Earth, Environmental, and Planetary Sciences

For students interested in studying the world beneath their feet or other worlds farther away, the Department of Earth, Environmental, and Planetary Sciences provides the tools for understanding the processes that shape our planet and other bodies within the solar system. Understanding the Earth system is also the key to addressing many environmental challenges, including climate change, water supply and energy issues. Earth, environmental, and planetary scientists are uniquely poised to help solve some of society's most pressing problems. Because planets are complex systems, Earth, environmental, and planetary sciences is, by necessity, an interdisciplinary field. It applies biology, chemistry, physics and math to the investigation of topics such as early life on Earth, the structure of the Earth's deep interior, the nature of contaminant transport, and the surfaces of other planetary bodies.

For students who have developed a passion for the basic sciences and who are looking for a way to study these sciences outside of traditional disciplinary boundaries, Earth, environmental, and planetary sciences is an ideal choice of major. The department offers majors and minors in Earth Science, Environmental Science, and Planetary Science. All programs offer a range of customization that allows students to focus on topics with the greatest relevance to their academic interests and career plans.

All students have the opportunity to participate in faculty research programs; however, this participation is not required. Many of our students take advantage of these varied research opportunities, which provide them with valuable experience for future employment or for graduate school. Each year, several scientific papers and abstracts are co-authored by undergraduate students, and undergraduate students have presented papers at many national science meetings.

Department Policies for Majors and Minors

Minimum grade performance: A grade of C- is the minimum acceptable performance for each unit of credit for each required course, including those in mathematics, chemistry and physics. Courses with grades of D may fulfill the College's 120 total units requirement, but they do not meet the departmental requirements. A grade of C- is also the minimum acceptable performance for each unit of credit for any course required as a prerequisite to enrolling in advanced or sequential courses.

Transfer credits and the School of Continuing & Professional Studies: Course work completed at another college or university must have prior approval of the department to be used to fulfill major requirements. Courses taken at the School of Continuing & Professional Studies normally may not be substituted for courses required for an Earth, environmental, and planetary sciences major. Written consent from the director of undergraduate studies is required for any such substitutions to apply and must be sought before the course is taken.

Graduate-level courses: All Earth, environmental, and planetary sciences graduate courses (i.e., courses numbered 500 and above) are open to advanced undergraduates with permission of the specific course instructor.

Faculty

Chair

David A. Fike (https://eps.wustl.edu/people/david-fike/)
Glassberg/Greensfelder Distinguished University Professor of Earth, Environmental, and Planetary Sciences
Director of the Environmental Studies Program
Director of the International Center for Energy, Environment and Sustainability
PhD, Massachusetts Institute of Technology

Associate Chair

Philip A. Skemer (https://eps.wustl.edu/people/philip-skemer/)
PhD, Yale University

Endowed Professors

Feng Sheng Hu (https://eps.wustl.edu/people/feng-sheng-hu/)
Richard G. Engelsmann Dean of Arts & Sciences
Professor of Biology and of Earth, Environmental, and Planetary Sciences
Lucille P. Markey Distinguished Professor in Arts & Sciences
PhD, University of Washington

Bradley L. Jolliff (https://eps.wustl.edu/people/bradley-l-jolliff/)
Director of the McDonnell Center for the Space Sciences
Scott Rudolph Professor of Earth, Environmental, and Planetary Sciences
PhD, South Dakota School of Mines and Technology

Douglas A. Wiens (https://eps.wustl.edu/people/douglas-wiens/)
Robert S. Brookings Distinguished Professor
PhD, Northwestern University

Professors

Jeffrey G. Catalano (https://eps.wustl.edu/people/jeffrey-g-catalano/)
PhD, Stanford University

M. Bruce Fegley (https://eps.wustl.edu/people/bruce-fegley-jr/)
PhD, Massachusetts Institute of Technology

David A. Fike (https://eps.wustl.edu/people/david-fike/)
Director of Environmental Studies
PhD, Massachusetts Institute of Technology

William B. McKinnon (https://eps.wustl.edu/people/william-b-mckinnon/)
PhD, California Institute of Technology

Philip A. Skemer (https://eps.wustl.edu/people/philip-skemer/)
PhD, Yale University

Jennifer Smith (https://eps.wustl.edu/people/jennifer-r-smith/)
Vice Provost for Educational Initiatives
PhD, University of Pennsylvania

William Hayden Smith (https://eps.wustl.edu/people/william-h-smith/)
PhD, Princeton University

Viatcheslav S. Solomatov (https://eps.wustl.edu/people/slava-solomatov/)
PhD, Moscow Institute of Physics and Technology
and the Schmidt Institute of Physics of the Earth

Michael E. Wysession (https://eps.wustl.edu/people/michael-e-wysession/)
PhD, Northwestern University

Associate Professors

Alexander S. Bradley (https://eps.wustl.edu/people/alexander-s-bradley/)
PhD, Massachusetts Institute of Technology

Paul Byrne (https://eps.wustl.edu/people/paul-byrne/)
PhD, Trinity College Dublin

Michael Krawczynski (https://eps.wustl.edu/people/michael-j-krawczynski/)
PhD, Massachusetts Institute of Technology

Kun Wang (https://eps.wustl.edu/people/kun-wang/)
PhD, Washington University

Assistant Professors

Bronwen L. Konecky (https://eps.wustl.edu/people/bronwen-konecky/)
PhD, Brown University

Claire Masteller (https://eps.wustl.edu/people/claire-masteller/)
PhD, University of California, Santa Cruz

Roger Michaelides (https://eps.wustl.edu/people/roger-michaelides/)
PhD, Stanford University

Rita Parai (https://eps.wustl.edu/people/rita-parai/)
PhD, Harvard University

Professors Emeriti

Raymond E. Arvidson (https://eps.wustl.edu/people/raymond-e-arvidson/)
PhD, Brown University

Robert E. Criss (https://eps.wustl.edu/people/robert-e-criss/)
PhD, California Institute of Technology

Ghislaine Crozaz (https://eps.wustl.edu/people/ghislaine-crozaz/)
PhD, Université Libre de Bruxelles

Robert F. Dymek (https://eps.wustl.edu/people/robert-f-dymek/)
PhD, California Institute of Technology

Jill D. Pasteris (https://eps.wustl.edu/people/jill-d-pasteris/)
PhD, Yale University

Frank A. Podosek (https://eps.wustl.edu/people/frank-podosek/)
PhD, University of California, Berkeley

Majors

The Department of Earth, Environmental, and Planetary Sciences (EEPS) offers majors in Earth Science, Environmental Science, and Planetary Science. The curriculum is broad, and the requirements are flexible enough to accommodate diverse needs and interests. Many courses present hands-on, problem-oriented experiences, including ample opportunity for fieldwork, laboratory work, and the use of state-of-the-art computational facilities and research instrumentation. All majors are required to complete certain core courses as well as electives and a capstone experience (https://eps.wustl.edu/capstone-experiences/) that must be presented at the Spring EEPS Undergraduate Research Symposium.

Note: The following requirements apply to students matriculating in Fall 2022 and later. For earlier requirements, please visit our prior Bulletin pages (https://bulletin.wustl.edu/about/prior/) and consult with the department's director of undergraduate studies.

Requirements for All Majors

Required Core Courses

Students pursuing any Earth, environmental, and planetary sciences major must complete the following courses:

Code	Title	Units
Chem 105	Introductory General Chemistry I	3
EEPS 202	Introduction to Earth, Environmental, and Planetary Science	3
Math 131	Calculus I	3
Math 132	Calculus II	3
Math 2200	Elementary Probability and Statistics	3
or Math 233	Calculus III	
or Math 3200	Elementary to Intermediate Statistics and Data Analysis	
Physics 191	Physics I	3

Additional Electives

In addition to the disciplinary electives below, which are specific to each major, students must choose three L19 EEPS elective courses at the 300, 400, or 500 level.

Skills Course

Students must complete one of the following:

Code	Title	Units
EEPS 387	Geospatial Science	4
EEPS 400	Special Topics	3
EEPS 492	Field Camp	-6
EEPS 496	Undergraduate Field Geology	3
EnSt 380	Applications in GIS	3
EnSt 364	Field Methods for Environmental Science	3

Capstone Experience

Students completing any Earth, environmental, and planetary sciences major must also build a portfolio of their work from projects completed in courses such as EEPS 496 Undergraduate Field Geology, EnSt 405 Sustainability Exchange: Community and University Practicums, EnSt 539 Interdisciplinary Environmental Clinic or EnSt 452 International Climate Negotiation Seminar; internship experiences; or research. All capstones must be presented at the Spring EEPS Undergraduate Research Symposium.

The Major in Earth Science

Students must complete all of the requirements listed above for all majors as well as the following:

Disciplinary Requirements

Students must complete the following two courses:

Code	Title	Units
EEPS 340	Minerals, Rocks, Resources and the Environment	4
EEPS 353	Earth Forces	4

Disciplinary Electives

Students select five of the following courses:

Code	Title	Units
EEPS 317	Soil Science	3
EEPS 323	Biogeochemistry	3
EEPS 385	Earth History	3
EEPS 386	The Earth's Climate System	3
EEPS 401	Earth Systems Science	3
EEPS 407	Remote Sensing	3
EEPS 409	Surface Processes	3
EEPS 422	Sedimentary Geology	3
EEPS 428	Hydrology	3
EEPS 437	Igneous & Metamorphic Petrology	4
EEPS 441	Introduction to Geochemistry	3
EEPS 452	Introduction to Seismology	3
EEPS 453	Interior of the Earth	3
EEPS 454	Exploration and Environmental Geophysics	4
EEPS 459	Geodynamics	3
EEPS 460	Introduction to Structural Geology	4
EEPS 486	Paleoclimatology	3

The Major in Environmental Science

Students must complete all of the requirements listed above for all majors as well as the following:

Disciplinary Requirements

Students must complete the following two courses:

Code	Title	Units
EEPS 340	Minerals, Rocks, Resources and the Environment	4
or EEPS 353	Earth Forces	
EEPS 342	Environmental Systems	3

Disciplinary Electives

Students select five of the following courses:

Code	Title	Units
Biol 381	Introduction to Ecology	3
Econ 451	Environmental Policy	3
or Pol Sci 2010	Introduction to Environmental Policy	
EECE 101	Introduction to Energy, Environmental and Chemical Engineering	3
EEPS 308	Topics in Environmental Sustainability	3
EEPS 317	Soil Science	3
EEPS 323	Biogeochemistry	3
EEPS 386	The Earth's Climate System	3
EEPS 407	Remote Sensing	3
EEPS 409	Surface Processes	3
EEPS 428	Hydrology	3
EEPS 442	Aqueous Geochemistry	3
EEPS 454	Exploration and Environmental Geophysics	4
EEPS 486	Paleoclimatology	3

The Major in Planetary Science

Students must complete all of the requirements listed above for all majors as well as the following:

Disciplinary Requirements

Students must complete the following two courses:

Code	Title	Units
EEPS 340	Minerals, Rocks, Resources and the Environment	4
EEPS 353	Earth Forces	4

Disciplinary Electives

Students select five of the following courses:

Code	Title	Units
EEPS 401	Earth Systems Science	3
EEPS 407	Remote Sensing	3
EEPS 437	Igneous & Metamorphic Petrology	4
EEPS 441	Introduction to Geochemistry	3
EEPS 459	Geodynamics	3
EEPS 460	Introduction to Structural Geology	4
EEPS 467	Planetary Mission Design	3
EEPS 473	Planetary Geology	3
EEPS 474	Planetary Geochemistry	3
EEPS 567	Planetary Materials	3
EEPS 568	Scientific Exploration of the Moon	3
EEPS 570	Planetary Geophysics & Dynamics	3
EEPS 576	Advanced Planetary Geology: Ice Worlds	3

Minors

Requirements for All Minors

Students pursuing any Earth, environmental, and planetary sciences minor must complete the following course:

Code	Title	Units
EEPS 202	Introduction to Earth, Environmental, and Planetary Science	3

The Minor in Earth Science

Students must complete all of the requirements listed above for all minors as well as the following:

Disciplinary Requirements

Students must complete the following two courses:

Code	Title	Units
EEPS 340	Minerals, Rocks, Resources and the Environment	4
EEPS 353	Earth Forces	4

Disciplinary Electives

Students select two of the following courses:

Code	Title	Units
EEPS 317	Soil Science	3
EEPS 323	Biogeochemistry	3
EEPS 385	Earth History	3
EEPS 386	The Earth's Climate System	3
EEPS 401	Earth Systems Science	3
EEPS 407	Remote Sensing	3
EEPS 409	Surface Processes	3
EEPS 422	Sedimentary Geology	3
EEPS 428	Hydrology	3
EEPS 437	Igneous & Metamorphic Petrology	4
EEPS 441	Introduction to Geochemistry	3
EEPS 452	Introduction to Seismology	3
EEPS 453	Interior of the Earth	3
EEPS 459	Geodynamics	3
EEPS 460	Introduction to Structural Geology	4
EEPS 486	Paleoclimatology	3

The Minor in Environmental Science

Students must complete all of the requirements listed above for all minors as well as the following:

Disciplinary Requirements

Students must complete the following two courses:

Code	Title	Units
EEPS 340	Minerals, Rocks, Resources and the Environment	4
or EEPS 353	Earth Forces	
EEPS 342	Environmental Systems	3

Disciplinary Electives

Students select two of the following courses:

Code	Title	Units
Biol 381	Introduction to Ecology	3
Econ 451	Environmental Policy	3
or Pol Sci 2010	Introduction to Environmental Policy	
EECE 101	Introduction to Energy, Environmental and Chemical Engineering	3

EEPS 308	Topics in Environmental Sustainability	3
EEPS 317	Soil Science	3
EEPS 323	Biogeochemistry	3
EEPS 386	The Earth's Climate System	3
EEPS 407	Remote Sensing	3
EEPS 409	Surface Processes	3
EEPS 428	Hydrology	3
EEPS 442	Aqueous Geochemistry	3
EEPS 454	Exploration and Environmental Geophysics	4
EEPS 486	Paleoclimatology	3

The Minor in Planetary Science

Students must complete all of the requirements listed above for all minors as well as the following:

Disciplinary Requirements

Students must complete the following two courses:

Code	Title	Units
EEPS 340	Minerals, Rocks, Resources and the Environment	4
EEPS 353	Earth Forces	4

Disciplinary Electives

Students select two of the following courses:

Code	Title	Units
EEPS 401	Earth Systems Science	3
EEPS 407	Remote Sensing	3
EEPS 437	Igneous & Metamorphic Petrology	4
EEPS 441	Introduction to Geochemistry	3
EEPS 459	Geodynamics	3
EEPS 460	Introduction to Structural Geology	4
EEPS 467	Planetary Mission Design	3
EEPS 473	Planetary Geology	3
EEPS 474	Planetary Geochemistry	3
EEPS 567	Planetary Materials	3
EEPS 568	Scientific Exploration of the Moon	3
EEPS 570	Planetary Geophysics & Dynamics	3
EEPS 576	Advanced Planetary Geology: Ice Worlds	3

The Minor in Geospatial Science

Students must complete all of the requirements listed above for all minors as well as the following:

Disciplinary Requirements

Students must complete the following two courses:

Code	Title	Units
EEPS 387	Geospatial Science	4
or EEPS 587	Geospatial Science	
EnSt 380	Applications in GIS	3

Disciplinary Electives

Students select three of the following courses:

Code	Title	Units
Anthro 4803	Advanced GIS Modeling and Landscape Analysis	3
CSE 217A	Introduction to Data Science *	3
CSE 314A	Data Manipulation and Management *	3
CSE 417T	Introduction to Machine Learning *	3
EEPS 407	Remote Sensing	3
EEPS 468	Geospatial Field Methods	3
EnSt 481	Advanced GIS	3
EnSt 482	Applications in Geospatial Intelligence	3
EnSt 483	Introduction to Spatial Epidemiology	3
ESE 417	Introduction to Machine Learning and Pattern Classification *	3

* Previous or concurrent enrollment in CSE 131 Introduction to Computer Science is recommended.

Courses

Visit online course listings to view semester offerings for L19 EEPS (https://courses.wustl.edu/CourseInfo.aspx?sch=L&dept=L19&crslvl=1:4).

L19 EEPS 103A Oceanography
Emphasis on geological, chemical, and physical oceanography. Topics: topography and origin of ocean basins; origin and composition of sea water; effect of compositional variations on biological productivity; dynamics of water movements, including coastal processes.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EEPS 104 First-Year Seminar: Geology in the Field
This course is designed to develop foundational skills in field geology and Earth science while promoting leadership and teamwork. There are no prerequisites, and the class is suitable for students with little or no academic background in Earth science. Students are not required to have extensive outdoor experience, but they must demonstrate enthusiasm for work in challenging environments. Students will receive training in a variety of geological field methods, including field mapping, sampling protocols, section measurement, and structural identification and analysis. This course is field-intensive, with multiple field exercises during class periods and two or three weekend field trips that will involve camping, caving, and backcountry hiking. This course is primarily suited for students who enjoy working outdoors and who intend to major in Earth, Environmental, and Planetary Sciences, Biology, Anthropology, or Archaeology. Course enrollment preference is given to first-year students.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 105 Habitable Planets
Why does the Earth have water oceans? Where did our atmosphere come from? Is Earth uniquely habitable among solar system bodies? This course is an exploration of the origins of volatiles such as water and carbon on planetary bodies and of the internal features that help to regulate our planet's surface conditions. The importance of magnetic fields, plate tectonics, and climate feedbacks with respect to the origins and sustenance of life on Earth will be discussed.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 106 First-Year Opportunity: Exploring the Planets
How do humans explore other worlds? This course will introduce how NASA and other space agencies explore our Solar System and beyond. The first part of the course will describe why we explore planets, and how decisions are made as to what missions to fly; the latter portion of the course then focuses on past, current, and planned missions to major Solar System bodies. Course content will include faculty- and guest lecturer-led presentations on spacecraft mission design and how missions are implemented. Students will give individual presentations on a planetary body of their choice, and will work in groups to study spacecraft missions currently in flight.
Credit 3 units. A&S: FYO A&S IQ: NSM Art: NSM

L19 EEPS 108A Oceans and the Atmosphere
Basic concepts of the evolution and physical structures of the Earth's oceans and the atmosphere. Dynamic aspects of the oceans (waves, tides, tsunamis) and atmospheric circulation (weather). Role of biological processes (including anthropogenic) in defining the present oceans and atmosphere. Global climate issues discussed in EEPS 111.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 109A Quantitative Reasoning in Environmental Science
Introduction to practical mathematical methods for understanding environmental aspects of our planet, particularly how the environment changes with time through human interactions. Emphasis on intuitive approaches in devising simple relationships for understanding quantitative outcomes of natural processes. Introduction to basic statistical methods, including hypothesis testing, and how statistics can be applied to environmental problems.
Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI

L19 EEPS 111 Introduction To Global Climate Change In the 21st Century
Global climate and global climate change and their impacts on life and civilization. Integrated view of global climate and the diverse forces that can alter global climate. Historical and potential future consequences of global climate change on human life, our industrial civilization, and its sustainability.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 112 First-Year Seminar: Engineering the Climate
Geoengineering, the deliberate manipulation of the earth's climate, may be part of a solution to the predicted future global warming. Is this advisable, or even possible? Discussions,lectures, and readings used to learn how earth's climate works. Examination of some proposals for altering the climate. Past attempts for deliberate human alteration of natural systems discussed and evaluated. Consideration of geoengineering as an ethical issue. Prerequisite: first-year undergraduate status.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 118A Geology of National Parks
Survey of geologic processes occurring at the Earth's surface and its interior using national parks and monuments as the prime venue for presentation. Volcanism and mountain-building; the work of streams, glaciers, and wind; lake and coastline development; stratigraphy and sedimentation; and Earth history. Material presented in a geographic context, with emphasis on landforms and landscape evolution, relating geology to the development and settlement of the U.S.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 131 Natural Disasters
Examination of the effects of natural hazards on landscapes of the Earth in general, as well as on populated areas specifically, through numerous case studies. Social, economic, and political consequences of natural disasters. Locations, particularly in the U.S.A., where disasters are likely to occur in the future. Nature of the hazards and what preparations are possible to minimize damage and the number of casualties.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 141 First-Year Seminar: Unearthing the Science of Climate Change
How and why does the climate change? How does the climate system interact with human systems? This course investigates the physical principles of Earth's ever-changing climate, with a special focus on the present-day. Topics include Earth's energy balance; the components of the climate system, including the atmosphere; oceans, cryosphere, geosphere, and biosphere; natural and anthropogenic causes of climate change; climate change detection and attribution; weather extremes; and climate adaption/vulnerability in past and present human societies. Students will explore the science behind "hot topics" in climate change and learn how peer-reviewed science is communicated to popular audiences. The course format will be a mixture of lectures, demos, facilitated discussions, and student presentations. In addition to gaining scientific background on climate change, students will develop skills in scientific writing and communication to a variety of audiences. No prior coursework in earth science is necessary. This course is open to students of any background who wish to gain literacy in the science of climate change.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 145 Land Dynamics: Case Studies of Environmental Sustainability
This course is designed for first- and second-year students and will use lectures, discussions, GIS-related and computational exercises, and field trips to introduce students to a systems approach for identifying, characterizing, and solving issues associated with environmental degradation. The course will focus on three case studies. The first will cover rapid lake drawdown of Mono Lake in northern California due to engineered diversions and subsequent court-ordered recovery to an environmentally sustainable lake level. The second will focus on unresolved consequences associated with channelization and levee development on the lower Missouri River, which put federal agencies in conflict with one another on how to manage the river and its floodplains. The third will cover past and present Pb-Cu-Zn sulfide mining practices in Missouri and attempts to balance the need for these nonrenewable resources while minimizing environmental consequences.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 171A The Solar System
Survey of the planets and satellites of our solar system. Includes results from Apollo manned missions to the Moon and spacecraft missions to the planets and their major satellites. Present ideas about the age, formation, and early history of the sun, Earth, and meteorites.

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 201 Earth and the Environment

Introduction to the study of the Earth as a dynamic, evolving planet. Emphasis on how internal and surface processes combine to shape the environment. Themes: Earth's interior as revealed by seismic waves; Earth history and global tectonics shown by changes to ocean floors, mountain-building, formation of continents, earthquakes, and volcanism; climate history and global biogeochemical cycles, influenced by circulation of atmosphere and oceans, ice ages, and human activity. Composition and structure of rocks and minerals. Part of the introductory sequence of courses for all Earth and Planetary Sciences and Environmental Studies majors. Three class hours and one two-hour lab a week.

Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 202 Introduction to Earth, Environmental, and Planetary Science

Introduction to the Earth, its environment, and its place in the solar system. This course is intended to be a starting point for majors in the Department of Earth and Planetary Sciences, or as a standalone course for students from all interests and backgrounds. Themes for this course include Earth's history; the structure and composition of Earth and other planets; the evolution of Earth's surface; natural hazards; climate history; global biogeochemical cycles; and the solar system. No Prerequisites. Students may not take both EEPS 202 and EEPS 201 for college credit.

Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI

L19 EEPS 219 Energy and the Environment

Examination of the topic of energy from many human-relevant perspectives. Humans use an enormous amount of energy, at the rate of 18 terawatts. Where does this energy come from? How long will it last? What are the consequences? Examination of energy resources and consumption from scientific, social, economic, and political viewpoints. Relationship of energy to concepts such as heat, work, and power. Energy use by society. Energy sources, pros and cons of use, availability now and in the future. Types, abundance, advantages, challenges of renewable energy sources.

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 308 Topics in Environmental Sustainability

Mathematical sustainability models; ocean, atmospheric, wetland, agricultural, hydrological, and energy sustainability; depletion of non-renewable resources; effects of pollution, human population, urban environment. Prerequisite: Chem 111A and Chem 112; or permission of instructor.

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 317 Soil Science

Physical, chemical, and biological processes that occur within soil systems. Types of soils and their formation. Major components of soil, including soil water, minerals, organic matter, and organisms. Soils in wetlands and arid regions. Mapping of soils and their spatial variability. Cycling of nutrients and contaminants in soils. Sustainable use of soils and their role in climate change. Prerequisites: EEPS 202, EEPS 323 or Chem 106 (or AP Chem score of 4); or permission of instructor.

Credit 3 units. A&S IQ: NSM

L19 EEPS 319 Physical Oceanography

Ocean circulation, El Nino, dynamical tides, tsunami, coastal ocean, enclosed seas, paleo-ocean, sedimentation, ice-atmosphere-ocean interaction, biology-carbon cycle. Prerequisites: Chem 112A ,Physics 118A, Math 133; or permission of instructor.

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 323 Biogeochemistry

Basic concepts of how elements cycle among Earth's crust, oceans, and atmosphere, including perturbations due to human activities. Carbon, nitrogen, phosphorus, sulfur, and water cycles. Isotopic tracers. Feedbacks, forcings, and residence times. Redox cycling and thermodynamics. Biogeochemical box models, and changes in biogeochemical cycles over Earth history. Biogeochemistry of greenhouse gases, biogeochemical feedbacks in the climate system. This course is appropriate for EEPS students, engineering students, environmental science majors, and other students with interest in the environmental or geological sciences. Prerequisites: EEPS 202 or EECE 101.

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 340 Minerals, Rocks, Resources and the Environment

This course is designed for undergraduate majors and minors in the Department of Earth, Environmental, and Planetary Sciences to master fundamentals of mineralogy and their context within sedimentary, metamorphic, and igneous rocks, including an introduction to mineral resources and the role of minerals and mineral resources in current environmental issues. The course will provide fundamentals of mineralogy and crystallography, important mineral groups, and foundations of sedimentary, metamorphic, and igneous rock systems. It will provide an overview and lab demo of the modern analytical methods used in mineralogy. The course includes lecture (three hours per week) and a lab component (two hours per week). Prerequisites: EEPS 202 and Chem 105, or permission of instructor.

Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 342 Environmental Systems

Introduction to the science of environmental systems and processes. Exploration of key functions of major environmental systems on land, in rivers and lakes, in air, at sea, and in diverse transitional settings at the boundaries between these environments. Evaluation of the ways in which humans alter and are affected by environmental systems. Interspersed throughout the semester will be a review of the major U.S. laws governing human management of environmental systems as well as case studies of environmental disparities in the St. Louis region. Prerequisites: EEPS 202, or permission of the instructor.

Credit 3 units. A&S IQ: NSM, AN

L19 EEPS 353 Earth Forces

Basic concepts regarding the forces that act upon the Earth, how geological materials react to these forces, and the time scale over which they respond. Emphasis on physical concepts needed to understand the geodynamical behavior of the Earth over a broad range of length and time scales. Application and interpretation of geophysical methods to probe the interior of the Earth. Prerequisite: EEPS 202(may be taken concurrently), Phys 191; or permission of instructor. Three class hours and one two-hour laboratory a week.

Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 361 Structural Geology

The landforms that surround us are constantly being modified by tectonic forces. Structural geology provides a framework for investigating, describing, and quantifying these changes. This course will provide an introduction to the structures that form at all scales, from millimeter-sized fractures to rifts in Earth's lithosphere thousands of kilometers long. Through the study of these features and processes that form them, students will gain a fundamental understanding of the

physical evolution of our planet. Topics will include descriptive analysis of microscopic and macroscopic structures, field methods, the physical basis for rock deformation, and global tectonics. Prerequisites: EEPS 202
Credit 4 units. A&S IQ: NSM BU: SCI

L19 EEPS 385 Earth History
Introduction to the concept of "deep time" and the parallel biological evolutionary and environmental changes that have occurred throughout Earth history. Topics include early evolution of life, rise of atmospheric oxygen, global glaciation, mass extinctions. Prerequisite: EEPS 202 or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 386 The Earth's Climate System
This course introduces an integrative view of the Earth's climate system and its coupled components - the atmosphere, the oceans, the cryosphere, the biosphere, and the geosphere - and how they interact with each other. The goal is to provide the physical scientific background that is needed to understand climate variability and climate change, both natural and anthropogenic. Topics include energy balance; general circulation of the atmosphere and the oceans; the greenhouse effect; modes of variability such as El Nino; geologic-scale climate change in the geologic past; climate models; climate change detection and attribution; projection of future climates; and societal impacts. In addition to lectures, students will gain hands-on experience analyzing and interpreting real datasets through inquiry-based "practicum" exercises and in-class discussions. Prerequisites: EEPS 202 or permission from the instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 387 Geospatial Science
This course introduces students to the interdisciplinary field of geospatial science, which bridges the fields of geographic information systems (GIS), remote sensing, data science, and spatiotemporal analysis. This course will provide an overview of the fundamental concepts of geospatial science, including: visualizing and analyzing raster and vector datasets within a GIS database; coordinate systems, reference frames, and projections; the Geoid and geodetic techniques; remote sensing methods; image acquisition and interpretation; spatiotemporal analysis of geospatial data; sampling, interpolation, and time series analysis; uncertainty, error, accuracy, and precision. This course will be available at both the upper-level undergraduate and the graduate levels. Material will be covered through lectures, assignments, and computer exercises that will give students hands-on experience analyzing and interpreting real geospatial datasets. Exercises for students enrolled in the 587 option will be more in-depth and will require some basic programming experience and familiarity with quantitative techniques. These exercises will provide students with a sampling of geospatial science applications, such as environmental studies, cryospheric science, wildlife management, contagious disease monitoring, demography, and human geography. Students will complete a final project of their choosing that synthesizes the concepts and themes learned in this course; students enrolled in the 587 option are encouraged to develop a project proposal that aligns with their own research interests. Students particularly interested in GIS and remote sensing are further encouraged to also consider EnSt 380 and EEPS 407, respectively.
Credit 4 units. A&S IQ: NSM, AN

L19 EEPS 390 Independent Study
Independent study for undergraduates, to be supervised by a faculty member. Prerequisite: permission of instructor. Credit to be determined.
Credit variable, maximum 3 units. Art: NSM

L19 EEPS 400 Special Topics
The content of this course varies each time it is offered, as announced by the Department. With permission of the advisor, this course may be repeated for credit. Prerequisite: permission of instructor. Variable credit.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 401 Earth Systems Science
This is a quantitative introduction to physical and chemical interactions among the atmosphere, oceans and solid earth. Topics covered include terrestrial atmospheric chemistry, geochemical cycles, inventories, and reservoirs of carbon, nitrogen, & sulfur, and bulk composition of the Earth. Prerequisite: EEPS 340 or permission of instructor or the graduate advisor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 407 Remote Sensing
Use of different parts of the electromagnetic spectrum (visible, ultraviolet, infrared, and radio wavelengths) for interpretation of physical and chemical characteristics of the surfaces of Earth and other planets. Digital image systems and data processing. Prerequisite: Phys 192; or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 408 Earth's Atmosphere & Global Climate
Structure and dynamics of Earth's atmosphere. Basic factors controlling global climate of Earth. Quantitative aspects of remote sensing of atmosphere. Remote sensing instrumentation. Prerequisites: Math 233 and Phys 191; or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 409 Surface Processes
How do landscapes evolve? This course focuses on the physical processes of erosion and deposition that shape Earth and planetary surfaces. Course aims (1) understanding emergent landscape patterns, (2) reconstructing past conditions using the sedimentary record, and (3) predicting landscape change under climate scenarios. Review of relevant climatic and tectonic processes, followed by detailed discussion of rivers and deltas, hillslopes, weathering, glaciers, and coasts. Two one-day field trips required. Prerequisites: EEPS 353 or Physics 191).
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 413 Introduction To Soil Science
Physical, chemical, and biological processes that occur within soil systems. Types of soils and their formation. Major components of soil, including soil water, minerals, organic matter, and organisms. Soils in wetlands and arid regions. Mapping of soils and their spatial variability. Cycling of nutrients and contaminants in soils. Sustainable use of soils and their role in climate change. Prerequisites: EEPS 202, EEPS 323 or Chem 106 (or AP Chem score of 4); or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 422 Sedimentary Geology
Survey introduction to sedimentary processes and materials, including description, formation, and interpretation. Sedimentary materials account for most of the Earth's crust, and much of our understanding of Earth history comes from their examination. Many of our economic resources, such as coal, oil, and natural gas, and many environmental problems, are related to or derive from sediments. Goals: understanding and identifying sediments and processes and using them to interpret stratigraphic, paleoenvironmental, and tectonic

information; obtaining the understanding of sedimentology that is relevant to environmental issues; increasing scientific literacy and critical thinking. Prerequisite: EEPS 202 or permission of instructor. Mandatory field trips.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 428 Hydrology
Survey of principles that govern the flow of water in river and groundwater systems in deep geologic environments. Basic equations of fluid flow, dynamics, and the characteristics of drainage basins, rivers, floods, and important aquifers. Exploitation of ground water systems. Prerequisite: EEPS 353 or Physics 191.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 430 Environmental Mineralogy
Topics connected with environmental mineralogy, some selected by students. Topics may include: mineral dust such as asbestos, containment materials for nuclear waste disposal, environmental ramifications of the processing and use of phosphate fertilizers, lead in the environment, acid mine drainage, microbial mediation of sulfide oxidation, minerals in the human body, weathering of building materials, materials engineering, and engineering of materials for more effective recycling. Three class hours and one two-hour laboratory a week. Participation in discussions, term paper, two field trips required. Most readings from primary sources. Prereq: EEPS 352 or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 437 Igneous & Metamorphic Petrology
Classification, origin, mineralogy, and geological occurrence of major igneous and metamorphic rocks. Laboratory emphasis on identification of rocks and minerals in hand specimens and in thin sections. Prerequisite: EEPS 352 or permission of instructor. Three class hours and one two-hour laboratory a week.
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 441 Introduction to Geochemistry
Application of the principles of nuclear and physical chemistry to problems of the composition and differentiation of the Earth. Introduction to nucleosynthesis of the elements, stellar evolution, the periodic properties of the elements, chemical bonding and ionic substitution, geochronology and stable isotope geochemistry, and the age and composition of the Earth, Moon and meteorites. Prerequisites: EEPS 202 and Chem 106 (or AP Chem score of 4), or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 442 Aqueous Geochemistry
Introduction to the geochemistry of natural waters and the processes that alter their composition. Key principles of aqueous geochemistry are introduced and then used to describe the main controls of the chemistry of pristine and polluted soil, surface, and ground water environments. Topics covered include mineral solubility, complexation, acids and bases, carbonate chemistry, rock weathering and clay formation, adsorption and ion exchange, redox reactions, microbial energetics and redox zonations, the geochemistry of iron, sulfur, trace elements, and radionuclides, and geochemical kinetics. Geochemical modeling will be introduced. Prerequisites: Chem 106 or 112A; EEPS 202 is recommended.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 444 Environmental Geochemistry
Introduction to the geochemistry of natural waters and the processes that alter their composition. Key principles of aqueous geochemistry and their application to describe the main controls on the chemistry of pristine and polluted soil, surface, and ground water environments. Acids and bases, mineral solubility, carbonate chemistry, chemical speciation, redox reactions, adsorption and ion exchange, and the speciation, mobility, and toxicity of metals. Prerequisites: EEPS 202 and Chem 106 (or AP Chem score of 4); or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 445 Organic Geochemistry
Introduction to the composition and analysis of organic material in the environment and geological record. Molecular to global-level perspective of organic matter cycling, reactivity, and fluxes; formation and classification of organic matter, its preservation potential, diagenesis, catagenesis, and kerogen formation; coal, petroleum, and gas formation and accumulation; biomarkers in Earth history; genetics and phylogeny of biomarker compounds; overview of analytical techniques including both structural and isotopic aspects; oceanographic and paleoenvironmental applications of organic biomarkers; contaminants and residue analysis. Prerequisites: EEPS 202 and Chem 106; or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 446 Stable Isotope Geochemistry
Applications of equilibrium and kinetic isotope fractionation and material balance principles to the distribution of oxygen and hydrogen isotopes in natural systems. Geothermometry and paleotemperatures, mass spectrometry, isotope hydrology and ice cores, fluid-rock interaction, igneous rocks and meteorites. Prerequisites: EEPS 441 and MATH 233, or permision of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 452 Introduction to Seismology
Introduction to earthquake and exploration seismology. Seismic wave propagation, data analysis and processing, earthquake mechanisms, seismic contraints on the structure of the Earth, relationship of seismicity to plate tectonics. Prerequisites: EEPS 353 and Math 217, or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EEPS 453 Interior of the Earth
Composition and temperature of Earth's mantle and core, determined by geophysical methods. Inferences about mantle and core dynamics, especially interactions. Current understanding and history of interior in fields of seismology, geomagnetism, mineral physics, geodynamics. Prerequisite: EEPS 353, or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 454 Exploration and Environmental Geophysics
Basic geophysical techniques used in exploration and environmental geophysics, emphasizing seismic and electromagnetic methods. Basic theory, field procedures, and interpretation of data. Use of geophysical instruments on field trips, followed by reduction and analysis of acquired data. Prerequisites: EEPS 353, Phys 191, Math 132; or permission of instructor. Two class hours and one two-hour laboratory a week, and approximately four one-day field trips during the semester.
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 459 Geodynamics
Fundamental physical processes necessary to understand plate tectonics and a variety of geological phenomena. Heat flow, gravity, elasticity and flexure, rheology of Earth materials. Prerequisites: EEPS 353, Math 217; or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 460 Introduction to Structural Geology
The landforms that surround us are being modified constantly by tectonic forces. Structural geology provides a framekwork for investigating, describing, and quantifying these changes. This course provides an introduction to the structures that form at all scales, from millimeter-sized fractures to plate-boundary-scale rifts. Topics include descriptive analysis of microscopic and macroscopic structures, field methods, the physical basis for rock deformation, and global tectonics. Prerequisite: EEPS 340 and EEPS 353 or permission of instructor. Three hours of lecture and one two-hour laboratory a week.
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 467 Planetary Mission Design
This course will introduce EEPS, physics, and engineering students to the combined scientific and engineering aspects required for the development of a robotic spacecraft exploration mission to a body in the Solar System. Through Instructor delivered lectures, individual presentations, and a group presentation and a report, students will design a robotic spacecraft exploration mission that satisfies specific target, cost and schedule constraints. Prerequisites L31 Physics 191; and enrollment by permission of the Instructor only.
Credit 3 units. A&S IQ: NSM

L19 EEPS 468 Geospatial Field Methods
This course is an introduction to field geospatial surveying using high-precision GNSS systems and UVA's (drones) outfitted with a variety of sensors such as cameras, multispectral sensors, and lidar. Coursework will cover basic principles as well as provide hands on experience. Most of the course is project based, and students will complete a series of exercises designed to familiarize them with the effective use of field equipment. Students will design data collection strategies, collect data, and become familiar with data processing pipelines and visualization techniques. After completing the course, students will be prepared to safely and effectively conduct independent GNSS and drone surveys, and use the data for studies in Earth, environmental, and planetary science, archaeology, environmental science, ecology, landscape architecture, urban design, agriculture and a variety of other field-based disciplines. Prerequisites: Previous 300+ level coursework in Earth sciences, archaeology, ecology, or other coursework for which these methods are relevant.
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EEPS 473 Planetary Geology
Discussion of the evolution of the terrestrial planets and the outer-planet satellites as evidenced by the geologic records left on the surfaces of these bodies. Focus on major processes affecting planetary surfaces:impact cratering, volcanism, tectonism, and erosion and sedimentation by wind and water. Prerequisite: EEPS 352 and EEPS 353, or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 474 Planetary Geochemistry
A survey of the geochemistry of the planets and their satellites using data from Earth-based, Earth-orbital, and spacecraft observations. Prerequisite: EEPS 352 or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 486 Paleoclimatology
The history of Earth's changing climates and environments on timescales from decades to millions of years. Key concepts in paleoclimatology include: external factors affecting the climate system (e.g., orbital cycles, volcanic eruptions, greenhouse gases); internal feedbacks, such as with monsoons and the El Nino- Southern Oscillation; abrupt versus gradual change; interactions with the biosphere (including hominins/humans); and comparison to present-day climate change. Current controversies in paleoclimate. EEPS 386 or EEPS 586 (or equivalent), or permission from the instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 490 Independent Study
Independent study for advanced undergraduates or for graduate students, to be supervised by a faculty member. Prerequisite: permission of instructor. Credit to be arranged.
Credit variable, maximum 12 units.

L19 EEPS 492 Field Camp
Practical methods of data collection and interpretation in Earth and Planetary Sciences. Content may include field-based geologic mapping or laboratory-based studies emphasizing particular analytical tools. Prerequisite: permission of major advisor.
Credit variable, maximum 6 units. A&S IQ: NSM

L19 EEPS 493 Internship
Internship experience in Earth and Planetary Sciences, providing learning opportunities with future careers and employers. Direct supervision by approved partner, with oversight by Earth and Planetary Sciences faculty. Prerequisite: permission of major advisor.
Credit variable, maximum 6 units.

L19 EEPS 494 Study Abroad
Studies related to Earth, Environmental, and Planetary Sciences conducted with external institutions. Prerequisite: permission of Department Study Abroad Coordinator.
Credit variable, maximum 6 units.

L19 EEPS 496 Undergraduate Field Geology
Hands-on application of geological field methods, providing an opportunity for students to synthesize classroom knowledge in a field setting. Students will develop the ability to recognize and analyze Earth processes, and deconstruct complex regional geology. Participation in an extended international field trip during spring break is required. Students must be prepared for an intensive, group-oriented experience. Prerequisite: must be an Earth, Environmental, and Planetary Sciences major and have permission of instructors. Enrollment is limited, and students will be selected through a written application. May be repeated for credit, with instructor permission. Juniors and Seniors may use to fulfill Capstone experience. Credit: 3 units
Credit 3 units.

L19 EEPS 499 Honors Research
Independent work for undergraduate Honors, to be supervised by a faculty member. Prerequisites: Senior standing, eligibility for Honors, and permission of instructor.
Credit 3 units.