Geophysics

Program Description

Founded in 1926, the Department of Geophysics at Colorado School of Mines is recognized and respected around the world for its programs in applied geophysical research and education. Geophysics is a multidisciplinary field that blends geology, physics, mathematics, computer science, and electrical engineering. Professionals working in geophysics often come with training from programs in these allied disciplines, as well as from formal programs in geophysics.

Geophysicists study and explore the interior of the Earth (and other planetary bodies) through physical measurements collected at its surface and in the subsurface, as well as remotely via airborne and satellite platforms. Using a combination of mathematical analyses based on data collected using a multitude of sensitive sensors, and insight into physical and chemical processes cast in the relevant geological contexts, geophysicists reveal the detailed structure of the Earth's interior and explain a multitude of societally relevant natural processes. Noninvasive imaging beneath the surface of geologic bodies by geophysicists is directly analogous to noninvasive imaging of the human body by medical specialists.

Earth supplies all the materials needed by our society, serves as the repository of used products, and provides a home to all its inhabitants. Geophysicists and geophysical engineers have important roles to play in solving challenging problems facing the inhabitants of the Earth, such as providing fresh water, food, and energy for its growing population, evaluating sites for underground construction and containment of hazardous waste, noninvasive monitoring of aging infrastructure (water and telecommunication conduits, transportation networks), mitigating the threat of geohazards to populated areas (earthquakes, volcanoes, landslides, avalanches), aid homeland security (through detection of underground activity and removal of unexploded ordnance or land mines), evaluating changes in climate and managing humankind's response to them, as well as satisfying the human thirst for knowledge by exploring Earth and other planetary bodies.

Energy and mineral companies employ geophysicists to explore subsurface resources worldwide. Engineering firms hire geophysical engineers to assess Earth's near-surface properties for large construction and infrastructure projects. Environmental organizations rely on geophysics to conduct groundwater surveys and to track the flow, distribution, and concentration of contaminants. Geophysicists employed by universities and government agencies (e.g., U.S. Geological Survey or NASA), study dynamic Earth processes at all scales, from its deep interior to the oceans, ice sheets, and atmosphere.

With 12 full-time faculty members and small class sizes, Geophysics students receive individualized attention in a close-knit environment. Given the multidisciplinary nature of geophysics, the undergraduate curriculum equips students with a broad skillset including applied mathematics and physics, geology, computing, and sensor engineering, in addition to theoretical and practical aspects of the geophysical field and laboratory methodologies.

For the past decade, nearly all Mines geophysics graduates have found employment in their chosen field, with about half of them pursuing graduate studies. The program leading to the degree of Bachelor of Science in Geophysical Engineering is accredited by the Engineering Accreditation Commission of ABET: https://www.abet.org/, under the commission's General Criteria with no applicable program criteria.

Bachelor of Science Program in Geophysical Engineering

The Bachelor of Science in Geophysical Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org/, under the commission's General Criteria with no applicable program criteria.

Geophysical Engineering undergraduates interested in professional registration as engineers are encouraged to take the Engineer in Training (EIT)/Fundamentals of Engineering (FE) exam as seniors. The Geophysical Engineering program has the following objectives and associated outcomes:

> Program Educational Objective 1: Graduates will be competent professionals who are capable of independent and innovative problem solving, are skilled in scientific computing, and are working to address important Earth, energy, and /or environmental problems.
>
> Program Educational Objective 2: Graduates will be effective oral and written communicators with exceptional team skills, allowing them to grow in their careers and professional societies.
>
> Program Educational Objective 3: Graduates will recognize the economic and social impacts of their work and will have the ability to communicate this to a range of stakeholders (e.g., management, public, peers)

Graduates with a BS in Geophysical Engineering will demonstrate an ability to:

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

Geophysics Field Camp

Each summer, a base of field operations is set up for four weeks for students who have completed their junior year. Students prepare geological maps and subsurface models as the basis for applying their multidisciplinary knowledge to design and implement geophysical surveys and integrate and interpret geophysical and geological data to address geoscientific real-world problems. Most recently, the department has focused on using seismic, gravimetric, magnetic, electrical, electromagnetic, and distributed acoustic sensing surveys to understand geothermal systems and hot springs in Colorado. In addition to the required four-week program, students can participate in other diverse field experiences. In recent years, these have included participation in seismic acquisition ships in the Gulf of Mexico, archaeological studies, investigations at environmental sites, and surveys of an active volcano in Hawaii.

Study Abroad

The Department of Geophysics encourages undergraduates to study abroad for one or two semesters. At selected universities abroad, credits can be earned to substitute course requirements in the geophysical engineering program at Mines. The Office of Global Education can provide information on universities that have established formal exchange programs with Mines. Recent exchange programs in which our students have participated include Curtin University, Australia; the University of Edinburgh, Scotland; the University of Leeds, England; and Utrecht University in the Netherlands.

Combined BS/MS Program

Students enrolled in Mines' combined undergraduate/graduate program may double-count up to six credits of graduate coursework to fulfill their undergraduate and graduate degree program requirements. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Summer Jobs in Geophysics

In addition to the summer field camp experience, many Geophysical Engineering students participate in summer internships or research activities in industry, at Mines, or with government agencies such as the U.S. Geological Survey.

Undergraduate Research

Students are encouraged to try their hand at research by working on a project with a Mines faculty member, either during the semester or the summer. This research is often supported by grants or university funds through the Mines Undergraduate Research program (https://www.mines.edu/undergraduate-research). As an alternative to a summer internship, students may participate in a Research Experience for Undergraduates (REU) at either Mines or at another university. REUs are typically sponsored by the National Science Foundation (NSF) and are listed on the NSF website (https://www.nsf.gov/crssprgm/reu/reu_search.jsp).

The Cecil H. and Ida Green Graduate and Professional Center

The meeting rooms, laboratories, and computer-aided instruction areas of the Department of Geophysics are located in the Green Center. The department also maintains equipment for conducting geophysical field measurements, including magnetometers, gravity meters, ground-penetrating radar, and instruments for recording seismic waves. Students may request access to the department petrophysics laboratory to measure the properties of porous rocks or study one of the world's largest repositories of core samples in the Core Lab. The Department also maintains the Ken Larner GeoMaker Space, a collaborative, multidisciplinary workspace for students to design, build, and test their own novel hardware or instruments.

Curriculum

Geophysics is an applied and multidisciplinary science; therefore, students must have a strong foundation in physics, mathematics, geology, and computing. This foundation includes comprehensive courses on the theory and practice of geophysical methods. As geophysics and geophysical engineering involve studying and exploring entire geologic bodies, our graduates have great opportunities to work anywhere on and even off planet Earth. The curriculum includes electives in the Culture and Society (CAS) that give students an understanding of international issues and cultures. Every student who obtains a Bachelor's Degree in Geophysical Engineering completes the Mines Core Curriculum plus the program-specific courses outlined below. We recommend that students download the current curriculum flowchart (Undergrad Curriculum Flowchart) and work closely with their academic advisor to create an individualized pathway to their degree.

Degree Requirements (Geophysical Engineering)

Freshman

Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR	1.0		1.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
S&W ELECTIVE	SUCCESS AND WELLNESS ELECTIVE			1.0
				15.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
CSCI250	PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM			3.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
GPGN228	INTRODUCTION TO GEOPHYSICS			3.0
HASS200	GLOBAL STUDIES			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				18.0

Spring		lec	lab	sem.hrs
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
GPGN268	GEOPHYSICAL DATA ANALYSIS			3.0
GEGN212	THE ROCK CYCLE			4.0
GPGN229	MATHEMATICAL GEOPHYSICS			3.0
				17.0

Junior

Fall		lec	lab	sem.hrs
MATH332	LINEAR ALGEBRA			3.0
MATH201	INTRODUCTION TO STATISTICS			3.0
GPGN328	PHYSICS OF THE EARTH - I	3.0		3.0
GPGN318	APPLIED GEOPHYSICS I			3.0
ELECTIVE	EARTH ELECTIVE	3.0		3.0
				15.0

Spring		lec	lab	sem.hrs
GPGN404	DIGITAL SIGNAL PROCESSING			3.0
CSCI303	INTRODUCTION TO DATA SCIENCE			3.0
GPGN329	PHYSICS OF THE EARTH - II			3.0
GPGN319	APPLIED GEOPHYSICS II			3.0
FREE	FREE ELECTIVE	3.0		3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective[2]			3.0
				18.0

Summer		lec	lab	sem.hrs
GPGN486	GEOPHYSICS FIELD CAMP		4.0	4.0
				4.0

Senior

Fall		lec	lab	sem.hrs
GPGN436	GEOPHYSICAL COMPUTING			3.0
GPGN409	INVERSION			3.0
GP ELECT	GPGN Advanced Elective[3]	3.0	3.0	3.0
GP ELECT	GPGN Advanced Elective[3]	3.0	3.0	3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective[2]	3.0		3.0
				15.0

Spring		lec	lab	sem.hrs
GPGN438	GEOPHYSICS PROJECT DESIGN			3.0
GP ELECT	GPGN Advanced Elective[3]	3.0		3.0
GP ELECT	GPGN Advanced Elective[3]			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective[2]	3.0		3.0
FREE	FREE ELECTIVE	3.0		3.0
				15.0

Total Semester Hrs: 132.0

1. Students must take at least 3 credits of GEGN or GEOL electives.
2. Within these 9 Culture and Society (CAS) electives, students must take at least 3 credits at the 400-level.
3. Students must take 12 credits of advanced GPGN elective courses at the 400- or 500-level. At least 6 of these credits must be from geophysical methods courses (GPGN411, GPGN420, GPGN461, and GPGN470).

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- GPGN100 through GPGN599 inclusive

Geophysics Tracks

Beginning in the academic year 23-24, our undergraduate students will have the opportunity to delve deeper into various subjects within Geophysics without the need for additional coursework. Our faculty has approved the implementation of Geophysics tracks, which will provide students with a structured course selection path for gaining advanced knowledge in specific subdisciplines. These tracks include Climate, Energy, Hazards, Humanitarian, Minerals, and Space Geophysics. Many of the courses required for these tracks are already offered within our Geophysics Engineering or other programs, but the defined tracks provide a focused alignment of courses in these areas. It should be noted that participation in these tracks is optional and not required for undergraduate students. They are simply provided as a suggestion for students who wish to gain advanced knowledge in a specific subdiscipline.

Energy Geophysics

Energy Geophysics generates detailed high-resolution images of the Earth interior to access energy resources (hydrocarbons, geothermal, Hydrogen) and facilitate Carbon capture and storage.

Geophysics Electives		
GPGN411	GRAVITY AND MAGNETIC METHODS	3.0
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN461	SEISMIC DATA PROCESSING	4.0
GPGN458	SEISMIC INTERPRETATION	3.0
Earth Electives		
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY	3.0
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS	4.0
GEOL314	STRATIGRAPHY	4.0
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY	3.0
PEGN308	RESERVOIR ROCK PROPERTIES	3.0
PEGN350	GEOTHERMAL ENERGY	3.0
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
CAS and Free Electives		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
PEGN201	PETROLEUM ENGINEERING FUNDAMENTALS	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

Minerals Geophysics

Minerals Geophysics generates detailed high-resolution images of the Earth interior to give access critical minerals necessary to sustain our current and future critical technological and energy needs.

Geophysics Electives		
GPGN411	GRAVITY AND MAGNETIC METHODS	3.0
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN461	SEISMIC DATA PROCESSING	4.0
Earth Electives		
GEOL310	EARTH MATERIALS	3.0
GEOL311	MINING GEOLOGY	3.0
GEGN401	MINERAL DEPOSITS	4.0
GEGN432	GEOLOGICAL DATA MANAGEMENT	3.0
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
CAS and Free Electives		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
MNGN210	INTRODUCTORY MINING	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

Hazard GEOPHYSICS

Hazard Geophysics monitors and quantifies with high temporal and spatial density the occurrence and distribution of destructive Earth hazards (earthquakes, volcano eruptions, tsunamis, and landslides).

Geophysics Electives		
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN455	EARTHQUAKE SEISMOLOGY	3.0
GPGN473	CRYOSPHERE GEOPHYSICS	
Earth Electives		
GEGN432	GEOLOGICAL DATA MANAGEMENT	3.0
GEOL440	PLATE TECTONICS	3.0
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
CEEN419	RISK ASSESSMENT IN GEOTECHNICAL ENGINEERING	3.0
GEGN498A	SURFACE PROCESSES	3.0
CAS and Free Electives		
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
HASS427	RISK COMMUNICATION	3.0
HASS467	HISTORY OF EARTH AND ENVIRONMENTAL SCIENCES	3.0
MATH432	SPATIAL STATISTICS	3.0

Humanitarian Geophysics

Humanitarian Geophysics develops technology in support of human communities for cost effective access to water, safe construction, assessment of soil conditions, and noninvasive subsurface archaeology.

Geophysics Electives		
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN455	EARTHQUAKE SEISMOLOGY	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN474	HYDROGEOPHYSICS	3.0
GPGN461	SEISMIC DATA PROCESSING	4.0
Earth Electives		
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY	3.0
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS	4.0
GEOL314	STRATIGRAPHY	4.0
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY	3.0
GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
CAS and Free Electives		
EDNS192	DESIGN AND HUMAN VALUES	4.0
EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0

HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

Climate Geophysics

Climate Geophysics investigates dynamic processes at and near Earth's surface to give insight on physical, thermal, and chemical properties revealing climate evolution affecting communities worldwide.

Geophysics Electives		
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN473	CRYOSPHERE GEOPHYSICS	
GPGN474	HYDROGEOPHYSICS	3.0
Earth Electives		
GEGN466	GROUNDWATER ENGINEERING	3.0
GEOL440	PLATE TECTONICS	3.0
GEGN498A	SURFACE PROCESSES	3.0
CAS and Free Electives		
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
HASS427	RISK COMMUNICATION	3.0
HASS448	GLOBAL ENVIRONMENTAL ISSUES	3.0
HASS484	US WATER POLITICS AND POLICY	3.0
MATH432	SPATIAL STATISTICS	3.0

Space Geophysics

Space Geophysics investigates the surfaces and interiors of planetary bodies to give insight into the Solar System's formation and evolution, provide access to natural resources, and enable planetary defense.

Geophysics Electives		
GPGN411	GRAVITY AND MAGNETIC METHODS	3.0
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN473	CRYOSPHERE GEOPHYSICS	
GPGN455	EARTHQUAKE SEISMOLOGY	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
Earth Electives		
GEOL410	PLANETARY GEOLOGY	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
CAS and Free Electives		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
PHGN324	INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS	3.0
HASS427	RISK COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

The Mines guidelines for Minor/ASI are in the Undergraduate Information section of the Mines Catalog.

Minor in Geophysics/Geophysical Engineering

Geophysics plays an important role in many aspects of civil engineering, petroleum engineering, mechanical engineering, and mining engineering, as well as mathematics, physics, geology, chemistry, hydrology, and computer science. Given the natural connections between these various fields and geophysics, it may be of interest for students in other majors to consider choosing to minor in geophysics, or to choose geophysics as an area of specialization. The core set of courses required for a GP minor are as follows:

GPGN229	MATHEMATICAL GEOPHYSICS	3.0
GPGN328	PHYSICS OF THE EARTH - I	3.0
GPGN329	PHYSICS OF THE EARTH - II	3.0
GPGN318 & GPGN319	APPLIED GEOPHYSICS I and APPLIED GEOPHYSICS II	6.0

The remaining 3 credits can be satisfied by a geophysics course or a course in geology, mathematics, or computer science depending on the student's major. Students must consult with the department of Geophysics to have the remaining course approved. Previous or concurrent experience in programming is strongly recommended but not required.

Courses

GPGN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN228. INTRODUCTION TO GEOPHYSICS. 3.0 Semester Hrs.
(I) Introduction to sediment, rock, and fluid properties, their measurements, and geophysical applications. Course will introduce physical and mathematical framework, quantitative interpretations, and provide framework for geophysical analyses, data interpretation, and data inversion to help us understand the physical and chemical properties of sediments, rocks, and fluids.
Course Learning Outcomes

- TBD

GPGN229. MATHEMATICAL GEOPHYSICS. 3.0 Semester Hrs.
This course will address how specific mathematical approaches are used to understand and to solve geophysical problems. Topics that will be used in a geophysical context include continuum mechanics, linear algebra, vector calculus, complex variables, Fourier series, partial differential equations, probability, the wave equation, and the heat equation. 3 hours lecture; 3 semester hours. Prerequisite: MATH213, PHGN200. Co-requisite: MATH225.
Course Learning Outcomes

- TBD

GPGN268. GEOPHYSICAL DATA ANALYSIS. 3.0 Semester Hrs.
Geophysical Data Analysis focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Students work on projects from the geophysical engineering practice in which they analyze (process, model, visualize) data. In their projects, students encounter limitations and uncertainties in data and learn quantitative means for handling them. They learn how to analyze errors in data, and their effects on data interpretation and decision making. 3 lecture hours; 3 semester hours. Prerequisite: CSCI128.

GPGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN318. APPLIED GEOPHYSICS I. 3.0 Semester Hrs.
Applied Geophysics I is an introductory course on the application of static fields to image the Earth's subsurface. The static fields include electrostatics, magnetostatics, and gravitational field. These tools are employed in various geotechnical and environmental engineering problems, resource exploration and production monitoring, geothermal site characterization, hazards, and humanitarian efforts. Through the combination of two one-hour lectures and one three-hour lab each week, the students are provided with the fundamental theory and hands-on field experiments for each of these techniques, including the principles, instrumentation, and procedures of data acquisition, analysis, and interpretation. Co-requisite: GPGN328.
Course Learning Outcomes

- 1) Design electrical, magnetic, and gravity field experiments to investigate geoscience questions
- 2) Apply electrical, magnetic, and gravity concepts and theory learned in the classroom to a natural setting to answer geoscience questions
- 3) Synthesize geoscience datasets with geophysical (electrical, magnetic, and gravity) theory to develop a scientific interpretation
- 4) Create field experiments and data processing approaches that ensure repeatability and reproducibility
- 5) Communicate scientific results and their uncertainty clearly and effectively using written, verbal, and/or visual media
- 6) Develop personal, interpersonal, and scientific skills to safely and efficiently collect, process, and interpret geoscience data in a collaborative setting

GPGN319. APPLIED GEOPHYSICS II. 3.0 Semester Hrs.
Applied Geophysics II is an introductory course on the application of dynamic fields (electromagnetic and seismic) to image the Earth's subsurface. These tools are employed in various geotechnical and environmental engineering problems, resource exploration and production monitoring, geothermal site characterization, hazards, and humanitarian efforts. Through the combination of two one-hour lectures and one three-hour lab each week, the students are provided with the fundamental theory and hands-on field experiments for each of these techniques, including the principles, instrumentation, and procedures of data acquisition, analysis, and interpretation. Co-requisite: GPGN329.
Course Learning Outcomes

- 1) Design seismic and electromagnetic field experiments to investigate geoscience questions
- 2) Apply seismic and electromagnetic concepts and theory learned in the classroom to a natural setting to answer geoscience questions
- 3) Synthesize geoscience datasets with geophysical (electromagnetic and seismic) theory to develop a scientific interpretation
- 4) Create field experiments and data processing approaches that ensure repeatability and reproducibility
- 5) Communicate scientific results and their uncertainty clearly and effectively using written, verbal, and/or visual media
- 6) Develop personal, interpersonal, and scientific skills to safely and efficiently collect, process, and interpret geoscience data in a collaborative setting

GPGN328. PHYSICS OF THE EARTH - I. 3.0 Semester Hrs.
This course is the first part of a two-course sequence on Physics of the Earth and will introduce the static fields including the electrostatics, steady state current flow in conductive media, magnetostatics, and gravitational field as used in probing the interior of the Earth and physical processes therein. The spatial context will be earth's lithosphere and the associated geoscientific problems arise from a wide range of disciplines including environmental problems, hydrology, minerals and energy exploration, hydrology, tectonics, and climate science. The course will discuss static field theory, their interaction with different physical properties of earth materials, and the use of these fields in imaging, characterizing, and monitoring structures and processes in the earth lithosphere and on the interface between atmosphere and crust. 3 hours lecture; 3 semester hours. Prerequisite: GPGN229. Co-requisite: GPGN318.
Course Learning Outcomes

- TBD

GPGN329. PHYSICS OF THE EARTH - II. 3.0 Semester Hrs.
The second half of Physics of the Earth will aim to give a global perspective to Earth's formation and evolution. Starting from conservation laws and continuum mechanics, Earth's dynamic fields (theory of seismic and electromagnetic wave propagation) will be covered in the context of solid-Earth geophysics and integrated with various geophysical observations & measurements; the Earth seen by the waves, inferring the structure and composition of the interior of planetary bodies from crust to core, physical & thermo-chemical processes in mantle and core shaping Earth's surface and magnetic field, planetary cooling, "hot topics" and current challenges in illuminating Earth's deep structure, modern computational techniques that are used to improve our understanding of Earth's interior and history. 3 hours lecture; 3 semester hours. Prerequisite: GPGN328. Co-requisite: GPGN319.
Course Learning Outcomes

- Using math and physics to investigate Earth's formation and evolution.
- Investigating Earth's deep interior and adressing global-scale geophysical and geodynamical problems.
- Recent advances in (computational) global geophysics
- Reports of written and computer-based assignments

GPGN398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN404. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.
The fundamentals of digital signal processing as applied to geophysical investigations are studied. Students explore the mathematical background and practical consequences of Fourier series and 1D/2D Fourier transforms, linear time-invariant (LTI) systems, convolution and deconvolution, properties of discrete systems, sampling theorem and signal reconstruction, Z-Transforms, discrete-time Fourier transform, discrete Fourier series and discrete Fourier transform, windowing and spectrograms, realization of digital filters, FIR filter design and IIR filter design. Emphasis is placed on applying the knowledge gained in lecture to exploring practical signal processing issues. This is done through homework and in-class practicum assignments requiring the programming and testing of algorithms discussed in lecture. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: GPGN268, CSCI250, MATH225, MATH332.
Course Learning Outcomes

- Learning and exploiting similarities between concepts learned in calculus, differential equations, and elsewhere, and how they appear in the context of digital signal analysis
- Understanding how to use discrete Fourier transforms in the analysis and processing of digital signals. Learning how to digitally sample continuous analog signals, reconstruct continuous signals from sampled
- Learning how to digitally sample continuous analog signals, reconstruct continuous signals from sampled ones, and the conditions under which this reconstruction is feasible.
- Learning the pitfalls and tradeoffs in the design and application of common digital filters.
- Independently design, develop, validate and apply computer programs to solve digital signal analysis and processing tasks, largely using the Python language and its associated tool kits (i.e., Numpy, Scipy and Matplotlib).
- Gain experience in chosing and applying 1D/2D filters to achieve specific filtering tasks through a range of numerical exercises and an independent project.

GPGN409. INVERSION. 3.0 Semester Hrs.
This course provides an in-depth study of the fundamentals of inverse problem theory and its application to geophysics. Inversion technology is widely applicable in all areas of geophysical investigation, regardless of the physics employed, as well as in non-geophysical data analysis. The course will cover essential concepts of inversion in both probabilistic and deterministic frameworks and practical methods for solving discrete inverse problems. Specific topics to be explored include model and data discretization, Bayesian inversion, optimization criteria and methods, regularization techniques, and error and uncertainty analysis. Weekly homework assignments will require students to solve theoretical or numerical problems using programming assignments illustrating the concepts discussed in class. Knowledge of the Python programming language is assumed. 3 hours lecture; 3 semester hours. Prerequisite: GPGN329, GPGN404.
Course Learning Outcomes

- Formulate discrete GP inverse problems, capturing optimal parameterization and uncertainty
- Design numeric solutions to GP inverse problems using high-level programming environments
- Process and extract information from uncertain field data by quantifying the reliability of inversion results
- Report results orally and in writing based on reproducible numeric experiments

GPGN410. MACHINE LEARNING INVERSION IN APPLIED GEOSCIENCE. 3.0 Semester Hrs.
This course presents the fundamentals of formulating and solving inverse problems when the models to be recovered are functions in applied geosciences. The emphases are on the basic strategies for solving linear and nonlinear inverse problems and on the practical methodologies for constructing models that can be directly used in subsequent simulations and interpretations. The course will cover model construction and uncertainty quantification using Tikhonov regularization, machine learning (ML), and generative artificial intelligence. The course will and integration of information the data to be inverted and the information in the complementary data that are conceptual in nature. Prerequisite: None. Co-requisite: None.
Course Learning Outcomes

- Understanding and skills in the classical regularized inversion for model construction and appraisal
- Understanding and skills in the emerging machine learning and artificial intelligence inversions and uncertainty quantification.
- Understanding in information transfer and extraction through inversion for decision-making in applied geosciences

GPGN411. GRAVITY AND MAGNETIC METHODS. 3.0 Semester Hrs.
This course studies the theory and methods for processing and interpreting gravity and magnetic data acquired in geosciences and aims to enhance students' knowledge and skills in the application of gravity and magnetic methods. The course covers four major topic areas: (1) the data quantities measured in field surveys, (2) the methods for modeling, processing, and analyzing gravity and magnetic data; (3) 3D inversion of gravity, gravity gradient, and magnetic data; and (4) integrated interpretation of gravity and magnetic data through inversion and geology differentiation for extracting geology information. 3 hours lecture; 3 semester hours. Prerequisite: GPGN328, GPGN404.
Course Learning Outcomes

- 1. Have an understanding of the fundamental aspects of potential-field theory
- 2. Have enhanced their ability to model and process potential-field data
- 3. Have gained understanding and techniques for quantitative interpretation of potential-field data through inversions
- 4. Have an understanding of interpreting magnetic data affected by strong remanent magnetization

GPGN420. ELECTRICAL AND ELECTROMAGNETIC METHODS. 3.0 Semester Hrs.
Equivalent with GPGN422,

In-depth study of the application of electrical and electromagnetic methods to crustal studies, minerals exploration, oil and gas exploration, and groundwater. Laboratory work with mathematical models coupled with field work over areas of known geology. 3 hours lecture; 3 semester hours. Prerequisite: GPGN329, GPGN404.

Course Learning Outcomes

- An ability to apply knowledge of mathematics, science and engineering
- An ability to design and conduct experiments, as well as to analyze and interpret data
- An ability to communicate effectively
- An ability to analyze, quantitatively, the errors, limitations, and uncertainties in data

GPGN436. GEOPHYSICAL COMPUTING. 3.0 Semester Hrs.

Equivalent with GPGN435,
This course develops the principles of geophysical computing in the context of simulating and validating numerical solutions to geophysical data processing challenges (e.g., interpolation, regression, and numerical differentiation) and partial differential equations commonly found in geophysical investigations (e.g., Laplace/Poisson equation, heat flow/diffusion equation, acoustic wave equation). Students learn how algorithms from applied linear algebra can be leveraged to efficiently generate numerical solutions to multidimensional geophysical problems using both self-developed and existing numerical libraries. Offered concurrently with GPGN536.. Prerequisite: GPGN329, GPGN404.

Course Learning Outcomes

- Students will understand and be able to take theoretical concepts and use them to develop, prototype and validate numerical algorithms in the context of geophysical computing.
- Students will develop practical programming skills and combine with knowledge of numerical algorithms to solve real-world geophysical problems.
- Students will develop independent research skills by undertaking a project involving a substantial piece of analytic, numerical and computation work involving solving a real-world geophysical problem

GPGN438. GEOPHYSICS PROJECT DESIGN. 3.0 Semester Hrs.

(WI) Capstone design course for seniors majoring in Geophysics. Working either individually or on a team, students apply engineering design principles to solve a geophysical problem, leading to a project report or senior thesis and oral presentation thereof. Choice of design project is to be arranged between a student and the faculty member, who will serve as the project's advisor, subject to the instructor's approval. 1 hour lecture; 6 hours lab; 3 semester hours. Prerequisites: GPGN329.

Course Learning Outcomes

- 1. an ability to apply knowledge of mathematics, science, and engineering.
- 2. an ability to design and conduct experiments, as well as to analyze and interpret data
- 3. an ability to design a system, a component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health, safety, manufacturability, and sustainability
- 4. an ability to identify, formulate, and solve engineering problems
- 5. an understanding of professional and ethical responsibility
- 6. an ability to communicate effectively
- 7. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

GPGN455. EARTHQUAKE SEISMOLOGY. 3.0 Semester Hrs.

Equivalent with GPGN555,
Earthquakes are amongst the most significant natural hazards faced by mankind, with millions of fatalities forecast this century. They are also our most accessible source of information on Earth's structure, rheology and tectonics, which are what ultimately govern the distribution of its natural resources. This course provides an overview of how earthquake seismology, complemented by geodesy and tectonic geomorphology, can be used to determine earthquake locations, depths and mechanisms; understand Earth's tectonics and rheology; establish long-term earthquake histories and forecast future recurrence; mitigate against seismic hazards; illuminate large- and fine-scale features of Earth's interior using earthquake data. Students will also cover the recent developments in 3D numerical earthquake source and wave propagation modelling as well as common & modern seismic data formats and processing/visualization tools and techniques used in earthquake seismology. 3 hours lecture; 3 semester hours. Prerequisite: GPGN329, GPGN404.

Course Learning Outcomes

- Theory of wave propagation & earthqauke source (point and finite-source models).
- Acoustic - elastic wave simulations, observational seismology, seismic data processing, source and structural modelling.
- Recent advances in earthquake seismology: 3D wave simulations, big data and high-performance computing of wave simulations, earthquake source modelling and seismic tomography
- Modern seismic data formats and data processing/visualization tools, numerical solvers for seismic wave propagation, etc.

GPGN458. SEISMIC INTERPRETATION. 3.0 Semester Hrs.

This course gives participants an understanding of how to model, understand, interpret and analyze seismic data in a quantitative manner on several worldwide projects. When you look at seismic data, how does it relate to the rock properties, what do the amplitudes mean, what is tuning, what is a wavelet, how does the seismic relate to structure, and what are seismic attributes and inversion products? How do you use this information in exploration, production and basic volumetric and economics calculations? The course will go over these topics. Students will work in teams on several modeling and seismic field data exercises around the world in most widely used software platforms (Ikon-RokDoc, Schlumberger-Petrel, GEOX, CGG-HampsonRussell). The course aims to give participants knowledge and information to assist in professional and career development and to be operationally prepared for the work environment. Prerequisites: GPGN461.

Course Learning Outcomes

- Learning how to interpret seismic data through lectures and labs.

GPGN461. SEISMIC DATA PROCESSING. 4.0 Semester Hrs.

Equivalent with GPGN452,
This course covers the basic processing steps required to create images of the earth using 2D and 3D reflection seismic data. Topics include data organization and domains, signal processing to enhance temporal and spatial resolution, identification and suppression of incoherent and coherent noise, velocity analysis, near-surface statics, datuming, normal- and dip-moveout corrections, common-midpoint stacking, principles and methods used for poststack and prestack time and depth imaging, and post-imaging enhancement techniques. Field data are extensively used

throughout the course. A three-hour lab introduces the student to hands-on data processing using a Seismic Unix software package. The final project consists of processing a 2D seismic line with oral presentation of the results. 3 hours lecture; 3 hours lab; 4 semester hours. Prerequisite: GPGN404, GPGN329.
Course Learning Outcomes

- 1. Demonstrate knowledge and understanding of basic seismic data processing steps.
- 2. Successfully process a 2D marine seismic line using Seismic Unix. Design a processing sequence, evaluate possible processing steps, and apply appropriate quality-control tests to guide the data.

GPGN470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. 3 hours lecture; 3 semester hours. Prerequisite: CSCI128.
Course Learning Outcomes

- TBD

GPGN474. HYDROGEOPHYSICS. 3.0 Semester Hrs.
Application of geophysical methods to problems in hydrology. The course will consider both groundwater and surface water problems from the micro to basin scale. Topics may include characterizing groundwater surface water interaction, critical zone evaluation and weathering processes, snow and ice as a water resource, large scale imaging of aquifer systems, in situ estimation of aquifer parameters, evaluation of groundwater resources, delineation of thermal and chemical pollution of groundwater, and mapping of saltware intrusion. Readings and discussions will touch on social and political issues surrounding water use and the critical role that physical characterization plays in understanding water resources. 2 hours lecture; 3 hours lab; 3 semester hours.
Course Learning Outcomes

- TBD

GPGN486. GEOPHYSICS FIELD CAMP. 4.0 Semester Hrs.
(WI) Introduction to geological and geophysical field methods. The program includes exercises in geological surveying, stratigraphic section measurements, geological mapping, and interpretation of geological observations. Students conduct geophysical surveys related to the acquisition of seismic, gravity, magnetic, and electrical observations. Students participate in designing the appropriate geophysical surveys, acquiring the observations, reducing the observations, and interpreting these observations in the context of the geological model defined from the geological surveys. 12 hours lab; 4 semester hours. Prerequisite: GPGN318,GPGN319, GPGN404, GEGN212.
Course Learning Outcomes

- a. an ability to apply knowledge of mathematics, science and engineering b. an ability to design and conduct experiments, as well as to analyze and interpret data c. an ability to function on multidisciplinary teams d. an ability to identify, formulate, and solve engineering problems e. an understanding of professional and ethical responsibility f. an ability to communicate effectively 2. an ability to analyze, quantitatively, the errors, limitations, and uncertainties in data

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN499. GEOPHYSICAL INVESTIGATION. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

SYGN498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

Professors Emeriti

Thomas L. Davis

Dave Hale

Kenneth L. Larner

Gary R. Olhoeft

Phillip R. Romig, Jr.

Terence K. Young

Emeritus Associate Professor

Thomas M. Boyd

University Distinguished Professors

Kamini Singha

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Professors

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Brandon Dugan, Associate Department Head, Baker Hughes Chair of Petrophysics and Borehole Geophysics

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Paul C. Sava, Department Head, C.H. Green Chair of Exploration Geophysics

Jeffrey C. Shragge

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Ilya D. Tsvankin

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Associate professors

Ge Jin

Eileen Martin

Matthew Siegfried

Assistant Professors

Bia Villas Bôas

Joint appointment with loci within Geophysics

Eileen Martin, Associate Professor, Applied Mathematics and Statistics

Joint appointment with loci outside of Geophysics

Eric Anderson, Associate Professor, Civil and Environmental Engineering

Ebru Bozdag, Associate Professor, Applied Mathematics and Statistics

Elizabeth Reddy, Assistant Professor, Engineering, Design and Society

Danica Roth, Assistant Professor, Geology and Geological Engineering

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Nathaniel Putzig, Senior Scientist, Planetary Science Institute

Andrei Swidinsky, Associate Professor, University of Toronto

Whitney Trainor-Guitton, Geoscience Researcher, National Renewable Energy Laboratory

David Wald, Research Geophysicist, US Geological Survey

Joint Appointments

Fred Day-Lewis, Chief Geophysicist, Pacific Northwest National Laboratory