epidemiology, in vitro toxicology, regulatory toxicology, organs on a chip

David Pamies
In vitro models, alternative to animal testing, stem cells, microphysiological systems, Organ-on-a-chip, toxicology, brain development, neurotoxicology

Lena Smirnova
developmental neurotoxicity, gene environmental interactions, autism, cellular recovery and resilience, microRNA

Senior Scientist
Joanne Zurlo
animal welfare, animal models for human disease, alternatives to animal use

Lecturer
Justin C. Williams
environmental and urban systems

Assistant Scientists
Maureen A.F. Cadorette
occupational and environmental health, DOE Former Workers Program, occupational and environmental health nursing, thyroid dysfunction and work.

Jillian Parry Fry
agriculture, aquaculture, Chesapeake Bay watershed protection, climate change, communication, environmental justice, food system, health
EN.570.147. Adam Smith & Karl Marx. 3.0 Credits.
Smith and Marx are iconic figures in the history of political economic thought, often cited, rarely read. They are positioned as polar opposites in highly consequential debates about how society should be ordered. In this class, we will read and discuss their work, closely and carefully. We concentrate on the two iconic texts – The Wealth of Nations and Capital, Vol. 1 – but also explore some of their less well-known writings. Freshmen Only.
Instructor(s): E. Schoenberger; P. Jelavich
Area: Humanities, Social and Behavioral Sciences
Writing Intensive.

EN.570.205. Ecology. 3.0 Credits.
Introduction to processes governing the organization of individual organisms into populations, communities, and ecosystems. Interactions between individual organisms, groups of organisms, and the environment, including adaptation, natural selection, competition.
Instructor(s): G. Brush
Area: Natural Sciences.

EN.570.210. Computation/Math Modeling. 3.0 Credits.
An introduction to the use of computers in developing mathematical models. A structured approach to problem definition, solution, and presentation using spreadsheets and mathematical software. Modeling topics include elementary data analysis and model fitting, numerical modeling, dimensional analysis, optimization, simulation, temporal and spatial models. Recommended Course Background: AS.110.108 or equivalent.
Instructor(s): M. Beaudin
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.222. Environment and Society. 3.0 Credits.
Humans make their living in the environment. How do 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.
Instructor(s): E. Schoenberger
Area: Humanities, Social and Behavioral Sciences.

EN.570.239. Emerging Environmental Issues. 3.0 Credits.
Scientific principles underpinning environmental issues, with an emphasis on potential impacts of anthropogenic perturbation on human and ecosystem health. Recommended Course Background: two semesters of Chemistry.
Instructor(s): A. Roberts
Area: Engineering, Natural Sciences.

EN.570.285. Understanding Aid: Anthropological Perspectives for Technology-Based Interventions. 3.0 Credits.
This course combines anthropological perspectives with the discussion and examination of technology–based interventions in the field of development and aid policies, with particular focus on activities related to water resources, sanitation, and hygiene. Readings and discussions analyze some of the theoretical, historically rooted, and practical issues that challenge those who hope to provide effective aid. A key aim of this course is to provide students with better understanding of cultural, social, environmental and economic issues relevant to technical intervention in developing countries.
Instructor(s): E. Cervone; W. Ball
Area: Humanities, Social and Behavioral Sciences.

EN.570.301. Environmental Engineering Fundamentals I. 3.0 Credits.
Fundamentals and applications of physical and chemical processes in the natural environment and engineered systems. This class will cover material balances, chemical equilibrium, chemical kinetics, vapor pressure, dissolution, sorption, acid-base reactions, transport phenomena, reactor design, water quality, and environmental implications of nanotechnology.
Instructor(s): K. Chen
Area: Engineering, Natural Sciences.
EN.570.302. Water & Wastewater Treatment. 3.0 Credits.
Theory and design of water and wastewater treatment processes including coagulation, sedimentation, filtration, adsorption, gas transfer, aerobic and anaerobic biological treatment processes, disinfection, and hydraulic profiles through treatment units.
Prerequisites: EN.570.301 or permission required.
Instructor(s): W. Weiss
Area: Engineering, Natural Sciences.

EN.570.303. Environmental Engineering Principles and Applications. 3.0 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.
Instructor(s): C. Prasse
Area: Engineering, Natural Sciences.

EN.570.304. Environmental Engineering Laboratory. 3.0 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.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): A. Roberts
Area: Engineering, Natural Sciences.

EN.570.305. Environmental Health and Engineering Systems Design. 4.0 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.
Instructor(s): J. Ellis
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.314. Microbial Ecology. 3.0 Credits.
This course will highlight the latest methods in biotechnology revealing ecological principles determining the diversity and dynamics of microbial communities in a variety of ecosystems. We will explore advanced topics in ecology, such as niche theory, cooperation and speciation with examples from human health, engineering and environmental microbiology. Recommended Course Background: Ecology - EN.570.205 or Microbiology - AS.020.329
Instructor(s): S. Preheim
Area: Natural Sciences.

EN.570.328. Geography & Ecology of Plants. 3.0 Credits.
Patterns of aquatic and terrestrial plant species; historical changes in patterns using paleobotanical techniques; emphasis on biological and physical mechanisms controlling the patterns; the role of climate and man on plant distributions; several field trips; project required, which is the basis for the final grade.
Instructor(s): G. Brush
Area: Natural Sciences.

EN.570.334. Engineering Microeconomics. 3.0 Credits.
This course uses a calculus-based approach to introduce principles of engineering economics and microeconomics (demand and production theory) and their uses in engineering decision making. Recommended Course Background: AS.110.202
Instructor(s): B. Hobbs; P. Ferraro
Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences.

EN.570.351. Introduction to Fluid Mechanics. 3.0 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
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): J. Kim
Area: Engineering.

EN.570.353. Hydrology. 3.0 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
Instructor(s): C. Harman
Area: Engineering.

EN.570.395. Principles of Estuarine Environment: Chesapeake Bay. 3.0 Credits.
Topics include the physical, chemical, and biological components of the Chesapeake Bay ecosystem from the time it started to form some 10,000 to 12,000 years ago, when sea level began to rise as the continental glaciers receded; the geology, geomorphology, and biology of the watershed drained by the estuary; relationships between the watershed and the estuary through the millennia and the effect of climate, geomorphology, and humans on the ecology of the ecosystem and its economic productivity.
Instructor(s): G. Brush
Area: Engineering, Natural Sciences.

EN.570.402. Practicum on Appropriate and Sustainable Technology for Developing Communities. 2.0 Credits.
Suggested: Microeconomics, Introductory Statistics and Optimization.
Instructor(s): W. Ball
Area: Engineering.

EN.570.403. Ecology. 3.0 Credits.
This is a graduate level of EN.570.205; Addtional Writing Requirements.
Instructor(s): G. Brush
Area: Natural Sciences Writing Intensive.
EN.570.406. Environmental History. 3.0 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.
Instructor(s): E. Schoenberger
Area: Humanities, Social and Behavioral Sciences
Writing Intensive.

EN.570.411. Engineering Microbiology. 4.0 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.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): E. Bouwer
Area: Engineering, Natural Sciences.

EN.570.412. Landscape Hydrology and Watershed Analysis. 3.0 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 ecological 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.
Instructor(s): C. Harman
Area: Engineering, Natural Sciences.

EN.570.415. Current Trends in Environmental Microbiology. 3.0 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.
Instructor(s): S. Preheim
Area: Engineering, Natural Sciences.

EN.570.416. Data Analytics in Environmental Health and Engineering. 3.0 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 subseting 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.
Instructor(s): J. Ellis
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.418. Multiobjective Programming and Planning. 3.0 Credits.
Public sector problems are typically characterized by a multiplicity of objectives and decision makers. This course presents a relatively new area of systems analysis which is useful for such problems: multiobjective programming or vector optimization theory. The fundamental concepts are developed and various methods are presented, including multiattribute value and utility theory. Undergraduate level of EN.570.618. Recommended Prerequisites: EN.570.495, EN.570.305, EN.570.618.
Instructor(s): J. Williams
Area: Engineering, Natural Sciences.

EN.570.419. Environmental Engineering Design I. 2.0 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.
Instructor(s): E. Bouwer
Area: Engineering.

EN.570.420. Air Pollution. 3.0 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 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.
Instructor(s): J. Ellis
Area: Engineering, Quantitative and Mathematical Sciences.
EN.570.421. Environmental Engineering Design II. 3.0 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.570.302, EN.570.352, and EN.570.419
Instructor(s): E. Bouwer; H. Alavi
Area: Engineering.

EN.570.428. Problems in Applied Economics. 3.0 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.
Prerequisites: EN.660.203 AND AS.180.101 AND AS.180.102
Instructor(s): S. Hanke
Area: Social and Behavioral Sciences
Writing Intensive.

EN.570.429. Methods in Microbial Community Analysis. 3.0 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
Instructor(s): S. Preheim
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.431. Collaborative Modeling for Resolving Water Resources Disputes. 3.0 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.
Instructor(s): D. Sheer
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.435. Principles of Estuarine Environment: Chesapeake Bay. 3.0 Credits.
Topics include the physical, chemical, and biological components of the Chesapeake Bay ecosystem from the time it started to form some 10,000 to 12,000 years ago, when sea level began to rise as the continental glaciers receded; the geology, geomorphology, and biology of the watershed drained by the estuary; relationships between the watershed and the estuary through the millennia and the effect of climate, geomorphology, and humans on the ecology of the ecosystem and its economic productivity.
Instructor(s): G. Brush
Area: Engineering, Natural Sciences.

EN.570.441. Environmental Inorganic Chemistry. 3.0 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
Instructor(s): A. Stone
Area: Natural Sciences.

EN.570.442. Environmental Organic Chemistry. 3.0 Credits.
Advanced undergraduate/graduate course focusing on examination of processes that affect the behavior and fate of anthropogenic organic contaminants in aquatic environments. Students learn to predict chemical properties influencing transfers between hydrophobic organic chemicals, air, water, sediments, and biota, based on a fundamental understanding of intermolecular interactions and thermodynamic principles. Recommended Course Background: AS.030.104 or permission required.
Instructor(s): A. Roberts
Area: Engineering, Natural Sciences.
EN.570.443. Aquatic and Biofluid Chemistry. 3.0 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).
Instructor(s): A. Stone
Area: Engineering, Natural Sciences.

EN.570.445. Physical and Chemical Processes I. 3.0 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).
Prerequisites: EN.570.301 AND EN.570.302 or permission of instructor
Instructor(s): W. Ball
Area: Engineering, Natural Sciences.

EN.570.446. Biological Process of Wastewater Treatment. 3.0 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
Instructor(s): E. Bouwer
Area: Engineering, Natural Sciences.

EN.570.448. Physical and Chemical Processes II. 3.0 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.
Instructor(s): H. Arora
Area: Engineering.

EN.570.449. Social Theory for Engineers. 3.0 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?
Instructor(s): E. Schoenberger
Area: Humanities, Social and Behavioral Sciences
Writing Intensive.

EN.570.452. Experimental Methods in Environmental Engineering and Chemistry. 4.0 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
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): A. Stone
Area: Engineering, Natural Sciences
Writing Intensive.

EN.570.454. Geostatistics: Understanding Spatial Data. 3.0 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.
Instructor(s): S. Miller
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.470. Applied Economics & Finance. 3.0 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.
Prerequisites: EN.660.203 AND (EN.570.428 OR AS.360.528)
Instructor(s): S. Hanke
Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences
Writing Intensive.
EN.570.490. Solid Waste Engineering and Management. 3.0 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.
Instructor(s): H. Alavi
Area: Engineering.

EN.570.491. Hazardous Waste Engineering and Management. 3.0 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
Instructor(s): H. Alavi
Area: Engineering.

EN.570.492. Wolman Seminar - Undergraduates. 1.0 Credit.
Undergraduates only with permission of instructor.
Instructor(s): S. Preheim.

EN.570.493. Economic Foundations for Environmental Engineering and Policy Design. 3.0 Credits.
This course includes an exposition of intermediate level price theory, combined with a survey of applications to the analysis of public sector decisions. Theoretical topics include demand, supply, the function and behavior of the market, and introductory welfare economics.
Recommended Course Background: AS.180.101-AS.180.102, AS.110.202 or equivalent.
Instructor(s): J. Boland
Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences.

EN.570.495. Environmental Health and Engineering Systems Design. 3.0 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
Instructor(s): J. Ellis
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.496. Urban and Environmental Systems. 3.0 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.
Instructor(s): J. Williams
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.497. Risk and Decision Analysis. 3.0 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.
Instructor(s): B. Hobbs
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.501. Undergraduate Research. 3.0 Credits.
Instructor(s): Staff.

EN.570.502. Undergraduate Research. 0.0 - 3.0 Credits.
Instructor(s): Staff.

EN.570.504. Financial Market Research. 3.0 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.
Instructor(s): S. Hanke
Writing Intensive.

EN.570.505. Undergraduate Independent Study. 3.0 Credits.
Instructor(s): Staff.

EN.570.506. Maryland Department of the Environment Independent Study. 0.0 - 3.0 Credits.
This independent study within the MDE's Water Management Administration (WMA) will engage the student in scientific/policy literature and data research and management, field investigations, or evaluation of emerging issues and innovative approaches to surface and ground water protection and drinking water management, wastewater management, wetlands and non-point source pollution control. Each independent course will focus on a scientific, regulatory or policy topic designed to further the mission of the administration, which is to protect the public health and the aquatic environment. The student will be assigned to a WMA engineer, scientist or project manager to develop a course of study. Hours can be tailored to accommodate student's schedule.
Instructor(s): E. Bouwer.

EN.570.507. Independent Study: Baltimore City Energy Office. 3.0 Credits.
This Independent Study within Baltimore City's Energy Office will engage students in local energy policies, energy initiatives, data and City operations. Interns will have the chance to apply optimization and modeling skills to one of many projects. These projects can include: • Measurement and verification of performance contracts with energy service contractors • Collection of data from City operated co-generation and solar plants and developing operation models • Analyzing energy usage data from City buildings and making recommendations As part of an independent student project, students will be required to submit a final report and present their findings to the City. Hours can be tailored to accommodate student's schedule but a minimum of 10 hours per week during the semester is required. Permission required.
Instructor(s): E. Bouwer.

EN.570.510. Internship-Geog/Envr Eng. 0.0 - 3.0 Credits.
Instructor(s): E. Bouwer.
EN.570.511. Group Undergraduate Research. 3.0 Credits.
This section has a weekly research group meeting that students are expected to attend.
Instructor(s): C. Harman.

EN.570.590. Internship - Summer. 1.0 Credit.
Instructor(s): E. Bouwer; G. Brush; K. Chen; S. Guikema.

EN.570.597. Undergraduate Research-Summer. 3.0 Credits.
Instructor(s): Staff.

EN.570.599. Independent Study. 0.0 - 3.0 Credits.
Instructor(s): A. Roberts; B. Hobbs; S. Guikema.

EN.570.601. IGERT Water, Climate and Health Colloquium. 3.0 Credits.
Instructor(s): G. Brush.

EN.570.602. IGERT-Water, Climate & Health-Capstone. 3.0 - 20.0 Credits.
Instructor(s): G. Brush.

EN.570.603. Ecology. 3.0 Credits.
Introduction to processes governing the organization of individual organisms into populations, communities, and ecosystems. Interactions between individual organisms, groups of organisms, and the environment, including adaptation, natural selection, competition.
Instructor(s): G. Brush.

EN.570.605. Interdisciplinary Research Practice in Sustainability and Health. 3.0 Credits.
Through the application of interdisciplinary research methods and skills to case studies in environmental sustainability and health, the course will provide hands-on training in the management, coordination, and practice of interdisciplinary research. The goal is to enable doctoral students to work effectively on interdisciplinary research and prepare them for professional success in an increasingly interdisciplinary funding environment. This course will be in the format of a weekly seminar and laboratory and is open to all Johns Hopkins University doctoral students from any school. No prior knowledge of sustainability or public health is required.
Instructor(s): A. Monopolis; B. Hobbs.

EN.570.606. Statistical Computing. 1.0 Credit.
This course assumes a basic familiarity with programming in R. Some knowledge of probability and statistics will be a plus. The course introduces some key methods in implementing data-driven research. The course starts with a very brief review of programming in R and basics of probability and statistics and then spans into topics such as random variable generation, Monte Carlo integration, variance reduction techniques, uncertainty estimation, MCMC, probability density estimation and numerical methods. Recommend Course Background: EN.570.608 or equivalent.
Instructor(s): R. Nateghi.

EN.570.607. Energy Policy and Planning Models. 3.0 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.
Instructor(s): B. Hobbs.

EN.570.610. Engineering Microbiology. 4.0 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.
Instructor(s): E. Bouwer
Area: Engineering, Natural Sciences.

EN.570.614. Microbial Ecology. 3.0 Credits.
This course will highlight the latest methods in biotechnology revealing ecological principles determining the diversity and dynamics of microbial communities in a variety of ecosystems. We will explore advanced topics in ecology, such as niche theory, cooperation and speciation with examples from human health, engineering and environmental microbiology. Recommended Course Background: Ecology - EN.570.205 or Microbiology - AS.020.329
Instructor(s): S. Preheim
Area: Natural Sciences.

EN.570.615. Current Trends in Environmental Microbiology. 3.0 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
Instructor(s): S. Preheim
Area: Engineering, Natural Sciences.

EN.570.616. Data Analytics in Environmental Health and Engineering. 3.0 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.
Instructor(s): J. Ellis
Area: Engineering, Quantitative and Mathematical Sciences.
EN.570.618. Multiobjective Programming and Planning. 3.0 Credits.
Public sector problems are typically characterized by a multiplicity of objectives and decision makers. This course presents a relatively new area of systems analysis which is useful for such problems: multiobjective programming or vector optimization theory. The fundamental concepts are developed and various methods are presented, including multiattribute value and utility theory. Graduate level of EN.570.418. Recommended Prerequisites: EN.570.495, EN.570.305, EN.553.361
Instructor(s): J. Williams
Area: Engineering.

EN.570.619. Methods in Microbial Community Analysis. 3.0 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
Instructor(s): S. Preheim

EN.570.631. Collaborative Modeling for Resolving Water Resources Disputes. 3.0 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.
Instructor(s): D. Sheer
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.635. Principles of Estuarine Environment: Chesapeake Bay. 3.0 Credits.
Topics include the physical, chemical, and biological components of the Chesapeake Bay ecosystem from the time it started to form some 10,000 to 12,000 years ago, when sea level began to rise as the continental glaciers receded; the geology, geomorphology, and biology of the watershed drained by the estuary; relationships between the watershed and the estuary through the millennia and the effect of climate, geomorphology, and humans on the ecology of the ecosystem and its economic productivity.
Instructor(s): G. Brush
Area: Engineering, Natural Sciences.

EN.570.641. Environmental Inorganic Chemistry. 3.0 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
Instructor(s): A. Roberts
Area: Natural Sciences.

EN.570.642. Environmental Organic Chemistry. 3.0 Credits.
Advanced undergraduate/graduate course focusing on examination of processes that affect the behavior and fate of anthropogenic organic contaminants in aquatic environments. Students learn to predict chemical properties influencing transfers between hydrophobic organic chemicals, air, water, sediments, and biota, based on a fundamental understanding of intermolecular interactions and thermodynamic principles. Recommended Course Background: AS.030.104 or permission required.
Instructor(s): A. Roberts
Area: Engineering, Natural Sciences.

EN.570.643. Aquatic and Biofluid Chemistry. 3.0 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)
Instructor(s): A. Stone
Area: Engineering, Natural Sciences.

EN.570.644. Physical and Chemical Processes. 3.0 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).
Instructor(s): W. Ball
Area: Engineering.

EN.570.645. Reaction Mechanisms in Environmental Organic Chemistry. 3.0 Credits.
Detailed investigation of mechanisms of abiotic and biochemical transformations of organic pollutants in natural and engineered environments. Recommended Course Background: EN.570.442.
Instructor(s): A. Roberts
Area: Engineering, Natural Sciences.
EN.570.646. Water Quality and Treatment: Global Issues and Solutions. 3.0 Credits.
This course involves extensive student participation and is intended for motivated graduate students from both engineering and non-engineering disciplines who are interested in understanding technological aspects of water quality in the contexts of drinking water treatment, wastewater disposal, and sanitation for public health. The course involves extensive outside reading, in-class reflections on those readings, and a combination of instructor- and student-led in-class presentations. After this course, students should have improved understanding of: (1) Fundamental concepts of water quality and treatment as related to the application of engineering principles to the design and operation of unit operations for the removal of traditional and "emerging" contaminants; (2) Challenges to providing water of appropriate quality for drinking, sanitation, and environmental sustainability in the face of population growth and climate change; and (3) Alternative approaches for meeting those challenges, particularly as related to the design and application of technological interventions.
Instructor(s): W. Ball.

EN.570.647. Hydrologic Transport in the Environment. 3.0 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.
Instructor(s): C. Harman
Area: Engineering, Natural Sciences.

EN.570.648. Physical and Chemical Processes II. 3.0 Credits.
Fundamentals and applications of physical and chemical processes used in water and wastewater treatment. This class will cover particle interactions, coagulation, floculation, granular media filtration, membrane processes, and emerging water treatment processes. Recommended Course Background: EN.570.449 or Permission Required. Instructor(s): H. Arora
Area: Engineering.

EN.570.652. Experimental Methods in Environmental Engineering and Chemistry. 4.0 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
Prerequisites: EN.570.443 OR EN.570.643 OR Permission of Instructor
Instructor(s): A. Stone
Area: Engineering, Natural Sciences
Writing Intensive.

EN.570.653. Hydrology. 3.0 Credits.
The occurrence, distribution, movement, and properties of the waters of the Earth. Topics include precipitation, infiltration, evaporation, transpiration, groundwater, and streamflow. Analyzes 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
Instructor(s): C. Harman
Area: Engineering.

EN.570.654. Geostatistics: Understanding Spatial Data. 3.0 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/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.
Instructor(s): S. Miller
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.657. Air Pollution. 3.0 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.
Instructor(s): J. Ellis
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.676. Stochastic Programming. 3.0 Credits.
The course deals with computationally tractable methodologies for incorporating risk/uncertainty into mathematical programming (optimization) models. Focal topics include chance-constrained programming, stochastic linear programming, two-stage programming under uncertainty and stochastic dynamic programming. Some of these techniques may result in the creation of nonlinear models thus nonlinear/nonseparable optimization techniques are presented as well. Numerous applications are presented involving, for the most part, environmental (i.e., water and air resources) problems. Prerequisites: linear programming or equivalent, and introductory probability and statistics.
Instructor(s): J. Ellis.
EN.570.690. Solid Waste Engineering and Management. 3.0 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.
Instructor(s): H. Alavi
Area: Engineering.

EN.570.691. Hazardous Waste Engineering and Management. 3.0 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.
Instructor(s): H. Alavi
Area: Engineering.

EN.570.693. Economic Foundations for Environmental Engineering and Policy Design. 3.0 Credits.
This course includes an exposition of intermediate level price theory, combined with a survey of applications to the analysis of public sector decisions. Theoretical topics include demand, supply, the function and behavior of the market, and introductory welfare economics.
Recommended Course Background: AS.180.101-AS.180.102, AS.110.202 or equivalent. This course runs concurrently with EN.570.493 (Undergrads may register by special request for EN.570.493 in order to take this course.)
Instructor(s): J. Boland
Area: Quantitative and Mathematical Sciences, Social and Behavioral Sciences.

EN.570.695. Environmental Health and Engineering Systems Design. 3.0 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
Instructor(s): J. Ellis
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.697. Risk and Decision Analysis. 3.0 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.
Instructor(s): B. Hobbs
Area: Engineering, Quantitative and Mathematical Sciences.

EN.570.800. Graduate Independent Study. 1.0 - 3.0 Credits.
Instructor(s): Staff.

EN.570.801. Doctoral Research. 3.0 - 20.0 Credits.
Instructor(s): Staff
Area: Engineering, Natural Sciences.

EN.570.803. Master's Research. 3.0 - 10.0 Credits.
Instructor(s): Staff
Area: Engineering.

EN.570.805. Jensen Internship. 3.0 Credits.
Instructor(s): M. Wills-Karp.

EN.570.841. Wolman Seminar- Graduates. 1.0 Credit.
Instructor(s): S. Preheim.

EN.570.850. Graduate Independent Study. 1.0 - 3.0 Credits.
Instructor(s): E. Bouwer; M. Hilpert; S. Guikema; S. Preheim; W. Ball.

EN.570.873. Environmental Science & Management Seminar. 1.0 Credit.
Instructor(s): B. Hobbs; D. Sheer.

EN.570.881. Environmental Engineering Seminar. 1.0 Credit.
Instructor(s): A. Roberts; A. Stone; E. Bouwer.

Cross Listed Courses
Earth Planetary Sciences

AS.270.205. Introduction to Geographic Information Systems and Geospatial Analysis. 3.0 Credits.
The course provides a broad introduction to the principles and practice of Geographic Information Systems (GIS) and related tools of Geospatial Analysis. Topics will include history of GIS, GIS data structures, data acquisition and merging, database management, spatial analysis, and GIS applications. In addition, students will get hands-on experience working with GIS software.
Instructor(s): X. Chen
Area: Engineering, Natural Sciences.

Public Health Studies

AS.280.335. The Environment and Your Health. 3.0 Credits.
This course surveys the basic concepts underlying environmental health sciences (toxicology, exposure assessment, risk assessment), current public health issues (hazardous waste, water- and food-borne diseases), and emerging global health threats (global warming, built environment, ozone depletion, sustainability). Public Health Studies, Global Environmental Change and Stability, and Earth and Planetary Science majors have 1st priority for enrollment. Your enrollment may be withdrawn at the discretion of the instructor if you are not a GECS, PHS, or EPS major.
Instructor(s): J. Bressler; J. Yager; M. Latshaw
Area: Natural Sciences.

Interdepartmental

AS.360.147. Freshmen Seminar:Adam Smith and Karl Marx. 3.0 Credits.
This course will compare the ideas of Adam Smith, the most famous proponent of free trade and free enterprise, with those of Karl Marx, the greatest critic of capitalism. For freshmen only.
Instructor(s): E. Schoenberger; P. Jelavich
Area: Humanities, Social and Behavioral Sciences
Writing Intensive.
AS.360.528. Problems in Applied Economics. 2.0 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-
Bloomberg certification is a requisite.
Prerequisites: EN.660.203
Instructor(s): S. Hanke
Writing Intensive.

General Engineering
EN.500.112. Gateway Computing. 3.0 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.
Instructor(s): I. Sekyonda; J. Selinski; M. Darvish Darab
Area: Engineering, Natural Sciences.