Earth, Environmental and Planetary Sciences

Students in Earth, Environmental, and Planetary Sciences develop a comprehensive grasp of principles as well as an ability to think critically and creatively. Formal instruction places an emphasis on fundamental principles, processes, and recent developments, using lecture, seminar, laboratory, colloquium, and field trip formats. Undergraduates as well as graduate students have opportunities to carry out research in current fields of interest.

The principal research fields of the department are geochemistry, mineral physics, igneous petrology; geophysics, structural geology, tectonophysics; environmental science, hydrology; paleoceanography, paleoclimatology, sedimentology; and planetary geosciences. Emphasis in these different areas varies, but includes experimental, theoretical, and observational approaches as well as applications to field problems. Field studies of specific problems are encouraged rather than field mapping for its own sake. Interdisciplinary study with other departments and divisions is encouraged.

For additional information, please visit the department's website: http://www.brown.edu/academics/earth-environmental-planetary-sciences/

Earth and Planetary Science Concentration Requirements

Earth and Planetary Science is a highly interdisciplinary concentration employing principles from physics, chemistry, and biology to understand processes on and in the Earth and other planetary bodies. Concentrators can study Earth and planetary interiors, including the formation of rocks and minerals, movement of the Earth's tectonic plates, and mountain building and volcanism. Other areas emphasize surface processes, such as coastal erosion, formation of water resources, and desertification. This concentration is a good choice for students who seek a broad scientific understanding of the processes that shape the physical world around us.

Both A.B. and Sc.B. degrees are offered, requiring 12 and 19 courses, respectively. These degrees build skills in critical thinking, data analysis and modeling, finding solutions to complex problems, and written and oral communication. DEEPS provides a highly collaborative learning environment that emphasizes process-oriented, hands-on approaches in the classroom, in labs and on field trips. There are many opportunities for students to do paid research during the summer or academic year.

Students interested in this concentration may also wish to consider related concentrations: Earth, Climate and Biology, Geophysics and Climate Physics, and Geochemistry and Environmental Chemistry.

Note - For students still enrolled with the prior Concentration in Geological Sciences A.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Standard program for the A.B. degree

This program provides a broad introduction to the geosciences. It is recommended for students seeking to combine diverse educational interests with a general understanding of Earth processes and Earth history. It is attractive for double concentrations, such as geoscience and economics as a career path to law or business, or geoscience and English as a career path to journalism or technical writing. Some course requirements may be flexible based on consultation with the concentration advisor.

Three basic supporting science courses		
CHEM 0330	Equilibrium, Rate, and Structure (or equivalent)	1
Two courses to build quantitative skills:		2
MATH 0090	Single Variable Calculus, Part I (or higher)	
BIOL 0495	Statistical Analysis of Biological Data	
or APMA 1650	Introduction to Probability and Statistics with Calculus	
CSCI 0111	Computing Foundations: Data (or higher)	
ENGN 0040	Engineering Statics and Dynamics (or higher)	
APMA 0350	Applied Ordinary Differential Equations (or higher)	
PHYS 0050	Foundations of Mechanics (or higher)	
Nine Concentration courses		
Two of these four fundamentals courses:		2
EEPS 0220	Understanding Earth and Environmental Processes	
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	
EEPS 0240	Earth: Evolution of a Habitable Planet	
EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	
Select three of the following:		3
EEPS 1240	Stratigraphy and Sedimentation	
EEPS 1410	Mineralogy	
EEPS 1420	Petrology	
EEPS 1450	Structural Geology	
Three additional upper level EEPS courses or an approved substitute such as a field course		3
One additional upper level science or math course with approval from the concentration advisor.		1
Total Credits		**12**

Standard program for the Sc.B. degree

This program is recommended for students interested in more in-depth study in geoscience, planetary science and related fields, potentially including graduate school and wide-ranging careers in these areas. Some course requirements may be flexible based on consultation with the concentration advisor.

Note - For students still enrolled with the prior Concentration in Geological Sciences Sc.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Basic supporting science courses		
CHEM 0330	Equilibrium, Rate, and Structure (or equivalent)	1
Four courses to build quantitative skills:		4
MATH 0090	Single Variable Calculus, Part I (or higher)	
BIOL 0495	Statistical Analysis of Biological Data	
or APMA 1650	Introduction to Probability and Statistics with Calculus	
CSCI 0111	Computing Foundations: Data (or higher)	
APMA 0350	Applied Ordinary Differential Equations (or higher)	
ENGN 0040	Engineering Statics and Dynamics (or higher)	
PHYS 0050	Foundations of Mechanics (or higher)	
EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	
Fourteen Concentration courses		
EEPS 0220	Understanding Earth and Environmental Processes	1
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	1
EEPS 0240	Earth: Evolution of a Habitable Planet	1
Three of the following:		3

EEPS 1240	Stratigraphy and Sedimentation	
EEPS 1410	Mineralogy	
EEPS 1420	Petrology	
EEPS 1450	Structural Geology	
Three additional upper level EEPS courses or an approved substitute such as a field course		3
Four upper level science or math courses with approval from the concentration advisor		4
EEPS 1970	Individual Study of Geologic Problems (Senior Research Thesis)	1
Total Credits		**19**

Earth, Climate, and Biology Concentration Requirements

Students in Earth, Climate and Biology apply principles from Earth science, biology, chemistry, and physics to understand how major components of the Earth system, such as its atmosphere and oceans, interact with and sustain life over time. Many courses emphasize climate change, environmental quality, and biogeochemistry, so this concentration is a good match for students interested in studying the environment. Courses also investigate Earth history, including past climate, extinction events, and using the Earth's sedimentary record to investigate environmental change.

Both A.B. and Sc.B. degrees are offered, requiring 12 and 19 courses, respectively. These degrees build skills in critical thinking, data analysis and modeling, finding solutions to complex problems, and written and oral communication. DEEPS provides a highly collaborative learning environment that emphasizes process-oriented, hands-on approaches in the classroom, in labs and on field trips. There are many opportunities for students to do paid research during the summer or academic year.

Students interested in this concentration may also wish to consider related concentrations: Geochemistry and Environmental Chemistry, Geophysics and Climate Physics, and Earth and Planetary Science.

Standard program for the A.B. degree

This program provides a broad introduction to the geologic and biologic processes that shape the Earth and our environment. It is recommended for students seeking to combine diverse educational interests with a general understanding of Earth processes, including the evolution of climate and the environment, global environmental change and Earth history. The program prepares students for careers in environmental science, geoscience, ecology, oceanography, and global change. Some course requirements may be flexible based on consultation with the concentration advisor.

Note - For students still enrolled with the prior Concentration in Geology-Biology A.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Basic supporting science courses		
BIOL 0200	The Foundation of Living Systems (or equivalent)	1
or BIOL 0210	Diversity of Life	
CHEM 0330	Equilibrium, Rate, and Structure (or equivalent)	1
A course to build quantitative skills:		1
MATH 0090	Single Variable Calculus, Part I (or higher)	
BIOL 0495	Statistical Analysis of Biological Data	
or APMA 1650	Introduction to Probability and Statistics with Calculus	
CSCI 0111	Computing Foundations: Data (or higher)	
ENGN 0040	Engineering Statics and Dynamics (or higher)	
PHYS 0050	Foundations of Mechanics (or higher)	
APMA 0350	Applied Ordinary Differential Equations (or higher)	
Nine Concentration courses		
Two of these four fundamentals courses:		2
EEPS 0220	Understanding Earth and Environmental Processes	
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	
EEPS 0240	Earth: Evolution of a Habitable Planet	
EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	
EEPS 1240	Stratigraphy and Sedimentation	1
Select three upper level Biology courses such as:		3
BIOL 0410	Invertebrate Zoology	
BIOL 0420	Principles of Ecology	
BIOL 0430	The Evolution of Plant Diversity	
BIOL 0480	Evolutionary Biology	
BIOL 1470	Conservation Biology	
Three EEPS courses such as:		3
One of EEPS 0220, EEPS 0230, EEPS 0240, or EEPS 0250 if not already taken		
EEPS 0850	Weather and Climate	
EEPS 1120	Paleoceanography	
EEPS 1130	Ocean Biogeochemical Cycles	
EEPS 1150	Limnology: The Study of Lakes	
EEPS 1310	Global Water Cycle	
EEPS 1320	Introduction to Geographic Information Systems for Environmental Applications	
EEPS 1370	Environmental Geochemistry	
EEPS 1615	Climate Change, Human Rights, and the Policy Process	
EEPS 1970	Individual Study of Geologic Problems	
Total Credits		**12**

Standard program for the Sc.B. degree

This program is recommended for students interested in more in-depth study in the Earth, environmental, or biological sciences, potentially including graduate school and diverse careers in these areas. It is relevant for students interested in environmental science, paleoclimate, Earth systems science, biogeochemistry, oceanography, or paleobiology. Some course requirements may be flexible based on consultation with the concentration advisor.

Note - For students still enrolled with the prior Concentration in Geology-Biology Sc.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Five supporting science courses:		
BIOL 0200	The Foundation of Living Systems (or equivalent)	1
or BIOL 0210	Diversity of Life	
CHEM 0330	Equilibrium, Rate, and Structure (or equivalent)	1
Three courses to build quantitative skills:		3
MATH 0090	Single Variable Calculus, Part I (or higher)	
BIOL 0495	Statistical Analysis of Biological Data	
or APMA 1650	Introduction to Probability and Statistics with Calculus	
CSCI 0111	Computing Foundations: Data (or higher)	
ENGN 0040	Engineering Statics and Dynamics (or higher)	
APMA 0350	Applied Ordinary Differential Equations (or higher)	
PHYS 0050	Foundations of Mechanics (or higher)	
Fourteen concentration courses:		

EEPS 0220	Understanding Earth and Environmental Processes	1
EEPS 0240	Earth: Evolution of a Habitable Planet	1
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	1
or EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	
EEPS 1240	Stratigraphy and Sedimentation	1
Three upper level Biology courses such as:		3
BIOL 0410	Invertebrate Zoology	
BIOL 0420	Principles of Ecology	
BIOL 0430	The Evolution of Plant Diversity	
BIOL 0480	Evolutionary Biology	
BIOL 1470	Conservation Biology	
Three upper level EEPS courses such as:		3
EEPS 0850	Weather and Climate	
EEPS 1120	Paleoceanography	
EEPS 1130	Ocean Biogeochemical Cycles	
EEPS 1150	Limnology: The Study of Lakes	
EEPS 1310	Global Water Cycle	
EEPS 1320	Introduction to Geographic Information Systems for Environmental Applications	
EEPS 1330	Global Environmental Remote Sensing	
EEPS 1370	Environmental Geochemistry	
EEPS 1430	Principles of Planetary Climate	
EEPS 1615	Climate Change, Human Rights, and the Policy Process	
Three upper level science or math courses with approval from the concentration advisor		3
EEPS 1970	Individual Study of Geologic Problems (Senior Research Thesis)	1
Total Credits		**19**

Geochemistry and Environmental Chemistry Concentration Requirements

The Geochemistry and Environmental Chemistry concentration offers two different emphases. Low-temperature geochemistry involves study of chemical and biochemical processes on and near Earth's surface, including land, oceans and freshwater bodies, and how the geochemical record reflects climate conditions. High-temperature geochemistry includes study of the formation and evolution of the Earth and other planets, magma formation and properties, volcanic activity, and metamorphism.

Both A.B. and Sc.B. degrees are offered, requiring 12 and 19 courses, respectively. These degrees build skills in critical thinking, data analysis and modeling, finding solutions to complex problems, and written and oral communication. DEEPS provides a highly collaborative learning environment that emphasizes process-oriented, hands-on approaches in the classroom, in labs and on field trips. There are many opportunities for students to do paid research during the summer or academic year.

Students interested in this concentration may also wish to consider related concentrations: Earth, Climate and Biology, Geophysics and Climate Physics, and Earth and Planetary Science.

Standard program for the A.B. degree

This program is recommended for students interested in applying chemical and physical principles toward an understanding of Earth and planetary history and processes, and environmental and resource issues, while pursuing diverse academic goals. The program prepares students for careers in environmental science, Earth and planetary science, and global change. Some course requirements may be flexible based on consultation with the concentration advisor.

Note - For students still enrolled with the prior Concentration in Geology-Chemistry A.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Three basic supporting science courses		
CHEM 0330	Equilibrium, Rate, and Structure	1
Two courses to build quantitative skills:		2
BIOL 0495	Statistical Analysis of Biological Data	
or APMA 1650	Introduction to Probability and Statistics with Calculus	
MATH 0090	Single Variable Calculus, Part I (or higher)	
ENGN 0040	Engineering Statics and Dynamics (or higher)	
CSCI 0111	Computing Foundations: Data (or higher)	
APMA 0350	Applied Ordinary Differential Equations (or higher)	
PHYS 0050	Foundations of Mechanics (or higher)	
Nine Concentration courses		
Two of these four fundamentals courses:		2
EEPS 0220	Understanding Earth and Environmental Processes	
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	
EEPS 0240	Earth: Evolution of a Habitable Planet	
EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	
Three additional chemistry courses such as:		3
CHEM 0350	Organic Chemistry I	
CHEM 0360	Organic Chemistry II	
CHEM 0500	Inorganic Chemistry	
CHEM 1060	Advanced Inorganic Chemistry	
CHEM 1140	Physical Chemistry: Quantum Chemistry	
CHEM 1150	Physical Chemistry: Thermodynamics and Statistical Mechanics	
BIOL 0280	Biochemistry	
Two courses from the following:		2
EEPS 1410	Mineralogy	
EEPS 1420	Petrology	
EEPS 1130	Ocean Biogeochemical Cycles	
EEPS 1370	Environmental Geochemistry	
Two additional upper-level EEPS courses or substitutes with approval from the concentration advisor.		2
Total Credits		**12**

Standard program for the Sc.B. degree

This program is recommended for students interested in more in-depth study in geochemistry, climate science, planetary science and related fields, potentially including graduate school and wide-ranging careers in these areas. Some course requirements may be flexible based on consultation with the concentration advisor.

Note - For students still enrolled with the prior Concentration in Geology-Chemistry Sc.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Basic Supporting Science Courses:		
CHEM 0330	Equilibrium, Rate, and Structure	1
Four courses to build quantitative skills:		4
MATH 0090	Single Variable Calculus, Part I (or higher)	
BIOL 0495	Statistical Analysis of Biological Data	
or APMA 1650	Introduction to Probability and Statistics with Calculus	
CSCI 0111	Computing Foundations: Data	

ENGN 0040	Engineering Statics and Dynamics (or higher)	
APMA 0350	Applied Ordinary Differential Equations (or higher)	
PHYS 0050	Foundations of Mechanics (or higher)	
EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	
Fourteen Concentration Courses		
EEPS 0220	Understanding Earth and Environmental Processes	1
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	1
EEPS 0240	Earth: Evolution of a Habitable Planet	1
EEPS 1370	Environmental Geochemistry	1
EEPS 1410	Mineralogy	1
Three additional chemistry courses such as:		3
CHEM 0350	Organic Chemistry I	
CHEM 0360	Organic Chemistry II	
CHEM 0500	Inorganic Chemistry	
CHEM 1060	Advanced Inorganic Chemistry	
CHEM 1140	Physical Chemistry: Quantum Chemistry	
CHEM 1150	Physical Chemistry: Thermodynamics and Statistical Mechanics	
BIOL 0280	Biochemistry	
Two upper level courses from EEPS such as		2
EEPS 1130	Ocean Biogeochemical Cycles	
EEPS 1240	Stratigraphy and Sedimentation	
EEPS 1380	Environmental Stable Isotopes	
EEPS 1420	Petrology	
Three additional upper-level science or math courses with approval from the concentration advisor		3
EEPS 1970	Individual Study of Geologic Problems	1
Total Credits		**19**

Geophysics and Climate Physics Concentration Requirements

The Geophysics and Climate Physics concentration involves applying physics and mathematics to study processes that operate on and within the Earth and other planets, over short and long timescales. Geophysical approaches are fundamental for understanding how the oceans, atmosphere and ice sheets respond to climate change, managing resources such as water and geothermal energy, mitigating natural hazards such as earthquakes and volcanoes, and understanding the dynamic processes that shape the surfaces and control the interiors of Earth and other planetary bodies. Geophysics spans both theoretical modeling of physical processes and the analysis of geophysical data (including remote sensing and machine learning), and typically involves computing, as well as lab experiments and field work.

Both A.B. and Sc.B. degrees are offered, requiring 12 and 19 courses, respectively. These degrees build skills in critical thinking, data analysis and modeling, finding solutions to complex problems, and written and oral communication. DEEPS provides a highly collaborative learning environment that emphasizes process-oriented, hands-on approaches in the classroom, in labs and on field trips. There are many opportunities for students to do paid research during the summer or academic year.

Students interested in this concentration may also wish to consider related concentrations: Earth, Climate and Biology, Geochemistry and Environmental Chemistry, and Earth and Planetary Science.

Standard program for the A.B. degree

This program is recommended for students interested in applying physical and mathematical principles toward understanding and modeling processes affecting Earth, its environment and climate, and other planets. Its requirements are well-suited to students seeking to combine these fields with other educational interests, while preparing them for diverse careers including environmental science, global change, and Earth and planetary science. Some course requirements may be flexible based on consultation with the concentration advisor.

Note - For students still enrolled with the prior Concentration in Geology-Physics/Mathematics A.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Five supporting science courses:		
CHEM 0330	Equilibrium, Rate, and Structure (or equivalent)	1
A course involving mechanics such as:		1
PHYS 0050	Foundations of Mechanics	
PHYS 0070	Analytical Mechanics	
ENGN 0040	Engineering Statics and Dynamics (or the equivalent)	
Three courses in APMA or MATH, one of which must be APMA 0350 or equivalent		3
Seven concentration courses:		
Two of these four fundamentals courses:		2
EEPS 0220	Understanding Earth and Environmental Processes	
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	
EEPS 0240	Earth: Evolution of a Habitable Planet	
EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	
or EEPS 0350	Mathematical Methods of Fluid	
One of these courses:		1
EEPS 1430	Principles of Planetary Climate	
EEPS 1610	Solid Earth Geophysics	
Two of the following courses, can combine different focii:		2
Climate focus:		
EEPS 1310	Global Water Cycle	
EEPS 1510	Dynamic Meteorology	
EEPS 1520	Ocean Circulation and Climate	
Solid Earth and planets focus:		
EEPS 1410	Mineralogy	
EEPS 1450	Structural Geology	
EEPS 1620	Continuum Physics of the Solid Earth	
Data science focus:		
EEPS 1340	Machine Learning for the Earth and Environment	
EEPS 1690	Introduction to Methods in Data Analysis	
EEPS 1720	Tackling Climate Change with Machine Learning	
One additional EEPS course such as:		1
Climate focus:		
EEPS 1130	Ocean Biogeochemical Cycles	
EEPS 1630	Introduction to Quantitative Glaciology	
EEPS 1820	Geophysical Fluid Dynamics: Rotating, Stratified Turbulence Edition	
Solid Earth and planets focus:		
EEPS 1560	Global Tectonics	
EEPS 1650	Earthquake Seismology	
EEPS 1810	Physics of Planetary Evolution	
Data science focus:		
EEPS 1330	Global Environmental Remote Sensing	
Other alternatives:		

EEPS 1970	Individual Study of Geologic Problems	
a field or sea course or any EEPS course listed in the concentration		
One course in physics or engineering such as:		1
PHYS 0060	Foundations of Electromagnetism and Modern Physics	
PHYS 0470	Electricity and Magnetism	
PHYS 0500	Advanced Classical Mechanics	
PHYS 1600	Computational Physics	
ENGN 0310	Mechanics of Solids and Structures	
ENGN 0490	Fundamentals of Environmental Engineering	
ENGN 0510	Electricity and Magnetism	
ENGN 0810	Fluid Mechanics	
ENGN 1370	Advanced Engineering Mechanics	
Total Credits		**12**

Standard program for the Sc.B. degree

This program is recommended for students interested in more in-depth study in climate science, geophysics, planetary science and related fields, potentially including graduate school and careers in these areas. Students will gain hands-on experience with theoretical and numerical modeling of processes, data analysis, and computing. Some course requirements may be flexible based on consultation with the concentration advisor.

Note - For students still enrolled with the prior Concentration in Geology-Physics/Mathematics Sc.B., please refer to the Archived Bulletin link on left hand navigation for your requirements for the year you declared.

Five supporting science courses:		
CHEM 0330	Equilibrium, Rate, and Structure	1
A course involving mechanics such as:		1
PHYS 0050	Foundations of Mechanics	
PHYS 0070	Analytical Mechanics	
ENGN 0040	Engineering Statics and Dynamics (or the equivalent)	
Three courses in APMA or MATH, one of which must be APMA 0350 or equivalent		3
Fourteen Concentration Courses:		
EEPS 0220	Understanding Earth and Environmental Processes	1
EEPS 0230	Geochemistry: Earth and Planetary Materials and Processes	1
or EEPS 0240	Earth: Evolution of a Habitable Planet	
EEPS 0250	Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction	1
or EEPS 0350	Mathematical Methods of Fluid	
EEPS 1430	Principles of Planetary Climate	1
EEPS 1610	Solid Earth Geophysics	1
Three of the following courses, can combine different focii:		3
Climate focus:		
EEPS 1310	Global Water Cycle	
EEPS 1510	Dynamic Meteorology	
EEPS 1520	Ocean Circulation and Climate	
Solid Earth and planets focus:		
EEPS 1410	Mineralogy	
EEPS 1450	Structural Geology	
EEPS 1620	Continuum Physics of the Solid Earth	
Data science focus:		
EEPS 1340	Machine Learning for the Earth and Environment	
EEPS 1690	Introduction to Methods in Data Analysis	
EEPS 1720	Tackling Climate Change with Machine Learning	
One additional EEPS course such as:		1
Climate focus:		
EEPS 1130	Ocean Biogeochemical Cycles	
EEPS 1630	Introduction to Quantitative Glaciology	
EEPS 1820	Geophysical Fluid Dynamics: Rotating, Stratified Turbulence Edition	
Solid Earth and planets focus:		
EEPS 1560	Global Tectonics	
EEPS 1650	Earthquake Seismology	
EEPS 1810	Physics of Planetary Evolution	
Data science focus:		
EEPS 1330	Global Environmental Remote Sensing	
Other alternatives:		
a field or sea course		
or any EEPS course listed in the concentration		
Three courses in physics or engineering such as:		3
PHYS 0060	Foundations of Electromagnetism and Modern Physics	
PHYS 0470	Electricity and Magnetism	
PHYS 0500	Advanced Classical Mechanics	
PHYS 1600	Computational Physics	
ENGN 0310	Mechanics of Solids and Structures	
ENGN 0490	Fundamentals of Environmental Engineering	
ENGN 0510	Electricity and Magnetism	
ENGN 0810	Fluid Mechanics	
ENGN 1370	Advanced Engineering Mechanics	
One additional upper-level science or math course with approval from the concentration advisor		1
EEPS 1970	Individual Study of Geologic Problems	1
Total Credits		**19**

Geological Sciences Graduate Program

The department of Earth, Environmental and Planetary Sciences offers a graduate program leading to the Doctor of Philosophy (PhD) degree.

For more information on admission and program requirements, please visit the following website:

https://graduateprograms.brown.edu/graduate-program/earth-environmental-and-planetary-sciences-phd (https://graduateprograms.brown.edu/graduate-program/earth-environmental-and-planetary-sciences-phd/)

Courses

EEPS 0010. Face of the Earth.
This course covers the fundamental processes that have created and sculpted the Earth's surface, from the highest mountains to the deepest oceans; from the hottest deserts, to the coldest glaciers. These processes include plate tectonics, volcanism, earthquakes, glaciation and erosion. The goals are to provide an understanding of how our planet works and provide experience in interpreting geologic information. This will provide student with a deeper understanding of important issues such as climate change, pollution, natural resources, land use, and geologic hazards. For nonscience concentrators. Geoscience concentrators should take EEPS 0220.

Spr	EEPS0010	S01	26247	MWF	1:00-1:50(06)	(Y. Liang)

EEPS 0011. Geology in the Real World: Intersections Between Geology and Society.
Do you know how the Earth and its processes affect you? If you want to learn how geology influences the lives of everyone on Earth, this is the class for you. We will use case studies, like the Tohoku earthquake that displaced 200,000 people, to guide our exploration. Along the way, you will learn to critically evaluate how science is presented in the media. Ten years from now you might not remember how to tell gneiss from schist, but because of this class you should be able to tell your neighbor how geology affects the lives of everyone in the world.

EEPS 0030. Climate and Climate Change.
This course is designed to provide students with an understanding of the climate system on Earth, changes in Earth's climate over time, and interactions between climate change and human society. Topics will include: global energy balance; the structure, composition and role of the atmosphere and oceans; the influence of the global carbon cycle on climate; the social, economic and political drivers of human perturbations to the carbon cycle; and societal vulnerability, resilience and adaptive capacity in the face of environmental changes. No prerequisites; course open to all levels.

EEPS 0050. Mars, Moon, and the Earth.
Space exploration has revealed an astonishing array of surface features on the planets and their satellites. Why are atmospheres on the planets different from Earth's atmosphere? Do other planets represent our past or future environment? Is there life on other planets? The planets and their histories are compared to gain insight and a new perspective on planet Earth.

Fall	EEPS0050	S01	18886	MWF	2:00-2:50(01)	(J. Mustard)

EEPS 0070. Introduction to Oceanography.
Examines the ocean's role in Earth's global environment, emphasizing the dynamical interaction of the ocean with the atmosphere, biosphere, cryosphere, and lithosphere. Focus on physical/chemical/biological systems' interconnections needed to understand natural and anthropogenic variability on various time and space scales, from El Niño to global warming. Three lectures, written exercises on oceanographic problems; two field trips to study estuarine and coastal processes.

Fall	EEPS0070	S01	18252	MWF	1:00-1:50(08)	(S. Clemens)

EEPS 0100. Surviving the Apocalypse: Earth’s Journey Through Natural Disasters Past and Present.
The course explores Earth’s geological disasters, focusing on global changes over its long history We will work our way from past to present and explore whether, through our actions, we are plunging towards another Mass Extinction. Using the physical principles we learn from the geological past; we will apply these concepts to today’s natural hazards and explore how hazards are exacerbated in a warming world. The course will turn to the future towards paths to mitigate climate change through geoengineering. Unlike an engineering approach, we will mirror geo-engineering strategies with geological events we have already explored. We emphasize interdisciplinary processes occurring within Earth’s depths and surface, taking an expansive viewpoint on time. The student’s overarching learning outcome is scientific communication. Students will develop a term-long project creating a short documentary or a popular science article.

EEPS 0160A. Climate Justice.
In this course, we will cover the science behind the climate crisis, explore the history of climate change, and study case studies of climate change inequity and injustice. As scientists we will identify the principle processes that shape modern climate change. We will learn to think critically and reflect on the history of greenhouse gas emissions. We will work together to highlight climate injustices and propose change and solutions for climate equity.

EEPS 0160B. Global Change: Ecology and Climate.
Examines ways in which global change will affect ecosystems, considering how temperature, rainfall, and land use can modify the distribution of organisms in the future, and reduce biodiversity. Examine how biotic feedbacks to global change can modify climate change through their effects on the carbon cycle, absorption of sunlight at the land surface, and retention of water in soils. Enrollment limited to 19 first year students.

EEPS 0160C. Global Environmental Change.
Examination of evidence that supports or refutes various perspectives on global environmental change, with a foundation in the principles that govern the fundamental underlying processes. Example topics include climate change (warming, cooling, neutral), population growth (how many, how fast), and loss of natural resources (diversity). Topics explored through selected readings from the natural and social sciences. Enrollment limited to 19 first year students.

EEPS 0160D. Living Within the Landscape.
Physical processes that shape the Earth's surface provide an inescapable context for human activity. We will examine the physical principles that govern erosion and sedimentation, slope stability, river and coastal flooding, and groundwater flow, and analyze how these processes affect land-use philosophies and decision-making. Enrollment limited to 19 first year students.

EEPS 0160E. Volcanos, Windows into the Deep Earth.
Examines the physical and chemical principles controlling the generation of volcanoes and their different styles of eruption. Investigates where and why volcanoes occur, and what volcanic lavas can tell us about the composition and evolution of the Earth and other planets. Evaluates volcanic hazards and their environmental impacts and the economic benefits and cultural aspects of volcanism. Two-day field trip. Enrollment limited to 19 first year students.

EEPS 0160F. Patterns: in Nature, in Society.
The shapes of plants and animals, of mountains and shorelines arise because nature dissapates energy as rapidly as possible. These morphological patterns allow description of the "energy" landscape that produced them. Societies and economies show temporal and spatial patterns as well; does the "flow rate" of ideas and of money cause these patterns? We will explore just how "entropy rules." CAP course. Enrollment limited to 19 first year students.

EEPS 0160G. Energy Resources.
Most of our energy comes directly from the Earth - predominantly as fossil fuels, but also from geothermal, wind, and hydro sources. Developing technologies for alternative energy such as solar, nuclear, biomass and fuel cells also rely on Earth resources. The potential for these energy sources will be discussed. The science behind their utilization and environmental impact (e.g. carbon sequestration and nuclear waste disposal) will be introduced and the trade-offs in making decisions for the future will be explored. CAP course. Enrollment limited to 19 first year students.

EEPS 0160H. Chicken Little or Armageddon? Past and Future Cosmic Threats.
Explore the probability of the next impact on the Earth and assess the possible consequences through historic times (incidents), folklore/legends, examples in recent geological time (last 10 million years), and the catastrophic consequences 65 million years ago. Strategies for searching and possible mitigation of the next "big one" will be considered. This seminar will explore the realities of various predictions, consider public policy, investigate strategies for prevention, and assess the role of the press in shaping perceptions. Enrollment limited to 19 first year students.

EEPS 0160I. Diamonds.
Examines both the science and human history of diamonds, and shows how they have interacted over the years. Investigates how and where diamonds are formed in nature and what they tell us about the Earth. At the same time, explores the role diamonds have played in our history and culture. Enrollment limited to 12 first year students.

EEPS 0160J. The Natural History of Great Writers: From Goethe to Steinbeck.
Many great and influential writers have also been natural historians. This course examines selections from the writing of such authors as the romantic and naturalist Johann Wolfgang von Goethe, the rationalist Benedict de Spinoza, the intuitive thermodynamicist William Blake, the naturalist novelist John Steinbeck, the lepidopterist novelist Vladimir Nabokov, the amateur paleontologist Arthur Conan Doyle, the proto-ecologist Henry David Thoreau, and the philosopher and sociologist Herbert Spencer. We will examine in a modern scientific context how facts and theories of natural history informed their writing and influenced their worldviews. Specific topics in this seminar will include: man's place in nature and the importance of the discovery of this deep time perspective, Darwinian evolution and its impact on sociology, and the emerging science of ecology in 19th century American literature. Enrollment limited to 19 first year students.

EEPS 0160L. Apocalypse Now: Fact or Fiction?.
This FYS will focus on major concepts in earth and planetary sciences as depicted through the destruction of Earth and other worlds, both real and fictional, in media. Focus on depictions of apocalypses and assess their feasibility based on lectures, readings, and discussions of the evolution of Earth ,the Solar System, and the Universe. Types of apocalypses covered may include planetary collisions and impacts, disturbance of planetary magnetic fields, alien biological warfare, supernovae, catastrophic climate change, ice ages, lithospheric rifting, and other phenomena. Learning and Teaching Goals • Basic introduction to Solar System and Universe formation and evolution • Basic introduction to earth and planetary sciences, including some simple calculations • Ability to scientifically evaluate depictions of earth and planetary sciences in the media • Understanding of realistic events that could destroy planetary bodies and their host civilizations • Collaboration and team-building skills • Presentation and observation-backed argument skills • Execution and evaluation of good communication

EEPS 0160M. Natural Disasters.
This First Year Seminar will explore natural disasters: the physical processes that cause them, and their effects on human life. Types of natural disasters covered include earthquakes, volcanoes, tsunamis, hurricanes, tornadoes, and floods. We will explore how and why natural disasters disproportionately affect low-income and minority communities. The focus of the course will be case studies of specific disasters, allowing us to discuss both the science of natural hazards and the vulnerability of human populations to those hazards.

EEPS 0160N. Monsters of the Abyss: Oceanography and Sea Tales.
We will read from the logbooks of Cook, Darwin, Wallace, and Nansen. Their discoveries and expeditions inspired and were inspired by fiction that we will also read, including Moby Dick and 20,000 Leagues Under the Sea. The daring successes and cannibalistic dooms of the Essex, Beagle, Terror, Challenger, and Fram inspired 19th century writers to imagine what lay far across and deep beneath the oceans. These retellings--fictional, narrative, and scientific--helped formulate and fund further research. Who risks their life for a bird, a map, a widow, or an eclipse? How would these scientists and their ideas do today? Enrollment limited to 19 first year students.

Fall	EEPS0160NS01	18249	TTh	1:00-2:20(06)	(B. Fox-Kemper)

EEPS 0160P. From Human Migration to Solving Crimes: The World of Forensic Isotopes.
Chemistry, and isotope systems in particular, have wide-ranging applications that include unraveling the history of human migration, human diet, the role of trading and coins in antiquity, nuclear forensics, combating counterfeit pharmaceuticals, food fraud, illegal logging and animal trade, to missing person investigations. Even the age of Jupiter can be estimated based on isotopes! This course will review basic concepts in isotopes (what are isotopes and how are they measured?) with emphasis on practical applications and how isotopes are used to address questions relevant to ancient and modern societies. This course consists of lectures, readings and discussion of recent articles on forensic isotope applications, and a final project (short paper and presentation) selected by the student.

EEPS 0160Q. Building the Solar System.
In this First-Year Seminar we will explore the ingredients, processes, and timescales for building a planetary system like our own – the Solar System. This course provides an introduction to meteorites, and how we can decipher their compositional (i.e., petrographic, chemical, and isotopic) code in order to obtain direct insights into the earliest stages of the Solar System. By integrating such cosmochemical data with theoretical models and astronomical observations, the students will learn about the current understanding of key aspects of the Solar System's evolution; such as, the sources of its building materials, the processes of planet formation, and the origin of Earth's habitability. Furthermore, we will discuss the cultural importance of meteorites as well as the specifics of the Solar System compared to exoplanetary systems.

EEPS 0160R. Geollywood: Geosciences in Hollywood.
This course explores how Earth, environmental and planetary sciences are perceived by the public through Hollywood movies and TV shows. In this First Year Seminar, students will learn about basic geologic/environmental principles and how they are portrayed in popular culture. Students will critically analyze the depiction of geological processes, space exploration, and environmental issues in movies and explore how these portrayals influence public perception of these fields and the scientists who study them. This course aims to bridge the gap between scientific concepts and public engagement through the lens of popular culture, fostering a deeper appreciation for the geosciences and the role of media in shaping scientific knowledge of the general public.

EEPS 0160S. Assembling Rhode Island.
Rhode Island has existed as a state in the U.S. for over 200 years, but the land itself is the product of hundreds of millions of years of rich geologic history. As a participant in this First Year Seminar, you will engage with introductory principles of geology toward an understanding of the tectonic history of Rhode Island as well as the geological processes that presently influence and modify its landscape. The basis of our investigation of Rhode Island geology will come from observations made over a series of afternoon-long field trips to geological points of interest in the state and nearby.

EEPS 0160W. Earth Science Behind Protest Movements.
Exploitation of natural resources, contamination of water and air, and the response of the Earth system to human actions all lie at the root of protest movements such as the labor, environmental justice, and climate action movements. Motivated by the cultural, historical, and social context of these movements, this First Year Seminar will explore Earth processes such as: building the Appalachian Mountains and forming its energy resources, the environmental impacts of natural resource extraction, effects of human actions on air and water quality, and climate.
We will consider the connection of these topics to the local Providence community as well as their global contexts. Classes will be a combination of mini-lectures, seminar-style discussions, and in-class activities that allow students to synthesize course concepts while practicing data analysis and scientific communication.

EEPS 0160Z. Mountains: Past, Present and Future.
In this first-year seminar, students will learn about mountains from a variety of natural and social science perspectives. We will explore the geologic origins of mountain building, surface processes that shape mountains over time, mountain climates and ecosystems, tools for understanding past changes in mountain environments, societal and cultural importance of mountains, and future changes in mountains as the climate warms. Classes will be a combination of lectures and seminar-style discussions in order to provide students with various pathways for learning, synthesizing and communicating the course concepts. Through this course, students will learn about the complexities of mountain systems, explore scientific research related to various aspects of mountains, understand the interdisciplinary nature of earth science, practice reading and interpreting scientific papers, and develop skills for communicating scientific concepts in written and verbal form.

EEPS 0220. Understanding Earth and Environmental Processes.
How does plate tectonics create mountains, earthquakes and volcanoes? What processes drive climate change? How do humans exacerbate flooding? This course provides an introduction to the processes that shape the Earth's surface, govern the structure of its interior, cause natural hazards, contribute to climate change and affect the human environment. Topics include interior processes (plate tectonics, mountain building, volcanism, earthquakes, flow of solid rocks), environmental processes (climate change, atmospheric and oceanic circulation, flow of rivers, glaciers, groundwater, water and energy resources), and the connections between them. Lectures are complemented by three labs, informal small-group study sessions, and field trips. Collaborative learning is encouraged. Enrollment is limited to 100.

Fall	EEPS0220	S01	18247	TTh	10:30-11:50(13)	(K. Fischer)

EEPS 0230. Geochemistry: Earth and Planetary Materials and Processes.
This course is an introduction to the formation of minerals and rocks, and the physico-chemical processes acting during planetary evolution. Topics include: Earth formation and differentiation, determination of age and origin of volcanic, crustal and mantle rocks using their elemental compositions and radiogenic and stable isotopes. Weekly laboratory. Intended for science concentrators. Lab times TBD

Spr	EEPS0230	S01	26241	TTh	1:00-2:20(08)	(E. Cooperdock)

EEPS 0240. Earth: Evolution of a Habitable Planet.
Introduces Earth's surface environment evolution - climate, chemistry, and physical makeup. Uses Earth's carbon cycle to understand solar, tectonic, and biological cycles' interactions. Examines the origin of the sedimentary record, dating of the geological record, chemistry and life on early Earth, and the nature of feedbacks that maintain the "habitable" range on Earth. Two field trips; five laboratories arranged.

EEPS 0250. Computational Approaches to Modelling and Quantitative Analysis in Natural Sciences: An Introduction.
Application of numerical analysis to mathematical modelling in the natural sciences including topics such as ground water and glacier flow, earthquakes, climate models, phase equilibrium, and population dynamics. Numerical methods will include the solution of linear algebraic systems of equations, numerical integration, solution of differential equations, time series analysis, statistical data analysis tools. Development of computer programming skills in the Matlab programming environment. Suggested prerequisites: MATH 0090, 0100; PHYS 0030, 0040, or 0050, 0060.

Fall	EEPS0250	S01	18248	MWF	10:00-10:50(14)	(C. Huber)

EEPS 0300. Sustainability of Earth Resources.
Fossil fuels are not the only Earth resource we rely on in great quantities. Over 1.5 billion cell phones are made yearly; each using 64 different elements, at least 12 of which are currently irreplaceable. Iron, copper, nickel, rare earth elements, and even sand, are all key components of our modern world that we extract from the Earth. How much are left? How environmentally damaging is it to extract them? Are there alternative extraction methods, or alternative materials? Can they be recycled? What part of your world would you be willing to give up to reduce environmental impacts?

EEPS 0310. Fossil Record.
Integrated view of the history of life: biogeochemical cycles, biodiversity, evolution by natural selection, ecology, and physiology along a multiplicity of scales from the microbial to the planetary, as recorded in the fossil record. Attention is given to how biotic systems, in contrast to just physical systems, have changed through time maintaining the chemical and thermodynamic non-equilibrium state of the Earth's surface. Two lectures per week; several labs including dissections for paleobiological comparisons and one field trip to fossil localities and museum collections in Connecticut and Massachusetts. Prerequisites: EEPS 0220 or 0230 or 0240, BIOL 0200, or instructor permission.

EEPS 0350. Mathematical Methods of Fluid.
Intended for undergraduates concentrating in geological and physical sciences or engineering, especially those interested in the quantitative study of Earth. Problem sets will cover common approaches to quantify the dynamics and chemistry of solids and fluids in nature. Mathematical topics to be introduced include linear algebra, vectors and tensors, differential equations, dynamical systems, eigenvalues and eigenvectors, empirical orthogonal functions, fractals, chaos, and statistics. Applications include waves in the oceans, atmosphere, and solid earth, convective and conductive heat flow, reaction rates, gravitational potential energy, Newton's laws on a rotating planet, measuring coastlines and ranges, and dating errors in stratigraphy.

EEPS 0360. Solving the Climate and Carbon Challenge.
Explore the critical aspects of climate change, greenhouse gas emissions, and carbon management, reduction and removal. Through a series of engaging lectures, students will gain an understanding of the current state and future trends of climate and carbon challenges in the 21st century, Including the impacts and projections of climate change, the social cost of carbon, climate justice, the carbon cycle, and non-CO2 greenhouse gases. The course will cover the state of the art in emissions mitigation technologies and strategies, along with carbon dioxide removal approaches, to equip students with the knowledge and tools that are currently being explored for developing scalable carbon reduction strategies. The course will also delve into policy, economics, and social systems solutions, including international, national, and state-level climate policies, carbon markets, climate financing, and the role of innovation in addressing climate change. Students will also

Spr	EEPS0360	S01	25406	TTh	2:30-3:50(11)	(K. Cobb)

EEPS 0580. Foundations of Physical Hydrology.
Qualitative introduction to the dynamics of watersheds and groundwater flow from an intuitive perspective. Lays the foundations for understanding the physical mechanisms by which water is transported throughout a hydrologic system. Provides background for future studies, but is primarily designed to enable informed citizens to thoughtfully critique water management practices and public policy. Pre-college math and physics background is expected.

EEPS 0810. Planetary Geology.
This introductory level course will examine the evolution of our Solar System and the geology of planetary bodies, including Mercury, Venus, the Moon, Mars, asteroids, and the moons of Jupiter and Saturn. We will discuss the origin of the Solar System from a geological perspective and explore how scientists combine observations from extraterrestrial samples such as meteorites with data returned by satellites and rovers to develop and test hypotheses related to planetary evolution. Emphasis will be on comparing geologic processes on these bodies to well-understood processes on Earth, results from past, current, and upcoming planetary missions, and the future of human and robotic exploration of space.

Spr	EEPS0810	S01	26246	MWF	10:00-10:50(03)	(S. Birch)

EEPS 0830. Water in Our World.
This course will focus on understanding natural and societal dimensions of the water cycle. The coming century will see substantial pressure on global water resources owing to increasing human demand, alteration of river systems, and climate change. The first half of the course introduces fundamental concepts in physical hydrological science, and the second explores human modifications and environmental problems associated with a perturbed water cycle. The topical sequence of the class will progress first through different components of the water cycle (e.g. precipitation, evaporation, runoff), followed by different ways in which humans use and depend upon freshwater resources.

Fall	EEPS0830	S01	18253	F	10:00-12:30	(L. Smith)

EEPS 0850. Weather and Climate.
Weather phenomena occur on short time scales, and form the basis for understanding climate, the study of changes over longer time scales. This course aims to provide an understanding of the processes that drive weather patterns, the general circulation of the atmosphere, and climate on Earth. Topics include the structure and composition of the atmosphere, sources of energy that drive atmospheric processes, weather forecasting, the hydrological cycle, forces that create severe weather, the influence of humans on the atmosphere, and factors that influence climate, climate variability and climate change. Recommend courses or equivalent: MATH 0090, MATH 0010, PHYS 0050.

EEPS 1110. Descriptive Coastal and Estuarine Oceanography.
An introduction to coastal and estuarine oceanography, focusing on ocean environments landward of the continental shelf/slope break. These environments are of significant value, both environmentally and economically. They are under pressure and strongly impacted by human activities, both directly (e.g. commercial fishing) and indirectly (urbanization within the adjacent river drainage basins). The extent to which these waters continue to be economically valuable is intimately linked to their environmental health. As such, an understanding of coastal and estuarine processes is critical to their management. This course will address the coastal and estuarine circulation context as well as the environmental context. Coastal and estuarine oceanography will be addressed in class lectures, discussions, and exercises while the environmental concerns will be addressed in the context of individual student research projects culminating in a research paper and in-class presentation.

EEPS 1120. Paleoceanography.
An examination of the Cenozoic history of the world ocean with attention to the processes which have acted to change its circulation, climate, geometry, and biology. Develops a strategy to use marine sediments and microfossils to identify and understand past variations in the oceans. Class projects analyze and interpret various types of paleoceanographic data. Laboratory arranged. Offered alternate years.

EEPS 1130. Ocean Biogeochemical Cycles.
A quantitative treatment of the cycling of biologically important elements in the world ocean. Special attention paid to the carbon system in the ocean and the role that organisms, in conjunction with ocean circulation, play in regulating the carbon dioxide content of the atmosphere through exchange with the surface ocean. For science concentrators. Offered alternate years. Prerequisite: CHEM 0330 or equivalent, or instructor permission.

EEPS 1150. Limnology: The Study of Lakes.
This course will provide an interdisciplinary overview of the physics, chemistry, biology, and geology of lakes. Areas of emphasis will include the origin of lake basins, water circulation patterns, heat and water budgets, biogeochemical processes, lake ecosystems, and the stratigraphic record of lakes. We will also discuss human and climatic impacts on lakes. Prerequisites: EEPS 0220 and 0240, or instructor permission. Enrollment limited to 20.

EEPS 1220. Climate Extremes and Human Rights: Winter Session in Geneva.
People around the world are exposed to many hazardous extreme events, including wildfire, flood, heatwave and drought. The locations, frequency and intensity of these extremes are already changing, and increasingly these changes can be linked to increases in greenhouse gas emissions from human activities. But many factors must interact with extreme events to cause a humanitarian disaster. These include the exposure of people and infrastructure to the impacts of extreme events, and the response capabilities before, during, and after the disaster. Furthermore, the vulnerabilities created by poverty and conflict have an impact on the characteristics of disasters, and extreme events in turn can exacerbate existing human rights calamities. The disasters at the nexus of climate change and human rights can be understood through the lens of incident theory. Each damaging climate extreme tends to motivate if not force action.

EEPS 1240. Stratigraphy and Sedimentation.
Introduction to depositional environments and processes responsible for formation of sedimentary rocks. Major sedimentary environments in the Recent are discussed, general models are proposed, and stratigraphic sequences in older sediments are examined in the light of these models. The Phanerozoic stratigraphic record is examined from the perspective of Earth system history. Laboratory arranged. Prerequisites: EEPS 0220 or 0240, or instructor permission.

EEPS 1250. New England Field Geology.
How do geologists know what happened on earth thousands to millions of years ago? What is their evidence? Can our own observations, measurements, and analyses provide new insights and context for understanding the past? Through field trips and seminar discussion, this course will provide an introduction to geological field methods and an overview of the geologic history of the region in and around Rhode Island. In addition to field trips that focus on regional bedrock geology and developing mapping skills, the course will also involve field trips that develop field skills for investigating Pleistocene glacial deposits and Holocene soils. The course will introduce field methods, field mapping, structural analysis, and soil and site evaluation. The course will require attendance of weekend field trips, maintaining a detailed field notebook, making three geological maps, seminar participation, and writing one final report.

Fall	EEPS1250	S01	18245	MWF	9:00-9:50(09)	(E. Hodgin)

EEPS 1310. Global Water Cycle.
The goal of this class is to understand the physical principles and processes of the global water cycle. Topics include the climatic importance of water, circulation of atmospheric water vapor, formation of rain and snow, availability of soil water, plant-water relations, mass balance of glaciers, and ongoing and expected changes in the water cycle. Additional goals: become familiar with the current research literature, practice clear and concise science writing, and to use simple programming in Python to plot and analyze actual data sets.

Students are expected to have taken at least one geology-related course. Programming experience recommended, but not necessary.

EEPS 1320. Introduction to Geographic Information Systems for Environmental Applications.
This class serves as an introduction to Geographic Information Science (GIS). This innovative field explores the relationships between spatial information and a vast array of spatial data types. Through lab work and foundational lectures, this course covers the guiding principles behind various facets of GIS including the nature of spatial data, map projections, spatial model building, spatial analysis, and cartographic production. You will have the opportunity to explore cutting-edge GIS techniques and apply them to real-world problems across multiple disciplines. Throughout the course, you will be challenged to think spatially and practice basic GIS concepts and theory to enable you to make useful and meaningful contributions to various disciplines through spatial analysis and techniques. By evaluating the relationship between different spatial information, you'll develop a better understanding of how the world interacts and gain tools to make a difference.

EEPS 1330. Global Environmental Remote Sensing.
Introduction to physical principles of remote sensing across electromagnetic spectrum and application to the study of Earth's systems (oceans, atmosphere, and land). Topics: interaction of light with materials, imaging principles and interpretation, methods of data analysis. Laboratory work in digital image analysis, classification, and multi-temporal studies. One field trip to Block Island. Recommended preparation courses: MATH 0090, 0100; PHYS 0060; and background courses in natural sciences.

EEPS 1340. Machine Learning for the Earth and Environment.
This course introduces science students to modern data science tools for exploratory data analysis, predictive modeling with machine learning, and scalable algorithms for big data. The course will familiarize students with a cross-section of common machine learning models and algorithms with an emphasis on developing practical skills for working with data. Topics covered in the course may include dimensionality reduction, clustering, time series modeling, linear regression, regularization, linear classifiers, ensemble methods, neural networks, model selection and evaluation, scalable algorithms for big data, and data ethics. The course will present case studies of these tools applied to problems in the Earth sciences. The intended audience for this course is advanced undergraduate and graduate students in Earth, Environmental and Planetary Sciences or other physical science disciplines. Students will practice and develop their skills in data science through a hands-on project on a topic of their choice. This course is taught using the Python programming language.

EEPS 1350. Spatial Data Science.
Spatial Data Science explores the application of statistical, computational, and geographic principles to analyze and derive insights from spatial data. This class serves as an advanced Geographic Information Science (GIS) course focusing on three important stages of geographic information: modelling, analyzing, and visualization of spatial information. This course is designed for students interested in leveraging spatial data science techniques to analyze, visualize, and interpret spatial data for decision-making and problem-solving in diverse fields such as geography, environmental science, urban planning, and public health. Through lab work and foundational lectures, this course covers the guiding principles behind various facets of Spatial Data Science including big data, cluster analysis, geosimulation, pattern recognition, deep learning, network analysis, and geovisualization. You will have the opportunity to explore cutting-edge spatial data science techniques and apply them to real-world problems across multiple disciplines

Fall	EEPS1350	S01	18889	M	3:00-5:30(03)	(S. Salap-Ayca)

EEPS 1370. Environmental Geochemistry.
The course will examine the biogeochemical cycling, fate and transport of chemicals in the atmospheric and aquatic environments. Topics such as chemical weathering, natural water pollution and remediation, acid deposition, global warming and air pollution will be examined through natural ecosystem examples from rivers, lakes, estuaries, and ocean. Field trips and laboratory arranged. Prerequisites: CHEM 0100 or 0330, or instructor permission.

Fall	EEPS1370	S01	18251	TTh	9:00-10:20(05)	(Y. Huang)

EEPS 1380. Environmental Stable Isotopes.
Introduction to the concepts, analytical methods, theory and environmental applications of stable H, O, C, N and S isotopes. In addition, there will be an introduction to non-traditional stable isotopes of Li, Ca, Si and Mg as well as an introduction to clumped isotopes, mass fractionation laws and mass-independent isotope effects. Emphasis will be placed on theory and applications of light isotopes in paleoclimate studies, environmental hydrogeology and biogeochemistry. Prerequisites: CHEM 0100, EEPS 0220 or 0230 recommended, or instructor permission.

EEPS 1390. Planetary Surface Processes.
This course is designed to introduce students a variety of physical and chemical processes that shape and sculpt the surfaces of solid planetary bodies (asteroid, comets, moons, & terrestrial planets). We will learn the ways mountains can form and how their topography is supported (Is Venus' 11 km high Maxwell Montes the result of a rising mantle plume? among other questions). This course will cover the processes of faulting, tectonics, volcanism, impact cratering, landslides, and weathering from wind, and water. These processes will be explored from a physical quantitative perspective.

EEPS 1400. Climate Modeling I.
An introduction to climate modeling, focusing on the fundamental principles of climate dynamics and the techniques used to simulate and understand the climate system of Earth and other planets. Students will learn about the underlying physics, concepts, and computational methods involved in climate modeling. The course will explore the challenges and uncertainties associated with climate models and their role in predicting future climate change. The course has two tracks: quantitative and qualitative. Students in the quantitative track will gain hands-on experience with analyzing climate modeling output and software tools to do so and will be assessed with problem sets. Students in the qualitative track will focus on interpretation of model results and modeling concepts and have additional reading assignments and will be assessed with writing assignments.

Fall	EEPS1400	S01	18830	MWF	2:00-2:50(01)	(M. Freilich)

EEPS 1410. Mineralogy.
Introduction to mineralogical processes on Earth and the terrestrial planets. Topics include: crystallography; crystal chemistry; fundamentals of mineralogical thermodynamics and kinetics; mineral defects and their dynamics; physicochemical properties of minerals and magmas. Laboratory study devoted to analytical techniques for minerals/materials analysis: X-ray and electron diffraction; reflectance spectrometry; transmitted optical microscopy; electron microscopy; X-ray spectrometry. In addition to Earth scientists, the course should be of interest to chemical/materials engineering and chemistry concentrators. Prerequisites: EEPS 0230, CHEM 0100 or 0330 or equivalent, or permission of instructor.

EEPS 1420. Petrology.
Introduction to the origin and evolution of igneous rocks. Topics include: physical properties of magma, thermodynamics and phase equilibria, igneous rocks and their classification, magmatic processes, trace elements and isotopes, basalts and layered intrusions, survey of lunar and planetary petrology. Prerequisites: EEPS 1410, or instructor permission.

Fall	EEPS1420	S01	19192	TTh	10:30-11:50(13)	(S. Parman)

EEPS 1430. Principles of Planetary Climate.
This course provides the physical building blocks for understanding planetary climate. Topics include thermodynamics applied to planetary atmosphere, basic radiative transfer, energy balance in the atmosphere, and climate variability. In-class exercises and homework problems are designed to strengthen the understanding of basic concepts and to improve problem-solving skills.

EEPS 1450. Structural Geology.
Introduction to the geometry, kinematics and mechanics of rocks deformed by brittle fracture or faulting and ductile solid state flow, on scales from microscopic to mountain ranges. The emphasis is on using concepts to interpret the formation, strain history and rheology of deformed rocks in terms of the operative grain-scale processes, material properties and environmental conditions. Weekly 2 hour lab involving hands-on experience closely related to class topics. Two field trips. Prerequisites: EEPS 0220 or instructor permission.

EEPS 1470. Sea Level Rise (And Fall).
This course will explore the many themes that surround the global problem of sea level rise. Moving from Earth's early history to modern times, through different case studies, this course will explore the underlying physics that contribute to sea level rise on time scales of years to millions of years. The relevant physics that drive this change will be covered, from deep time geological processes (i.e., eustasy and dynamic topography), ice age sea level (glacial isostatic adjustment, viscoelastic deformation theory), and modern-day sea-level change (sea level feedbacks on ice sheet stability, thermal expansion, sea level fingerprinting). The emphasis of this course is the interplay between the dynamics of the solid Earth (mantle and crust) and the overlying oceanic and cryosphere system and so any student interested in a wide perspective on the Earth system is encouraged to join.

EEPS 1510. Dynamic Meteorology.
The objective of EEPS 1510 is to understand the fundamental physical principles that govern the motion of the atmosphere. Students will explore the dynamics of the atmosphere and the mathematical laws governing weather and climate. Topics include the fundamental equations of motion in rotating fluids, hydrostatic, geostrophic and thermal wind balance, and vorticity, as applied to phenomena, including sea breezes, planetary waves, midlatitude cyclones, fronts, and the global general circulation. The emphasis will be on physical interpretation of the equations but facility with vector calculus is critical. Enrollment limited to 30.

EEPS 1520. Ocean Circulation and Climate.
Examines physical characteristics, processes, and dynamics of the global ocean to understand circulation patterns and how they relate to ocean biology, chemistry, climate change. Assignments address ocean's role in the climate system; ocean observations and models; the origin, distribution, and dynamics of large-scale ocean circulation and water masses; energy and freshwater budgets; and variability of the coupled system on seasonal to centennial timescales e.g. El Niño. Intended for geological and physical sciences undergraduate and graduate students with quantitative skills and an interest in oceans, climate, paleoclimate. Pre-requisites: EEPS 0250, EEPS 0350, PHYS 0720, or MATH 0180. Offered alternate years.

EEPS 1530. Polar Oceanography.
Polar Oceanography examines the physical processes governing the behavior of the high-latitude (Arctic and Southern) oceans, with an emphasis on interactions between sea ice and the upper ocean. The course will focus on both modeling and remote-sensing of polar systems, drawing upon recent advances in sea ice physics, ocean circulation, and satellite remote sensing. While understanding observations will be an important component of the course, we will emphasize their interpretation through a physical and mathematical lens. This course is intended for students who are interested in climate and fluid dynamics as well as computational science. We will also explore how these concepts are implemented in the numerical models used in contemporary Earth system models. Recommended: ●

EEPS 1560. Global Tectonics.
Plate tectonic theory and the evolution of continents and the seafloor. Emphasis on the structure and tectonics of western U.S. considering geological, geophysical, and geochemical constraints as well as direct geodetic observations of plate motions from GPS measurements. Prerequisite: EEPS 0220 and 0230. Three or more of EEPS 0220, 0230, 1240, 1410, 1420, 1450 and 1610 are recommended.

EEPS 1580. Quantitative Elements of Physical Hydrology.
Physical hydrology with emphasis on fundamental physical principles and mathematical tools. Topics include precipitation, surface runoff, groundwater flow, water quality and contaminate transport. Prerequisites: APMA 0340; and ENGN 0510 or PHYS 0470; ENGN 0810 is recommended; or instructor permission.

EEPS 1590. Quantitative Modeling of Hydrologic Processes.
A quantitative overview of selected topics at the advanced undergraduate and beginning graduate student level of analytical and numerical models for simulating surface runoff, groundwater flow and contaminant migration. While participants will employ computers and scientific visualization to implement the material, no prior computing experience is expected. Non-concentrators encouraged. No exams. Prerequisites: PHYS 0470, or ENGN 0510.

EEPS 1590A. Quantitative Modeling of Hydrologic Processes.
A quantitative overview of selected topics at the advanced undergraduate, beginning graduate student level of analytical and numerical models for simulating surface runoff, groundwater flow and contaminant migration. While participants will employ computers and scientific visualization to implement the material, no prior computing experience is expected. Non-concentrators encouraged. No exams. Prerequisites: PHYS 0070, or ENGN 0510.

EEPS 1600. Environmental and Engineering Geophysics.
A hands-on introduction to non-invasive geophysical methods applied to subsurface investigations of soil and bedrock conditions, groundwater, geotechnical engineering, forensics, archaeology and other environmental applications. Students will use ground penetrating radar, seismic, gravity resistivity, electromagnetic and magnetic methods in the field one afternoon a week to investigate relevant environmental and geotechnical problems. A background in geology is not expected. Prerequisites: APMA 0340 and PHYS 0470, or ENGN 0510, or instructor permission.

EEPS 1610. Solid Earth Geophysics.
A survey of basic geophysical techniques for determining the structure and dynamics of Earth's interior. Topics include: global structure from seismic waves; gravity, magnetic field, and shape of the Earth; thermal processes within the Earth; structure of continental and oceanic lithosphere. Recommended courses: EEPS 0220, PHYS 0470, APMA 0330. No prerequisites.

Fall	EEPS1610	S01	18246	TTh	1:00-2:20(06)	(C. Dalton)

EEPS 1615. Climate Change, Human Rights, and the Policy Process.
The diminishing quality of Earth's systems and resources carries profound implications for the fulfillment of human rights and aspirations. But even as Western knowledge systems understand better the intrinsic interdependencies between humans and the non-human, policy gridlock persists. Indeed, scientific findings are regularly contested on political grounds. The purpose of this course is to learn how to apply diverse knowledges from Indigenous to Modern to map the relevant policy in problems at the intersection of human rights and environmental integrity, and to develop approaches to address them in ways that are creative, effective, responsible and just.

Fall	EEPS1615	S01	17302	TTh	10:30-11:50(13)	(A. Lynch)

EEPS 1620. Continuum Physics of the Solid Earth.
Physics of the Earth with emphasis on fundamental physical principles and mathematical tools. Topics include application of: conductive and convective heat transfer to cooling of the Earth; potential theory to interpretation of gravity anomalies; solid mechanics to deformation of Earth's lithosphere; fluid mechanics to flow in the Earth's interior and in porous media. Recommended courses: EEPS 0220; APMA 0340; PHYS 0470 or ENGN 0510.

EEPS 1630. Introduction to Quantitative Glaciology.
This class will focus on a quantitative understanding of glaciers. Topics will include glacier mass balance, energy balance in glaciers, ice deformation physics, glacier hydrology, subglacial mechanics, ice sheet stability, and planetary glaciology. Emphasis will be on a theoretical understanding of what physical processes are important for glaciers and how to make predictions of their long-term behavior. Primary course objective: To learn how to quantitatively understand glacier processes. Specific learning goals: - Gain a quantitative understanding of how glaciers behave and why - Gain an understanding of which processes are important and how to model them - Learn how to reason quantitatively about the Earth and make predictions

EEPS 1650. Earthquake Seismology.
This course is an introduction to seismology that focuses on the seismic waves generated by earthquakes, and how the information contained in these waves can be used to understand earthquake processes and the structure of the Earth. We will discuss applications of seismology that address earthquake hazards and other societal issues. Recommended courses: EEPS 1610; or EEPS 0220 and experience with differential equations; or the equivalent. Offered in alternate years.

EEPS 1690. Introduction to Methods in Data Analysis.
This class will be an overview of different ways one can quantitatively analyze data. Topics will include linear regression, least squares inversion, principal component analysis, and Bayesian methods. Emphasis will be on both a theoretical understanding of these methods and on practical applications to geophysical and earth science problems. Exercises will include using MATLAB to analyze data.

EEPS 1710. Remote Sensing of Earth and Planetary Surfaces.
Geologic applications of remotely sensed information derived from interaction of electromagnetic radiation (X-ray, gamma-ray, visible, near-IR, mid-IR, radar) with geologic materials. Applications emphasize remote geochemical analyses for both terrestrial and extraterrestrial environments. Several spectroscopy and image processing labs. EEPS 1410 (Mineralogy), PHYS 0060, or equivalent recommended.

EEPS 1720. Tackling Climate Change with Machine Learning.
Explore recent work that leverages machine learning (ML) as a tool for tackling climate change, with a focus on climate science and climate adaptation. We will discuss how modern machine learning can be used to assess, understand and respond to projected climate extremes, natural disasters, and environmental change. The target audience for this course is advanced undergraduate students or graduate students who are interested in using ML and AI to address high-impact global issues. Students will read and discuss recent research papers on ML for Climate and complete an original project as a member of a multidisciplinary team. Climate themes may include: Climate models and predictions; Extreme weather and natural disasters; Farms and forests; Oceans and marine ecosystems; Climate misinformation. Machine learning topics may include: Physics-informed learning and emulators; Explainable AI; Uncertainty quantification; Image super-resolution; Graph neural networks, Policy optimization.

EEPS 1730. Isotope Geochemistry.
This course provides a comprehensive introduction to radiogenic and stable isotope geochemistry. Beginning with a brief overview of nuclear physics and nucleosynthesis, it then reviews radioactive decay schemes including and their use in geochronology. Subsequent classes cover nucleosynthetic anomalies in meteorites and early solar system chronology and the use of radiogenic isotopes (including Uranium-series) in understanding the evolution of the Earth’s mantle, crust, and oceans. Attention then turns to stable isotopes reviewing the basic principles involved in controlling stable isotopes during both equilibrium and kinetic fractionation, followed by their application on diverse topics but particularly on climate evolution. Finally, the course explores recent developments including unconventional stable isotopes, mass-independent fractionation, isotopic ‘clumping’, noble gasses isotopes and their applications.

Fall	EEPS1730	S01	18680	TTh	2:30-3:50(12)	(A. Saal)

EEPS 1745. Planetary System Design: A Team Project Course.
Introduction to the research process for planetary systems. This upper-level undergraduate course includes a lecture phase that covers an overview of planetary science, the research project(s) to be pursued, problem-solving, scientific writing, communications, and diversity and bias in the field of planetary science. Subsequently, students experience the latest practices in planetary research by forming sub-project teams and collectively designing and planning a research project. Effective team and communication skills are emphasized. Scientific writing and presentations are required throughout, culminating in the final paper and public presentation. This course has been submitted for special designations in writing (WRIT), race, gender, and inequality (DIAP), and collaborative research & scholarly experiences (COEX). The following courses are recommended (and/or permission of the Professor): MATH 0090, MATH 0100; PHYS 0030, PHYS 0040 or PHYS 0050, PHYS 0060 or PHYS 0070; and, EEPS 0250, EEPS 0220,EEPS 1610, EEPS 1810, or EEPS 1950H.

EEPS 1750. Geomorphology.
Landscapes are one of the most accessible and striking parts of a planet’s geologic record. Because we live on Earth’s surface, landscapes and the forces that shape them are also integral parts of society. This course introduces students to the quantitative study of processes that shape Earth's surface. We will use a combination of theory and field observations to investigate major components of continental geomorphic systems, especially hillslopes and rivers. Our ultimate goal will be to understand how the major factors that shape Earth’s surface – tectonics, climate, and life – create the landscapes we observe. The course is designed to be accessible to undergraduate and graduate students from a range of disciplines, including Earth and planetary science, physics, engineering, and IBES. As such, we do not assume an extensive geology background.

EEPS 1810. Physics of Planetary Evolution.
The course will explore and expose students to the fundamental physics necessary to understand how planetary bodies evolve. The evolution of planetary bodies will be discussed on the basis of geological and geophysical evidence derived from exploration of the Solar System. This course will study the physical processes responsible for and that occur as a consequence of differentiation and deformation of planetary bodies. Includes the study of physical processes responsible for volcanism and deformation on the surface as well as the state and structure of the interior of planets.

EEPS 1820. Geophysical Fluid Dynamics: Rotating, Stratified Turbulence Edition.
Explores theories of the large-scale ocean and atmosphere, including quasigeostrophic, planetary geostrophic, and shallow water equations. Topics will vary to focus on features of the general circulation and climate system (e.g. thermocline, westward intensification, jet stream dynamics, polar vortex, meridional overturning circulations), instabilities and waves (e.g. gravity, Rossby, and Kelvin), or rotating stratified turbulence. May be repeated with permission of instructor. Pre-requisites: EEPS 0350 or PHYS 0720 or APMA 0340 and EEPS 1510 or EEPS 1520.

EEPS 1930P. Mathematics and Climate (APMA 1930P)..
Interested students must register for APMA 1930P.

EEPS 1950B. Atmospheric Chemistry.
Earth’s atmosphere touches everything on the surface of our planet has evolved, from the first signs of life on land and in the oceans to today’s This seminar course will provide students with an understanding of the chemical and physical processes that determine the composition of the atmosphere and its implications for climate, ecosystems, and human welfare. Topics to be covered include basic measures of the atmosphere; photolysis and reaction kinetics; atmospheric transport of trace species; stratospheric ozone chemistry; tropospheric hydrocarbon chemistry; oxidizing power and nitrogen, oxygen, sulfur, and carbon cycles; chemistry-climate-biosphere interactions; aerosols, smog, and acid rain.

EEPS 1950C. Planetary Materials.
A comparative planetology course that examines the origin and evolution of materials on the Earth, Moon, and Mars through sample analyses, spacecraft observations, and modeling approaches. Recommended courses: EEPS 1410, 1420. No prerequisites.

EEPS 1950D. Field and Tectonics Seminar.
Development of field mapping and interpretive skills used in the evolution of complex orogenic terranes. Structural field mapping is carried out in highly deformed metamorphic and igneous rocks in the New England Appalachians, the site of a continental collision associated with the formation of the supercontinent Pangea. Expected: EEPS 0230 and EEPS 1450, or equivalent, and field mapping experience (generally a summer geological mapping course). Students are required to arrive one week prior to the start of classes for the beginning of field work. Instructor permission required.

EEPS 1950F. Geomicrobiology.
Microbes were the predominant form of life for most of Earth's history and continue to drive many of the elemental cycles that sustain life in our contemporary biosphere. By taking this course students will learn about the phylogenetic and metabolic diversity of microbes in the environment and their influence on global biogeochemical cycles. Students will gain hands-on experience with molecular and environmental microbiological techniques and the bioinformatics tools required to analyze and interpret the resulting data. There are 2 sections or topical areas: Phylogenetic and ecological diversity of microbes; Microbial and metabolic diversity of biogeochemical cycling. Prerequisite: BIOL 0415 or 1460 or 1480 or EEPS 1130. Enrollment limited to 12. Instructor permission required.

EEPS 1950G. Astrophysical and Dynamical Processes in Planetary Sciences.
Astrophysical and Dynamical Processes in Planetary Sciences is a course that challenges students to use physical and geophysical analysis to construct a quantitative understanding of the formation and evolution of the Sun, the solar system's planets and small bodies, and extrasolar planets. The goal is to provide senior undergraduate and first-year graduate students with core knowledge of facts and current theories in the planetary sciences. Through lectures, problem sets, and exams, the students will construct quantitative framework on which to evaluate, and place into context, hypotheses and theories discussed in upper-level graduate courses. Prerequisites: MATH 0100; and one of EEPS 0050, PHYS 0210, 0220, or 0270. APMA 0330 is desirable but not required.

EEPS 1950H. Gravitational Fields and Data Analyses.
The course will cover fundamental and cutting-edge methods applied to Earth and planetary gravity data acquired by spacecraft, aircraft, sea, and surface gravimeters. Students will learn and practice how to represent, analyze, manipulate, and interpret gravitational data. The course will also include topics on potential field theory, geomagnetic data, pattern recognition methods, Monte Carlo methods, and computer modeling techniques. Topics covered in this course provide a foundation for a wide variety of advanced data analysis, representation, and manipulation techniques that extend beyond Earth and planetary sciences. The following courses are recommended prerequisites (and/or permission of the Professor): MATH 0090, 0100; PHYS 0030, 0040 or 0050, 0060 or 0070; and, GEOL 0250 or previous programming experience in MATLAB or a high-level programming language (e.g., C, C++, Fortran, etc.).

EEPS 1960A. Earthquakes and the Rheology of the Crust and Mantle.
Introduces the principles of rock rheology and uses them to describe brittle and ductile deformation processes in the crust and mantle .Topics to be covered include: brittle fracture and crack propagation, frictional sliding, the brittle/plastic transition, viscous deformation mechanisms,

EEPS 1960B. Special Topics in Geological Sciences: Physical Hydrology.
Physical Hydrology is the description of processes that involve the transport of aqueous fluids in the subsurface of the Planets. We will learn about the principle that govern the motion of these fluids and the common approaches to describe their dynamics in terms of governing equations. The goal of the course is to be introduced to flows in porous media, as well as transport of heat, chemical species and multiphase flows (unsaturated aquifers). We will discuss applications from geothermal energy extraction, CO2 geological sequestration strategies and reactive transport, such as those encountered for pollutant remediation and sediment diagenesis.

EEPS 1960F. Patterns: in Nature, in Society.
The shapes of plants and animals, of mountains and shorelines arise because nature dissipates energy as rapidly as possible. These morphological patterns allow description of the energy "landscape" that produced them. Societies and economies show temporal and spatial patterns as well: does the "flow rate" of ideas and of money cause these patterns? These societal patterns are statistically identical to the natural (i.e., non-human) ones. Does this fact challenge ideas of free will? Does it affect one's development of a personal philosophy? From a perspective grounded in natural philosophy, we will explore just how "entropy rules." Enrollment limited to 16. Instructor permission required.

EEPS 1960G. Geo-, Environmental + Planetary Sciences' curriculum design + teaching pract. for local high school.
A practical introduction to Geo-, Environmental and Planetary Sciences' curriculum design and teaching with a strong "learning by teaching" component. You will learn about the principles and best practices of science education and communication and will also participate in Earth Science teaching lessons for 10th and 11th grade students at a local high school (Hope HS) co-teaching material previously developed by DEEPS CORES outreach program alternating with in-class physics tutoring in 11th grade. You will observe and reflect on your in-school teaching experience. By the end of the course you will be familiar with the inquiry-driven teaching approach and backwards design and will be able to practice their application. For reasons of capacity at Hope High School, this course is capped at 18 students. The course consists of 2 main parts: 1) science-teaching principles and practical application (teaching at Hope

EEPS 1960H. The Early Earth.
Primary focus on evolution of the solid Earth (core, mantle, crust) but will also include discussion of the Archean hydrosphere, atmosphere and biosphere. Reading and discussing current literature, with lectures. Intended for graduate students and upper level undergraduates with advanced petrology and/or geophysics. Enrollment limited to 20.

EEPS 1960J. Reactions and Rheology: Chemical and Mechanical Kinetics in Mineral Systems.
Characterization of atomic diffusion and dislocation motion responsible for chemical and physical reactions and plastic rheology in ionic solids. Topics include: point-defect thermodynamics; atomic diffusion (physical and mathematical); solid-solution formation; solid-state compound formation; dislocation structures; grain boundary structure and chemical segregation; plastic rheology. Recommended three or more of EEPS 1410, EEPS 1420, or EEPS 0410, ENGN 1410, or CHEM 0330, CHEM 1060. Enrollment limited to 20.

EEPS 1960K. Carbon Cycle Seminar.
Consideration of quantitative models of the cycling of carbon between various reservoirs near Earth's surface. Topics include: mass balance models of carbon sedimentation; carbon chemistry in the ocean; exchange of carbon between atmosphere, ocean, and biosphere; and consumption of carbon in weathering reactions with rocks. Special emphasis will be placed on the use of isotopic tracers (d13C, 14C) to estimate present and past dynamics of the carbon cycle. Instructor's permission required. Enrollment limited to 20.

EEPS 1960L. Foundational Readings in the Earth Sciences.
This class focuses on the reading and discussion of a number of foundational and highly influential papers in the Earth sciences. Topics of papers will cover all aspects of Earth science, including the age of the Earth, plate tectonics, the discovery of planets, climate change, and chaos. The focus of writing assignments and discussion will be on gaining an appreciation for what sets these contributions apart from other science of that time and will include brief discussions about why the authors of the papers are not representative of a diverse world population. Specific Learning Goals: (A) Improving critical thinking and evaluation of groundbreaking ideas; (B) Understanding the scientific context in which breakthroughs are made; (C) Improving communication (written and oral); (D) Understanding the changing diversity of scientists in historical context.

EEPS 1960M. Lab and Field Methods in Hydrology.
A series of hands-on opportunitites for students to characterize the hydrologic properties of soils and simple hydrologic systems in the lab, combined with selected outdoor exercises using standard hydrologic tools in the field. High school math and physics recommended. Enrollment limited to 20.

EEPS 1960X. Ocean, Cryosphere, and Sea Level Change.
Or IPCC and you can, too! Interested in finding out how big climate science gets done? This graduate and undergraduate reading and writing seminar will emphasize study of the breakthrough science that has been published in the Intergovernmental Panel on Climate Change Assessment Reports. Focus will be on the physical science basis: past and future changes in the overall earth system, ocean circulation and properties, ice sheets, glaciers, sea ice, and sea level; evaluation of models and projection methods; detection and attribution; projections; abrupt change and long-term commitment; and extremes. Pre-requisite: any of EEPS 0850, EEPS 1430, EEPS 1510, EEPS 1520, EEPS 1820, or permission of instructor.

EEPS 1960Z. Physical Volcanology.

EEPS 1970. Individual Study of Geologic Problems.
One semester is required for seniors in Sc.B. and honors program. Course work includes preparation of a thesis. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course. Enrollment is restricted to undergraduates only.

EEPS 2300. Mathematical and Computational Earth Sciences.
For graduate students interested in quantitative study of the Earth in geological, physical, or engineering sciences. Mathematical topics to be introduced include tensor analysis, asymptotic and per turbation analysis of differential equations, numerical integration of differential equations, basis functions and pattern recognition, fractals and multifractals, and statistics. Applications will vary by offering, but examples include: statistics of turbulence and earthquakes, advection-reaction-diffusion systems, boundary layers, development of shocks and singularities, climate change, carbon sensitivity, and dimensional reduction of geophysical data. Intensive review of introductory mathematical methods through leading discussions in a lower level class. Earth, fluid, or solid science background recommended.

EEPS 2330. Advanced Remote Sensing.
Strategies and the physical principles behind the quantitative extraction of geophysical and biophysical properties from remotely sensed data. Emphasis on radiative transfer theory and modeling of spectra and spectral mixtures from optical constants. Advanced methods of digital image processing. Methods of integrating remotely sensed data into a GIS framework will be introduced. Recommended preparation course: EEPS 1330 or 1710; MATH 0100; PHYS 0600.

EEPS 2350. Quaternary Climatology Seminar.
Discussion of current problems in paleoclimatology and global climate change. Students analyze the primary literature, and do original analyses of their own on published data. Topics include: theories of ice ages, millennial-scale climate variability, the influence of greenhouse gases and radiative forcing on climate, and historical and future climate changes. Prerequisites: graduate student status; or EEPS 0240 and 1240; or instructor permission.

EEPS 2400. Life Beyond Earth.
This course will explore the questions of What is Life and Where does Life Exist? The course will utilize peer-reviewed literature and textbook excerpts to understand the basic, fundamental components of life on Earth to understand the conditions and environments that are conducive to the emergence and persistence of life on other worlds. Course topics that will be examined include: the definition and requirements of life, the emergence, persistence, and consequence of life on Earth, life beyond Earth, astrobiology, and the search for extant extraterrestrial life. The following courses are recommended prerequisites (and/or permission of the Professor): EEPS 0050 or 0240; and CHEM 0100 or higher-level chemistry course

EEPS 2410. Kinetics of Geochemical Processes.
Emphasizes kinetic theories and their geological applications. Topics include: rate laws of chemical reaction, rates of chemical weathering; fundamentals of diffusion, nucleation, crystal growth, and dissolution; transport theory. Recommended prerequisite: EEPS 2460 or equivalent.

EEPS 2430. Igneous Petrology.
Study of mineral equilibria in igneous rocks in relation to theoretical and experimental studies in silicate systems. Principles of the origin and evolution of igneous rocks in space and time. Offered alternate years.

EEPS 2440. Petrogenesis Metamorphic Rocks.
Study of metamorphic rocks with emphasis on mineral equilibria, metamorphic facies, and metamorphic facies series. Topics include: metasomatism, mobile components, partial anatexis, and petrogenetic grids. Prerequisite: EEPS 2460. Offered alternate years.

EEPS 2450. Exchange Scholar Program.

EEPS 2460. Phase Equilibria.
Principles of thermodynamics and phase equilibria in unary, binary, ternary, and multicomponent systems using analytical and graphical methods. Other topics include: solution theory, equations of state, and thermodynamics of surfaces.

EEPS 2520. Numerical Geodynamics.
Numerical methods for the solution of continuum physics problems arising in geophysics and geology: Basic theoretical formulations and algorithms implementing finite element, finite difference, and boundary element methods are developed. Applications include problems in viscous and plastic flow, elasticity, and heat and mass transport discussed within a geological framework. Course consists of lectures and a computer project applying the methods and concepts considered to a scientifically significant problem. Recommended: APMA 0330, 0340; ENGN 1750. Offered alternate years.

EEPS 2630. Interpretation Theory in Geophysics.
Use basic statistical theory and its matrix algebra representation and modern approaches for the optimum design of experiments, constructing model solutions to measurements, and describing nonuniqueness in models, with particular emphasis on generalized linear-inverse techniques. Introduction to stochastic processes and prediction. Recommended courses: EEPS 1610; MATH 0290, 0520, or APMA 0330, 0340, and computer programming skills. Offered alternate years.

EEPS 2650. Advanced Seismology.
The theory of modern seismology will be applied to imaging of Earth structure (from local to global scales) and determination of earthquake source models. Topics include elastic wave propagation, representation theorems, seismic tomography, moment tensors, source-time functions, and models of fault rupture. Offered alternate years.

EEPS 2800. The Chemistry and Mineralogy of Mars.
Examination of the chemical and mineralogical composition of Mars as revealed from meteorites and spacecraft missions. Example topics include: SNC meteorites, origin and evolution of the crust, alteration processes, remote near- and thermal-infrared observations, remote gamma-ray and neutron measurements, and petrology of surface materials. Recommended courses: EEPS 1410, 1420, 1710, or equivalent. No prerequisites.

EEPS 2810. Planetary Science Seminar.
New data for the Moon and Mercury from recent missions (including Chanrayaan-1, Lunar Reconnaissance Orbiter, GRAIL and MESSENGER) permit new insights into “The Crater to Basin Transition on the Moon and Mercury”. In this seminar course we will examine this transition using these new data and recent developments in cratering theory and modeling. The course will feature research from the NASA SSERVI activity. Prerequisites: Instructor permission.

EEPS 2840. Asteroids and Meteorites.
Compositional and petrographic characteristics of meteorites are examined along with the physical and compositional diversity of asteroids and other small bodies of the solar system. Possible links between specific types of asteroids and meteorite groups will be evaluated in the context of early solar system evolution. Data from spacecraft encounters with asteroids will be critically reviewed.

EEPS 2850. Regolith Processes.
Particulate material (regoliths) and soils develop on every planetary surface. Physical and chemical alteration of the uppermost surface results from interwoven active processes of specific environments. Understanding these processes and products is central to interpreting data returned from planetary surfaces. Regoliths reflect surface history over a variety of time scales. Several planetary environments are examined in detail. Prerequisites: EEPS 1410, 1710, 2880, or instructor permission.

EEPS 2860. Planetary Volcanology.
An examination of volcanism using observations of features and deposits on planetary bodies, comparing them to predictions from the theory of magma ascent and emplacement. Attention to the influence of different variables (e.g. gravity, composition, temperature, pressure, and atmospheric effects). The history of planetary volcanism, its relation to thermal evolution, and comparative planetary volcanology are also addressed. Offered alternate years.

EEPS 2870. Planetary Evolution – Origin/Evolution of the Moon: Touchstone for Understanding Planets.
The Moon forms a fundamental baseline for our understanding of the origin of planets and their early evolution, in terms of primary and secondary crustal formation, core and mantle formation and evolution, magnetism, impact basins, and global tectonics. A major goal of this course is to identify major outstanding questions and scientific and exploration goals for future robotic and human exploration missions to the Moon. Sponsored by NASA SSERVI, the lecture series is jointly organized by SSERVI teams at Brown University and the Lunar and Planetary Institute in Houston with many affiliated SSERVI institutes participating.

EEPS 2880. Planetary Cratering.
Impact cratering is arguably the most pervasive geologic process in the solar system. This course will study the physical process of impact cratering and its place in planetary science. The course will take a process oriented approach to understanding impact cratering with firm foundations in geologic observation and impact experiments. To explore the extreme process of impact cratering, we will use continuum/rock mechanics, thermodynamics, numerical modeling, experiments, and observations. Principal topics will include the formation of craters from contact of the projectile to final crater morphology; shock metamorphism; impact ejecta and products; cratered terrains; impacts and planetary evolution; and impact hazards.

EEPS 2910B. Advanced Remote Sensing and Geographical Information Systems (GIS).
Strategies and the physical principles behind the quantitative extraction of geophysical and biophysical measurements from remotely sensed data. Advanced methods of digital image processing and data integration. Introduction to Geographical Information Systems (GIS) and methods of integrating remotely sensed data into a GIS framework. Prerequisites: EEPS 1330 or 1710; MATH 0100; PHYS 0060; or permission of the instructor.

EEPS 2910C. The Global Nitrogen Cycle.
This seminar course will survey the literature and discuss aspects of the marine, atmosphere, biosphere and geologic cycles of reactive nitrogen. Topics include general evaluation of the N cycle in these systems and records of changes in the N cycle through time, particularly on relevant climate change timescales.

EEPS 2910E. Miocene: Prelude to the Ice Ages and Analogue to Future Climate Change.
The Miocene Epoch (~23 to 5 Ma) was characterized by a variety of interconnected changes including the tectonic evolution of various ocean gateways, changes in surface and deep-ocean circulation patterns and evolving ocean and atmospheric chemistry. In the Middle Miocene, these conditions resulted in reduced pole-to-equator temperature gradients and global mean annual surface temperatures of ~18°C, equivalent to warming predicted for the next century. These evolving conditions in the Late Miocene set the stage for the initiation of high amplitude northern hemisphere glacial cycles. Study of Miocene climate will yield insight into mechanisms relevant to past and future climate change.

EEPS 2910F. Earthquake Mechanics, Rheology and Rock Friction.
Reading current literature, class discussion, lectures to explore current research in fault mechanics and rheology. Time in the lab examining microstructures in both experimental and natural samples. Topics will include: (1) Deformation mechanisms associated with slow slip and tremor; (2) Grain-size evolution processes and their geophysical implications; (3) Grain-size sensitive deformation processes and their geophysical implications. Prior to each class, students will submit (via email) at least 2 questions about the assigned reading. After class, there will be 3 or 4 questions to answer on topics covered in the reading and during class discussion.

EEPS 2910G. Dynamics of Ice Sheets and Glaciers.

EEPS 2910H. Geophysical Phenomena Across the Solar System.
This graduate level course will survey the current state of knowledge for geophysical processes and mechanisms related to the formation and evolution of terrestrial bodies within the inner Solar System and will incorporate case study investigations of outer Solar System worlds (excluding gas giants). The course will apply fundamental science concepts in physics and chemistry to examine key topics within planetary geophysics, including planet-wide magma oceans, planetary collisions and impacts, volcanism, tectonics, and magnetism. Course is formatted to allow for lecture content and presentation and discussion of relevant themes and concepts. No prior background in the geological sciences is required.

EEPS 2910I. Marine Geophysical Techniques.

EEPS 2910J. Early Evolution of the Solar System.
The so-called NC-CC dichotomy describes the fundamental difference in the genetic make-up of inner (‘non-carbonaceous’) and outer (‘carbonaceous’) Solar System materials, and is one of the most influential discoveries in modern cosmochemistry. In this seminar, we will follow a series of scientific studies that ultimately led to its full recognition and use recent publications to discuss how it revolutionized our understanding of the early evolution of the Solar System. This includes diverse topics such as (i) the origin, processing, and transport of material in the protoplanetary disk, (ii) the timescales and processes of planetesimal/planet formation and migration, as well as (iii) the nature of Earth’s building blocks and origin of its habitability. No prior courses required; basic knowledge of cosmochemistry and isotope geochemistry is recommended. Intended for graduate students, but upper-level undergraduates may register with permission of the instructor.

EEPS 2910L. Planetary Crusts.
What are planetary crusts? How do they form? What mineralogic, petrologic, and structural characteristics are shared among the terrestrial planets, moons and asteroids and what are unique to a single body? We will examine the characteristics of crusts of the terrestrial planets, the Moon, Vesta, Ceres and several satellites of the giant planets. We will explore questions such as when and how do planets and moons develop primary crusts? How have they been characterized (samples, remote sensing, geophysics and in-situ)? What are the major processes that affect planetary crusts and their formation,? We will consider data from spacecraft missions like MESSENGER to Mercury, orbiter and lander for data from Mars, and the Dawn mission to Vesta and Ceres, as well as a host of other missions to bodies across the solar system.

EEPS 2910M. The Changing Arctic.
What is the fate of the Arctic and high latitude regions in a warming world? This course explores how the Arctic is changing and its implications to the physical, natural, and social systems. This class will provide a comprehensive overview of the Arctic and synthesize the latest scientific findings from an array of readings/reports. Topics covered will include changes in: snow, freshwater, ice, permafrost, sea level rise, shipping routes, Arctic policy and governance, and identify how these changes are impacting Arctic-dwelling communities and adaptation strategies available. Instructor override required. Email samiah_moustafa@brown.edu with a statement of interest, year and concentration.

EEPS 2910P. Origin and Evolution of Planetary Systems.
The goal of this course is to introduce students to our current understanding of how planetary systems form and evolve. We will focus on the physical theories describing how the structures of planetary systems develop and how planets, moons, and other heavenly bodies form. We will also consider the relationship between these theories and observations (astronomical, geophysical, cosmochemical) of the Solar System and extrasolar planetary systems. This will include some discussion how the Solar System fits into our understanding of the veritable menagerie of planetary systems.

EEPS 2910T. Lattice Boltzmann Modeling in Natural Sciences.
Introduction to the lattice Boltzmann method for solving problems such as diffusion in complex media, fluid dynamics, porous and reactive transport, multiphase flows, and the propagation of waves. The course will cover an introduction to Boltzmann theory and the discretization of the equations on the lattices, the implementation of various solvers (diffusion, Navier-Stokes equations…) and application to problems in Natural Sciences and Engineering. This course will be divided between lectures and coding practicum and has a final project designed by the student.

EEPS 2920B. Special Topics: Ocean Worlds.

EEPS 2920C. The Sedimentary Rock Cycle of Mars and Earth.
This course consists of a mixture of instructor and student-led discussions on topics related to the sedimentary rock cycle on Mars as viewed through the lens of how we understand such processes on Earth.
Topics:sediment transport and deposition, erosion processes and rates, lithification + diagenesis, water-rock interaction, and cyclicity in strata.
Major goal: Assess how the sedimentary rock record of Mars can be used to understand changes in depositional processes and environmental conditions through time. Results from Mars satellite and rover data will be discussed, with an emphasis on fundamental processes as understood from detailed studies of Earths sedimentary rock record. Prerequisite: Undergraduate level sedimentology/stratigraphy, or permission of instructor.

EEPS 2920D. Introduction to Geochemical Modeling.
Continuum descriptions of mass transfer in geochemical cycles. Topics include: fundamentals of diffusive and advective mass transfer, kinetics of weathering and early diagenesis, fluid flow in the Earth's crust and mantle, trace elements and isotopes in magmatic processes. Recommended: CHEM 0330, EEPS 1610 and APMA 0330, 0340.

EEPS 2920E. Introduction to Organic Geochemistry.
Mainly literature critiques and seminars, supplemented by introductory lectures. Topics include organic biomarkers, analytical methodologies, natural macromolecules, stable isotope ratios of biomarkers, application of organic geochemistry in studies of climatic and environmental change, fossil fuel exploration, and applied environmental research.

EEPS 2920F. Kinetics of Mineralogical and Petrological Processes.
Emphasizes kinetic theories and their geological applications. Topics include: fundamentals of diffusion in crystals and melts, theories of nucleation and crystal growth, kinetics of melting and dissolving, theory of phase transformation. Prerequisite: EEPS 2460 or equivalent.

EEPS 2920G. Special Topics in Geological Sciences:Exoplanet Seminar.
The goal of this course is to introduce students to the study of planets orbiting other stars. Learning outcomes:
Recognize the methods for detection and characterization of exoplanets, and the information these methods provide about exoplanetary systems
Discuss planet properties that can be derived from observational methods

Summarize our understanding of exoplanet populations
Recognize cutting edge work being done in the field of exoplanets – such as the search for exomoons, habitability, and biosignatures
Recall updated facilities (both ground and space based) for future exoplanet studies
Assessment of journal articles and synthesizing material across sources
Completion of an independent project on an outstanding question in exoplanet science

EEPS 2920H. Past Variations in the Global Carbon Cycle.
This course will examine variations in the earth's carbon cycle over multiple time scales. We will examine geological tools that measure rates of carbon storage and release, especially over the past one million years. Special emphasis will be given to monitoring rates of past biological carbon storage.

EEPS 2920I. Special Topics: Dynamics of Tropical Climate and Ecosystem.

EEPS 2920J. The Source of Liquid Water in the Nochian History of Mars.

EEPS 2920L. Evolution of the Moon II.
A seminar on the thermal and chemical evolution of the Moon. In this part II of lunar seminar, we will focus more on petrological and geochemical observations of lunar samples, terrestrial layered intrusions, related geophysical observations, and lunar petrogenesis. Prerequisite: EEPS 1420, 2730, or 2920K.

EEPS 2920O. Physics of Melt Migration.
A seminar course focusing on the physical processes and geochemical consequences of melt migration in the mantle. Topics include, but are not limited to: flow in porous media; compaction; adiabatic melting and melt-rock reaction; instabilities in melt migration; melt generation beneath mid-ocean ridge; and melt migration in other tectonic environments. Recommended course: EEPS 1620. Enrollment limited to 15. S/NC

EEPS 2920Q. Rheological Boundaries in the Earth.
The properties of lower crust control the coupling of mantle convection to shallow crustal dynamics, post-seismic creep and the chemical evolution of the Earth. On Earth we have xenolyths and exhumed lower crustal rocks to study and relate to geophysical, experimental and theoretical investigations. We will explore these avenues of research with the goal of synthesizing our understanding of the behavior of lower crust on Earth as well as other terrestrial planets.

EEPS 2920R. Evolution of the Moon.
Petrological, geochemical, and geophysical observations, physical and chemical processes relevant to the formation and evolution of the Moon.

EEPS 2920S. Continental Cratons.
The focus of this course is the formation, evolution, and structure of continental cratons. These topics will be explored through a survey of the observational constraints on cratons, including seismology, gravity, heat flow, geochemistry, and petrology. The use of dynamical models to investigate the assembly, destruction, and long-term stability of cratons will also be considered.

EEPS 2920T. Science Applications of Lunar Spectroscopy.
This course will focus on current science issues that are addressed with new lunar orbital or laboratory spectroscopy data. Each participant must identify a specific science topic (and data source) to be pursued and brought to completion during the term. Format will be seminar with very active participation by all attending. At the beginning of the term each participant will describe their chosen research topic. Subsequent sessions will critically examine issues that are associated with each topic in an iterative fashion, focusing on progress made, problems faced, solutions designed, insights found, and finally completed project. Prerequisites: EEPS 1710 and confirmation with instructor about the project.

EEPS 2920U. Climate Variations.
This course will examine the geologic record of lake basins on decadal to million-year time-scales. Students will gain hands-on experience with techniques in paleolimnology including sediment core acquisition, sediment description, petrography, sedimentology and environmental analysis, geochemistry, basic core scanning, and age determination, modeling, and time series analysis. The biotic content and interpretation of fossils will be stressed. The course will also cover theoretical aspects of paleolimnology and more specialized techniques according to student interests through student-led discussions and a course project on regional lake sediments. Graduate students only; enrollment limited to 20.

EEPS 2920V. Terrestrial Nitrogen and Carbon Cycling.
This course will examine aboveground/ belowground processes in the context of the global nitrogen and carbon cycles, and the impacts of both natural and anthropogenic disturbances. It will include discussion of processes such as (de)nitrification, N-fixation, respiration, photosynthesis, and decomposition and their relationship to soil properties; the coupling of N and C cycles in soils related to climate change and increasing N deposition. It will include emphasis on emerging new techniques to quantify N and C processes in the laboratory, field and through modeling, and field trip investigating current field studies. Prerequisites: BIOL 1480 or EEPS 1130 or equivalent biogeochemistry course. Enrollment limited to 15.

EEPS 2920W. Numerical Climate Change Scenarios for Southern New England.
This seminar will examine regional-scale climate model scenarios for past and future climate change in Southern New England. Reliable estimates of the trajectory and variability of climate change are needed to address specific climate impacts, adaptations, and mitigations. Global climate model simulations, based on a range of IPPC green house gas scenarios, need to be "downscaled" to achieve useful regional resolution. Understanding the generation of these high-resolution "downscaled" climate scenarios and compiling a number of observed and modeled climate variables to assess the trends and reliability of climate scenarios for Southern New England is the goal of the seminar.

EEPS 2920Z. The Evolution of Lacustrine Ecosystems.

EEPS 2980. Research in Geological Sciences.
Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course. Enrollment is restricted to graduate students only.

EEPS 2990. Thesis Preparation.
For graduate students who have met the residency requirement and are continuing research on a full time basis.

Fall	EEPS2990	S01	16673	Arranged	'To Be Arranged'
Spr	EEPS2990	S01	25248	Arranged	'To Be Arranged'