Geophysics

Degrees Offered

- Graduate Certificate (Energy Geophysics)

- Master of Science (Geophysics) (Non-Thesis)
- Master of Science (Geophysical Engineering) (non-thesis)

- Master of Science (Geophysics)
- Master of Science (Geophysical Engineering)
- Doctor of Philosophy (Geophysics)
- Doctor of Philosophy (Geophysical Engineering)

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 graduate 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.

Geophysicists are highly sought after, and for the past decade, 95% of Mines' geophysics graduates found employment in their chosen field within six months of graduation.

Research Emphasis

The department conducts research in a wide variety of areas that are mostly related, but not restricted, to applied geophysics. Candidates interested in the current research activities of specific faculty members are encouraged to visit the department's webpage and to contact faculty members directly to gain insight into their scholarship. To give prospective candidates an idea of the types of research activities available in geophysics at Mines, a brief summary of research emphases and strengths in the department is given below.

Discovering Earth and other planetary bodies. Earth is a dynamic planet evolving over geologic and human time scales. Using geophysical data and methods, the department explores Earth from its surface to its core at all spatial and temporal scales. This broad perspective allows investigation of a wide range of topics including plate tectonics, natural hazards, mineral exploration, and ocean-atmosphere interactions. The department also uses geophysical and computational approaches to study other planet-like bodies to better understand the origin and evolution of the solar system and to explore space resources.

Securing energy and mineral resources. Affordable and abundant energy and minerals have facilitated and accelerated humankind's growth and development. Responding to energy balance changes due to technological advances and greater societal demands for sustainable resource use, the department's teaching and research adapts rapidly to maintain its integral role in innovation for effective and responsible access to Earth resources. The department is a leader in conventional and unconventional hydrocarbon resource evaluation, in exploration for essential critical minerals, as well as in underground carbon capture and storage. The department approaches these societal challenges through theoretical advancements, the development of multiphysics techniques, as well as state-of-the-art data analysis and high-performance computing.

Sustaining communities and the environment. Environmental assessment through geophysics is integral to humankind's interaction with the uppermost Earth crust, where humans live and develop thriving economies. The department excels at advancing near-surface geophysics through theoretical and technological advancements, development of low-cost instrumentation, working with communities to improve their understanding of environmental issues, and promoting society-informed science and communication. Active research in the department includes projects related to freshwater resources, subsurface contamination, climate dynamics, and sustainable energy and minerals exploration.

These research endeavors are supported through diverse funding sources including U.S. government agencies, international agencies/universities, and industry. Research funding supports multiple research groups within the department.

- **Center for Wave Phenomena (CWP)** focuses on seismic modeling, imaging, and inversion methods for realistic highly heterogeneous geologic structures through the development and application of high-performance computing and advancement of innovative technologies (e.g., robotics and distributed acoustic sensing [DAS]).
- **Reservoir Characterization Project (RCP)** utilizes a unique research model emphasizing multidisciplinary, collaborative research integrating multicomponent time-lapse 3D seismic reflection data, downhole data, reservoir geology and production data, distributed acoustic sensing (DAS), machine learning, and compressive sensing to solve complex reservoir challenges and optimize reservoir development on active industry projects.
- **Center for Gravity, Electrical and Magnetic Studies (CGEM)** brings together diverse expertise to quantitatively interpret and integrate gravity, magnetic, electrical and electromagnetic, as well as nuclear magnetic resonance data to advance geophysical data interpretation for real-world problems (e.g., mineral exploration, hydrogeophysics, geotechnical problems).
- **Center for Rock and Fluid Multiphysics (CRFM)** uses advanced laboratory experimental techniques and machine learning to study fluid distributions in rocks and how these distributions affect characteristics such as wave attenuation, velocity dispersion, and seismic signature.
- **Hydrogeology and Geomechanics Laboratory** integrates data from laboratory and field experiments at various scales to inform process-based models of near-surface problems including coastal freshwater, contaminant plumes, geothermal systems, landslides, leakage in earth dams and embankments, and volcanic processes.
- **Glaciology Laboratory** uses satellite remote-sensing techniques in combination with field-based and airborne geophysical methods to understand physical processes of Earth's glaciers and ice sheets and to overcome the inherent difficulty of observing continent-scale ice masses that drive and react to other components of the Earth's global climate system.
- **Geophysical Oceanography Group** combines high-resolution observations of winds, currents, and waves with theory and modeling to bridge the gap between the ocean and the atmosphere and further our understanding of how coupled air-sea interactions affect the environment including through wave dynamics and heat transfer.

Program Requirements

The department offers both traditional, research-oriented graduate programs and a non-thesis professional education program designed to meet specific career objectives. The program of study is selected by the student, in consultation with an advisor, and with thesis committee approval, according to the student's career needs and interests. Specific degrees have specific requirements as detailed below.

Geophysics and Geophysical Engineering Program Objectives

The principal objective for students pursuing the PhD degree in Geophysics or Geophysical Engineering is for Geophysics PhD graduates to be regarded by their employers as effective educators and/or innovative researchers in their early-career peer group. In support of this objective, the PhD programs in the Department of Geophysics are aimed at achieving these student outcomes:

- Graduates will command superior knowledge of Geophysics and fundamental related disciplines and a superior understanding of their importance in the social context.
- Graduates will independently be able to devise and independently conduct research leading to significant new knowledge and geophysical techniques.
- Graduates will be able to report their findings orally and in writing to a variety of specialist, generalist, and public audiences.

The chief objective for students pursuing the MS degree in Geophysics or Geophysical Engineering is for Geophysics MS graduates to be regarded by their employers as effective practitioners addressing earth, energy, and environmental problems with geophysical techniques. In support of this objective, the MS programs in the Department of Geophysics aim to achieve these student outcomes:

- Graduates will command superior knowledge of geophysics and fundamental related disciplines.
- Graduates will be able to conduct original research that results in new knowledge and geophysical techniques.
- Graduates will be able to report their findings orally and in writing.

Master of Science Degrees (Non-Thesis): Geophysics and Geophysical Engineering

Students may obtain a Master of Science (MS) Degree (non-thesis) in either Geophysics or Geophysical Engineering, pursuant to the general and individual program requirements outlined below. Students typically complete this program in one to two years.

For either Master of Science (non-thesis) degree, the minimum credits required include:

LICM501	PROFESSIONAL ORAL COMMUNICATION	1.0
or SYGN683	ORAL COMMUNICATION SKILLS	
GPGN581	GRADUATE SEMINAR	1.0
GPGN583	READING SEMINAR	1.0
	THEORY COURSEWORK [1]	3.0
	APPLICATION COURSEWORK [1]	3.0
	COMPUTATIONAL COURSEWORK [1]	3.0
	EARTH & SPACE COURSEWORK [1]	3.0
	ADDITIONAL COURSEWORK	15.0
Total Semester Hrs		**30.0**

[1] The lists of pre-approved elective courses satisfying the Theory, Application, Computational and Earth & Space coursework requirements may be found below.

The student and advisor determine individual courses constituting the degree to address specific interests and career goals. The courses applied to all MS degrees must satisfy the following specific criteria:

- The 30-credit hour minimum total must include 15 credit hours of GPGN-listed courses.
- A maximum of 6 credit hours of independent study may be counted toward the degree program.

- All course, transfer, residence, and thesis requirements are as described in Registration and Tuition Classification and Graduate Degrees and Requirements sections of the catalog.
- Up to 6 credits of graduate level work may be double counted in the undergraduate and graduate degree for students enrolled in the Combined Degree.
- Additional courses may also be required by the student's advisor and committee to fulfill background requirements.

The coursework for the degree Master of Science, Geophysical Engineering, must meet the following specific requirements. Note that these requirements are in addition to those associated with the Master of Science in Geophysics.

- Students must complete, either prior to their arrival at Mines or while at Mines, no fewer than 16 credits of engineering coursework. What constitutes coursework considered as engineering is determined by the Geophysics faculty.

Computational Geophysics Track

The Computational Geophysics Track has the same requirements as the Geophysics Master's of Science (non-thesis) degree program described above except that students are expected to choose coursework that satisfies a minimum of 15 credit hours, of which a minimum of 6 credits hours must be GPGN listed from the list of pre-approved computational coursework electives may be found below.

Master of Science Degrees: Geophysics and Geophysical Engineering

Students may obtain a Master of Science (MS) Degree in either Geophysics or Geophysical Engineering, pursuant to the general and individual program requirements outlined below. Students typically complete this program in two years.

For either Master of Science degree, the minimum credits required include:

LICM501	PROFESSIONAL ORAL COMMUNICATION	1.0
or SYGN683	ORAL COMMUNICATION SKILLS	
GPGN581	GRADUATE SEMINAR	1.0
GPGN583	READING SEMINAR	1.0
	THEORY COURSEWORK [1]	3.0
	COMPUTATIONAL COURSEWORK [1]	3.0
	APPLICATION COURSEWORK [1]	3.0
	EARTH & SPACE COURSEWORK [1]	3.0
	ADDITIONAL COURSEWORK [2]	9.0
GPGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
Total Semester Hrs		**30.0**

[1]The lists of pre-approved elective courses satisfying the Theory, Application, Computational and Earth & Space coursework requirements may be found below.

[2]With the approval of the student's thesis committee, up to 4 additional GPGN707 research credits beyond the 6 GPGN707 credits required for the degree program can counted toward satisfying the additional coursework requirement.

The student and advisor, with approval from the thesis committee, determines individual courses constituting the degree to address specific interests and career goals. The courses applied to all MS degrees must satisfy the following specific criteria:

- The 30-credit hour minimum total must include 15 credit hours of GPGN-listed courses.
- A maximum of 6 credit hours of independent study may be counted toward the degree program.
- All course, research, transfer, residence, and thesis requirements are as described in Registration and Tuition Classification and Graduate Degrees and Requirements sections of the catalog.
- Up to 6 credits of graduate level work may be double counted in the undergraduate and graduate degree for students enrolled in the Combined Degree.
- Additional courses may also be required by the student's advisor and committee to fulfill background requirements.

The coursework and thesis topic for the degree Master of Science, Geophysical Engineering, must meet the following specific requirements. Note that these requirements are in addition to those associated with the Master of Science in Geophysics.

- Students must complete, either prior to their arrival at Mines or while at Mines, no fewer than 16 credits of engineering coursework. What constitutes coursework considered as engineering is determined by the Geophysics faculty.
- The student’s dissertation topic must be appropriate for inclusion as part of an Engineering degree, as determined by the Geophysics faculty.

As described in the Master of Science, Thesis and Thesis Defense section of this catalog, all MS candidates must successfully defend their MS thesis in a public oral thesis defense. The guidelines for the thesis defense enforced by the Department of Geophysics generally follow those outlined in in the Graduate Departments and Programs section of the catalog, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee a minimum of three weeks prior to the thesis defense date.

Mines' Combined Undergraduate/Graduate Degree Program

Students enrolled in Mines' combined undergraduate/graduate program may double count up to 6 credits of graduate level coursework to fulfill requirements of both their undergraduate and graduate degree programs. 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.

Doctor of Philosophy Degrees: Geophysics and Geophysical Engineering

We invite applications to our Doctor of Philosophy (PhD) program not only from those individuals with a background in geophysics, but also from those whose background is in allied disciplines such as geology, physics, mathematics, computer science, or electrical engineering. Our program is suitable for students who desire careers in research-intensive environments, including government agencies and academia. Students typically complete the PhD program in four to five years.

Students may obtain a PhD degree in either Geophysics or Geophysical Engineering, pursuant to the general and individual program requirements outlined below.

For either PhD degree, at least 72 credits beyond the bachelor's degree are required. Of that total, at least 24 research credits are required. At least 12 course credits must be completed in a minor program of study, approved by the candidate's PhD thesis committee. Up to 36 course credits may be awarded by the candidate's committee for completion of a thesis-based master's degree. Graduate-level coursework completed as part of a thesis-based master's degree with a focus on the Theory, Application, Computational, Earth & Space or Professional Development coursework may be used to satisfy the related theme with approval of the candidate's committee.

While individual courses constituting the degree are determined by the student and approved by the student's advisor and committee, courses applied to all PhD degrees must satisfy the following criteria:

- The 72-credit hour minimum total must include 36 credit hours of GPGN-listed courses.
- A maximum of 6 credit hours of independent study may be counted toward the degree program.
- All course, research, minor degree programs, transfer, residence, and thesis requirements are as described in Registration and Tuition Classification and Graduate Degrees and Requirements sections of the catalog.
- Students must include the following courses in their PhD program:

	THEORY COURSEWORK [1]	3.0
	APPLICATION COURSEWORK [1]	3.0
	COMPUTATIONAL COURSEWORK [1]	3.0
	EARTH & SPACE COURSEWORK [1]	3.0
	PROFESSIONAL DEVELOPMENT COURSEWORK [1]	3.0
	ADDITIONAL COURSEWORK [2]	20.0
	COMPLEMENTARY COURSEWORK [3]	12.0
LICM501	PROFESSIONAL ORAL COMMUNICATION [4]	1.0
or SYGN683	ORAL COMMUNICATION SKILLS	
GPGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	24.0
Total Semester Hrs		**72.0**

(1) The lists of pre-approved elective courses satisfying the Theory, Application, Computational, Earth & Space, and Professional Development coursework requirements may be found below.

(2) With approval of the student's thesis committee, additional GPGN707 research credits beyond the 24 GPGN707 required for the degree program can counted toward satisfying the additional coursework requirement.

(3) The complementary coursework requirement may be satisfied by minor, graduate certificate, or set of courses that provide the spirit of minor or graduate certificate, as approved by the PhD committee, the geophysics graduate advisory committee, and the Geophysics Department.

(4) Can be replaced by 1 credit from the pre-approved professional development coursework list if already taken as part of a previous graduate degree program.

Additional courses may also be required by the student's advisor and committee to fulfill background requirements described below. The coursework and thesis topic for the degree Doctor of Philosophy, Geophysical Engineering, must meet the following additional requirements:

- Students must complete, either prior to their arrival at Mines or while at Mines, no fewer than 16 credits of engineering coursework. What constitutes coursework considered as engineering is determined by the Geophysics faculty.
- The student's dissertation topic must be appropriate for inclusion as part of an Engineering degree, as determined by the Geophysics faculty.

Students in both PhD programs are also required to participate in a practical teaching experience. This requirement must be fulfilled, within a single semester and course, under observation and evaluation by the course instructor of record, and include:

- Planning and delivery of a minimum of 6 lecture hours, or 4 lecture hours and 2 labs.
- Creating and evaluating students' homework and laboratory reports, if appropriate.
- Holding office hours if necessary.

In both PhD programs, students must demonstrate the potential for successful completion of independent research and enhance the breadth of their expertise by completing a Doctoral Research qualifying exam not later than two years from the date of enrollment in the program. An extension of one additional year may be petitioned by students through their thesis committees. In the Department of Geophysics, the Doctoral Research qualifying exam consists of the preparation, presentation, and defense of one research project and a thesis proposal. The research project and thesis proposal used in this process must conform to the standards posted on the Department of Geophysics webpage. As described in the Doctor of Philosophy Thesis Defense section of this catalog, all PhD candidates must successfully defend their PhD thesis in an open oral thesis defense. The guidelines for the thesis defense enforced by the Department of Geophysics follow those outlined in the Graduate Departments and Programs section of the catalog, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee a minimum of three weeks prior to the thesis defense date.

Acceptable Thesis Formats

In addition to traditional dissertations, the Department of Geophysics also accepts dissertations that are compendia of papers published or submitted to peer-reviewed journals. Dissertations submitted in the latter format must adhere to the following guidelines.

- All papers included in the dissertation must have a common theme, as approved by a student's thesis committee.
- Papers should be submitted for inclusion in a dissertation in a uniform format and typeset.
- In addition to the individual papers, students must prepare abstract, introduction, discussion, and conclusions sections of the thesis that tie together the individual papers into a unified dissertation.

- A student's thesis committee might also require the preparation and inclusion of various appendices with the dissertation in support of the papers prepared explicitly for publication.

Graduate Program Background Requirements

All graduate programs in Geophysics require that applicants have a background that includes the equivalent of adequate undergraduate preparation in the following areas:

- Mathematics – Linear Algebra or Linear Systems, Differential Equations, and Computer Programming
- Physics – Classical Mechanics, and Electromagnetism
- Geology – Structural Geology and Stratigraphy
- Geophysics – Courses that include theory and application in three of the following areas: gravity/magnetics, seismology, electrical/electromagnetics, borehole geophysics, remote sensing, geodynamics, oceanography and fluid dynamics.
- Field and computational experience in the hands-on application or implementation of several geophysical methods.

NOTES:

Theory, Application, Computational, Earth & Space, and Professional Development Coursework Definitions

- **Theory Coursework (pre-approved 500/600 level course electives)**
  a. Provides graduate-level foundation in geophysical theory while allowing flexibility based on interest and/or need.
  b. Key Learning Outcome: Use first principles of mathematics and physics to derive models that explain fundamental processes of the Earth and other planetary bodies.

GPGN510	MACHINE LEARNING INVERSION IN APPLIED GEOSCIENCE	3.0
GPGN511	ADVANCED GRAVITY AND MAGNETIC METHODS	3.0
GPGN520	ELECTRICAL AND ELECTROMAGNETIC EXPLORATION	3.0
GPGN552	INTRODUCTION TO SEISMOLOGY I	3.0
GPGN553	INTRODUCTION TO SEISMOLOGY II	3.0
GPGN555	EARTHQUAKE SEISMOLOGY	3.0
GPGN651	ADVANCED SEISMOLOGY	3.0
GPGN658	SEISMIC WAVEFIELD IMAGING	3.0

- **Application Coursework (pre-approved 500/600 level course electives)**
  1. Provides graduate-level foundation in applied geophysics while allowing flexibility based on interest and/or need.
  2. Key Learning Outcome: Ability to design and execute experiments to collect, process, and interpret data in order to gain knowledge about the Earth and other planetary bodies.

GPGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	3.0
GPGN545	INTRODUCTION TO DISTRIBUTED FIBER-OPTIC SENSING AND ITS APPLICATIONS	3.0
GPGN547	PHYSICS, MECHANICS, AND PETROPHYSICS OF ROCKS	3.0
GPGN558	SEISMIC DATA INTERPRETATION AND QUANTITATIVE ANALYSIS	3.0
GPGN561	SEISMIC DATA PROCESSING I	4.0
GPGN570	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN574	ADVANCED HYDROGEOPHYSICS	3.0
GPGN577	HUMANITARIAN GEOSCIENCE	3.0
GPGN590	INSTRUMENTAL DESIGN IN APPLIED GEOSCIENCES	3.0
CCUS521	GEOLOGICAL CARBON CAPTURE UTILIZATION AND SEQUESTRATION (CCUS)	3.0

- **Computational Coursework (pre-approved 500/600 level course electives)**
  a. Provides graduate-level foundation in computational geophysics while allowing flexibility based on interest and/or need.
  b. Key Learning Outcome: Familiarization with numerical implementation of geophysical theory and modern computational techniques, such as data science, machine learning, algorithm development, cluster computing, and parallel processing.

GPGN536	ADVANCED GEOPHYSICAL COMPUTING I	3.0
GPGN537	ADVANCED GEOPHYSICAL COMPUTING II	3.0
GEOL558	EARTH RESOURCE DATA SCIENCE 2: APPLICATIONS AND MACHINE-LEARNING	3.0
MATH540	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
CSCI542	SIMULATION	3.0
CSCI563	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	3.0
CSCI568	DATA MINING	3.0
CSCI580	ADVANCED HIGH PERFORMANCE COMPUTING	3.0
EENG509	SPARSE SIGNAL PROCESSING	3.0
EENG511	CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS	3.0
EENG515	MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS	3.0
DSCI560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0
DSCI561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0
DSCI575	ADVANCED MACHINE LEARNING	3.0

- **Earth & Space Coursework (pre-approved 500/600 level course electives)**
  a. Provides graduate-level foundation in conceptual modeling of the Earth while allowing flexibility based on interest and/or need.
  b. Key Learning Outcome: Development of conceptual models to explain the observed natural complexity of earth materials and processes.

CCUS520	CLIMATE CHANGE AND SUSTAINABILITY	3.0
CHGC503	INTRODUCTION TO GEOCHEMISTRY	3.0
CHGC505	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
GEOL501	APPLIED STRATIGRAPHY	4.0
GEOL502	STRUCTURAL METHODS FOR SEISMIC INTERPRETATION	3.0
GEOL505	ADVANCED STRUCTURAL GEOLOGY	3.0
GEOL513	HYDROTHERMAL GEOCHEMISTRY	3.0
GEOL552	UNCONVENTIONAL PETROLEUM SYSTEMS	3.0
GEOL551	APPLIED PETROLEUM GEOLOGY	3.0
GEOL645	VOLCANOLOGY	3.0
GEGN508	ADVANCED ROCK MECHANICS	3.0
GEGN570	CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY	3.0
GEGN582	INTEGRATED SURFACE WATER HYDROLOGY	3.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN671	LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION	3.0
SYGN598	INTRODUCTION TO GEOTHERMAL RESOURCES	

- **Professional Development Coursework (pre-approved 500/600 level course electives)**

1. Provides opportunities for professional development while allowing flexibility based on interest and/or need.
2. Key Learning Outcome: Development of a superior understanding of the importance of geophysics and fundamental related disciplines within the social context.

SYGN501	RESEARCH SKILLS FOR GRADUATE STUDENTS	1.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS	1.0
GPGN581	GRADUATE SEMINAR	1.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
EBGN542	ECONOMIC DEVELOPMENT	3.0
EBGN553	PROJECT MANAGEMENT	3.0
EBGN563	MANAGEMENT OF TECHNOLOGY AND INNOVATION	3.0
EDNS515	INTRODUCTION TO SCIENCE AND TECHNOLOGY STUDIES	3.0
EDNS544	INNOV8X	3.0

Program Requirements

Graduate Certificate in Energy Geophysics

The Graduate Certificate in Energy Geophysics will be a fully online certificate. The applicant is required to have an undergraduate degree to be admitted into the program. Students working toward their graduate certificate are required to take 12 credits from the following list of approved courses:

GPGN519	ADVANCED FORMATION EVALUATION	3.0
GPGN545	INTRODUCTION TO DISTRIBUTED FIBER-OPTIC SENSING AND ITS APPLICATIONS	3.0
GPGN547	PHYSICS, MECHANICS, AND PETROPHYSICS OF ROCKS	3.0
GPGN558	SEISMIC DATA INTERPRETATION AND QUANTITATIVE ANALYSIS	3.0
GPGN651	ADVANCED SEISMOLOGY	3.0
CCUS521	GEOLOGICAL CARBON CAPTURE UTILIZATION AND SEQUESTRATION (CCUS)	3.0
SYGN598	INTRODUCTION TO GEOTHERMAL RESOURCES	3.0

Students must achieve a minimum average grade of B (3.0) for the four required courses.

Courses

GPGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

GPGN509. INVERSION. 3.0 Semester Hrs.
This course introduces the fundamentals of inverse problem theory as applied to geophysics. Students explore the fundamental concepts of inversion in probabilistic and deterministic frameworks, as well as practical methods for solving discrete inverse problems. Topics studied include optimization criteria, optimization methods, and error and resolution analysis. Weekly homework assignments addressing either theoretical or numerical problems through programming assignments illustrate the concepts discussed in class. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Students will understand the fundamental principles of probabilistic and deterministic inversion.
- Students will understand the main methods used to quantify measurement uncertainty.
- Students will understand the relationships between probabilistic and deterministic solutions to inverse problems.
- Students will understand the basic techniques for obtaining numeric solutions to inverse problems.

GPGN510. 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.
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

GPGN511. ADVANCED GRAVITY AND MAGNETIC METHODS. 3.0 Semester Hrs.

This course presents the theory and methods for processing and interpreting gravity and magnetic data acquired in geoscience applications. The course covers four major topic areas in the gravity and magnetic methods: (1) the data quantities measured in field surveys; (2) the methods for modeling, processing, and analyzing gravity, gravity gradient, and magnetic data; (3) 3D inversion of gravity and magnetic data; and (4) integrated interpretation of gravity and magnetic data through inversion and geology differentiation for extracting geology information. Prerequisites: GPGN314, GPGN328.

Course Learning Outcomes

- Graduates will demonstrate exemplary disciplinary expertise.

GPGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.

A detailed review of well logging and other formation evaluation methods will be presented. Course includes an overview of the logging environment, how different basic and advanced logging tools work, how logging measurements are converted to geophysical properties, how geophysical properties relate to physical and chemical properties of fluids and rocks, and how log data are tied with seismic data.

GPGN520. ELECTRICAL AND ELECTROMAGNETIC EXPLORATION. 3.0 Semester Hrs.

(II) Electromagnetic theory. Instrumentation. Survey planning. Processing of data. Geologic interpretations. Methods and limitations of interpretation. Offered Spring semester in conjunction with GPGN420. Prerequisite: GPGN314. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- NA

GPGN530. APPLIED GEOPHYSICS. 3.0 Semester Hrs.

(II) Introduction to geophysical techniques used in a variety of industries (mining, petroleum, environmental and engineering) in exploring for new deposits, site design, etc. The methods studied include gravity, magnetic, electrical, seismic, radiometric and borehole techniques. Emphasis on techniques and their applications are tailored to student interests. The course, intended for non-geophysics students, will emphasize the theoretical basis for each technique, the instrumentation used and data collection, processing and interpretation procedures specific to each technique so that non-specialists can more effectively evaluate the results of geophysical investigations. 3 hours lecture; 3 semester hours.

GPGN533. GEOPHYSICAL DATA INTEGRATION & GEOSTATISTICS. 3.0 Semester Hrs.

(I) Students will learn the fundamentals of and explore opportunities for further development of geostatistical data integration techniques for subsurface earth modeling. The class will build on probability theory, spatial correlations and geostatistics algorithms for combing data of diverse support and resolution into subsurface models. The emphasis of the material will be on stochastic methods for combining quantitative and qualitative data into many equi-probable realizations. Activities include computer modeling, written exercises, oral team presentations, and a semester project with opportunity to enhance student's respective research projects. Also, we will read, discuss and implement current research articles the in literature to encourage implementation of state-of-the-art practices and/or highlighting current opportunities for research. 3 hours lecture; 3 semester hours.

GPGN536. ADVANCED GEOPHYSICAL COMPUTING I. 3.0 Semester Hrs.

This course extends the principles of geophysical computing in the context of simulating and validating numerical solutions to geophysical data processing challenges and 2D/3D partial differential equations commonly found in geophysical investigations. Students develop 2D and 3D numerical solutions to geophysical problems through prototyping and validating code in both high- (e.g., Python) and low-level (e.g., C/C++/F90) languages. Offered in conjunction with GPGN435. Prerequisite: CSCI250 or instructor consent.

Course Learning Outcomes

- Students will gain experience in taking theoretical concepts and using them to develop, prototype and validate parallel numerical algorithms in the context of geophysical computing.
- Students will gain mastery of practical programming skills and combine with knowledge of numerical algorithms to solve real-world geophysical problems.
- Students will augment their independent research skills by devising and leading a research project involving a substantial piece of analytic, numerical and computation work involving solving a real-world geophysical problem

GPGN537. ADVANCED GEOPHYSICAL COMPUTING II. 3.0 Semester Hrs.

A survey of computer programming skills most relevant to geophysical modeling, data processing, visualization, and analysis. Skills enhanced include effective use of multiple programming languages, multicore systems, computer memory hierarchies, GPUs, and parallel computing strategies. Problems addressed include multidimensional geophysical partial differential equations, geophysical image processing, regularization of geophysical data acquired at scattered locations, and other geophysical computing problems encountered in research by students. Prerequisite: GPGN536 or instructor consent.

Course Learning Outcomes

- Students will gain mastery in taking theoretical concepts and using them to develop, prototype and validate parallel numerical algorithms in the context of geophysical computing.
- Students will gain mastery of practical programming skills and combine with knowledge of numerical algorithms to solve real-world geophysical problems.
- Students will augment their independent research skills by devising and leading a project involving a substantial piece of analytic, numerical and computation work involving solving a real-world geophysical problem.

GPGN543. MINERAL EXPLORATION GEOPHYSICS. 3.0 Semester Hrs.

This course focuses on geophysical methods in mineral exploration by integrating mineral deposit theory and commonly employed geophysical methods. We begin with a background discussion on the geological setting and physical property characteristics of major deposit types to lay the foundational understanding for different geophysical method. We will then discuss the physical principles and operations of different geophysical methods, and the interpretation of geophysical data sets to extract geological information through geophysical inversion. We will then discuss the emerging methods for efficient data acquisition, and integrated exploration methodology of geology differentiation that combines the geologic, physical property, and geophysical information to produce a quasi-geology model to image the geology.

Course Learning Outcomes

- Explain the connection between geophysical and economic geology
- Discuss the physical basis for different geophysical methods
- Evaluate the information in geophysical data and inverted physical property models
- Devise a geophysical exploration strategy for a mineral exploration program

GPGN545. INTRODUCTION TO DISTRIBUTED FIBER-OPTIC SENSING AND ITS APPLICATIONS. 3.0 Semester Hrs.

This course will first introduce the fundamentals of Distributed Fiber-optic Sensing (DFOS) technologies, including the measuring principles, calibration process, advantages, and limitations. Then we will explore the recent development of DFOS applications in geophysics, petroleum engineer, smart city, hydrology, and other fields. Three major technologies of DFOS will be introduced: distributed acoustic sensing (DAS), distributed temperature sensing (DTS), and distributed strain sensing (DSS). Prerequisite: Python programming, signal processing.

Course Learning Outcomes

- 1. Students will learn the principle, advantages, and limitations of DFOS systems.
- 2. Students will learn recent DFOS application developments.
- 3. Students will be able to apply the theories to realistic DFOS applications.
- 4. Students will be able to learn how to handle, process, visualize DFOS data using Python programming and Google Colab.
- 5. Students will be able to perform DFOS data analysis to obtain the required results.

GPGN547. PHYSICS, MECHANICS, AND PETROPHYSICS OF ROCKS. 3.0 Semester Hrs.

This course will discuss topics in rock physics, rock mechanics and petrophysics as outlined below. The class is a combination of lectures, practical sessions, and critical reading and discussion of papers. Topics addressed: Segment in Rock physics: stress, strain, stiffness, modulus, attenuation and dispersion, Segment in Petrophysics: seismic & log expression of various formations, wettability, shale analysis, diagenesis, formation evaluation.

Course Learning Outcomes

- First-order Level Learning Objectives • Gain an introduction to and a working knowledge of the main topics in rock physics • Understand and evaluate technical topics related to rock physics applications • Have insight into basic techniques to evaluate reservoirs • Learn tools to assess reserves, and learn best techniques to use rock physics principles
- Second-order Learning Objectives • identify major & minor rock-forming minerals • evaluate or recall elastic properties of major rock-forming minerals • classify mineral components as load-bearing or pore-filling • compute modulus of a dry rock frame constructed with major minerals • know isotropic and other (major) symmetries • predict modulus changes in fluid and frame with stress • predict modulus changes with cementation • evaluate / defend role of porosity, cementation and diagenesis on elastic properties • evaluate and appraise elastic modulus of frame with geological and well log information • explain differences between static and dynamic stresses, strains and moduli • classify lithological texture to expected acoustic anisotropy • compute elastic bounds: Voigt, Reuss, Hashin-Shtrikman, modified H-S • compute Empirical velocity models

GPGN552. INTRODUCTION TO SEISMOLOGY I. 3.0 Semester Hrs.

(I) Introduction to basic principles of elasticity including Hooke's law, equation of motion, representation theorems, and reciprocity. Representation of seismic sources, seismic moment tensor, radiation from point sources in homogeneous isotropic media. Boundary conditions, reflection/transmission coefficients of plane waves, plane-wave propagation in stratified media. Basics of wave propagation in attenuative media, brief description of seismic modeling methods. 3 hours lecture; 3 semester hours.

GPGN553. INTRODUCTION TO SEISMOLOGY II. 3.0 Semester Hrs.

(II) This course is focused on the physics of wave phenomena and the importance of wave-theory results in exploration and earthquake seismology. Includes reflection and transmission problems for spherical waves, methods of steepest descent and stationary phase, point-source radiation in layered isotropic media, surface and non-geometrical waves. Discussion of seismic modeling methods, fundamentals of wave propagation in anisotropic and attenuative media. Prerequisite: GPGN552. 3 hours lecture; 3 semester hours. Offered spring semester, even years.

GPGN555. EARTHQUAKE SEISMOLOGY. 3.0 Semester Hrs.

Equivalent with GPGN455,

(I) 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 Earth structure, earthquake locations, depths and mechanisms; understand Earth's tectonics and rheology; establish long-term earthquake histories and forecast future recurrence; and mitigate against seismic hazards. GPGN555 differs from GPGN455 in that the assignments are approximately 20% longer and encompass more challenging questions. GPGN555 is the appropriate course for graduate students and for undergraduates who expect to go on to study earthquake seismology at graduate school. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 3a, b, d, f, g, h, j, k

GPGN558. SEISMIC DATA INTERPRETATION AND QUANTITATIVE ANALYSIS. 0-3 Semester Hr.

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 or GPGN 561 and GEOL309 or GEOL314.

Course Learning Outcomes

- NA

GPGN561. SEISMIC DATA PROCESSING I. 4.0 Semester Hrs.

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, 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.

Course Learning Outcomes

- NA

GPGN570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.

(II) 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. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GPGN573. POLAR CRYOSPHERE IN THE EARTH SYSTEM. 3.0 Semester Hrs.

The polar cryosphere is a fundamental and rapidly changing component of the physical Earth system as well as of other planetary bodies that both drives and responds to climate perturbations. This course will provide an introduction to the interdisciplinary nature of permafrost, sea ice, glaciers, and ice sheets, then dive deeper into the fundamental physics of glacier and ice-sheet dynamics and their application to global sea level, paleoclimate, and planetary science questions. We will cover topics including glacier mass balance, ice material properties, ice rheology, models of ice #ow, supra-, en-, and subglacial hydrology, subglacial geologic processes, and the stability and history of Earth's ice sheets. Although aimed at a broad audience interested in climate, geophysics, and planetary science, students will be expected to have a background understanding of undergraduate-level mathematics through differential equations and basic Python programming experience. Succeeding in this class is certainly possible without formal coursework in differential equations and programming, but may require additional out-of-class self-study to learn these skills in real time. Prerequisite: CSCI 128 or similar; MATH 225 or similar.

Course Learning Outcomes

- 1. Demonstrate a conceptual understanding of feedbacks between the polar cryosphere and the Earth's climate system
- 2. Critically analyze peer-reviewed literature in polar cryosphere
- 3. Understand the equations that govern glacier evolution and evaluate output from complex ice sheet models
- 4. Analyze modern cryospheric datasets to quantify cryospheric processes and to recognize the limits of our knowledge about cryospheric evolution in a changing climate

GPGN574. ADVANCED HYDROGEOPHYSICS. 0-3 Semester Hr.

(II) Application of geophysical methods to groundwater problems from the grain scale to the basin scale. course introduces the groundwater flow and solute transport equations to understand the parameters controlling flow. Geophysical and numerical modeling techniques are introduced as a means to constrain transport parameters. Geophysical topics include electrical methods, seismic methods, downhole logging, and nuclear magnetic resonance. Modeling techniques include forward and inversion approaches for groundwater flow, solute transport, and geophysical data. Readings and discussions will be used to bring state-of-the-art applications of course content. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- NA

GPGN577. HUMANITARIAN GEOSCIENCE. 3.0 Semester Hrs.

(II) This interdisciplinary course introduces the concepts and practice of geoscientific investigations in humanitarian projects. Students will evaluate humanitarian geoscience case studies, devise the characteristics of successful projects, and identify how these best practices could improve previous case studies. This knowledge will be applied towards a group project. Students will split into groups and pair up with a faculty advisor and a local organization (e.g., NGO or community group) to design, execute and assess the impact of their project. A key emphasis in all aspects of the course will be on community engagement. This course is taught in collaboration with the Mines Engineering Design and Society Division and other participating departments.

Course Learning Outcomes

- Analyze humanitarian geoscience projects using established evaluation criteria
- Identify the most successful practices for humanitarian geoscience projects
- Determine different ways in which previous humanitarian geoscience projects could have been improved to yield more successful technical and social results
- Determine the most practical geoscientific methods for different humanitarian applications
- Work within a team to design, execute and evaluate a project with a local community organization
- Gain experience in engaging and communicating with community members and stakeholders
- Develop stronger professional communication skills through written assignments, group projects, discussions, presentations, and community engagement

GPGN581. GRADUATE SEMINAR. 0-1 Semester Hr.

(I, II) Attendance at scheduled weekly Heiland Distinguished Lectures during each semester of enrollment. Graduate students in Geophysics and Geophysical Engineering register each semester in residence in the program and receive 0.0 credit hours until the last semester in residence. For the last semester, 1.0 credit hours and a grade of PRG are awarded with satisfactory attendance.

Course Learning Outcomes

- Graduates will contribute to the advancement of their chosen fields through adopting, applying and evaluating state-of-the-art practices.

- Graduates will be viewed within their organizations as technologically advanced and abreast of the latest scholarship.

GPGN583. READING SEMINAR. 1.0 Semester Hr.
This course is designed to broaden the knowledge and perspective of MS students through reading and critiquing scientific publications. Student will read a scientific publication weekly that is related to the Heiland lecture of the week. Every week a student will present and lead the discussion of the paper during the class. Every student need to write a short discussion/summary/thinking/report after the Heiland lecture and post it on Canvas.
Course Learning Outcomes

GPGN590. INSTRUMENTAL DESIGN IN APPLIED GEOSCIENCES. 3.0 Semester Hrs.
A hands-on course on instrumental design for those interested in developing “sensors and software” solutions for use in applied geoscience and related engineering disciplines, including environmental, civil, electrical, mining, petroleum, and mechanical engineering. The first half of the course focuses on developing required skill sets in electronics microcomputers and device connectivity that enables students to construct a smart sensing system that is remotely accessible through the internet of things (IoT). The second half of the course consists of project work on multidisciplinary teams who devise, build, and validate usable prototype devices such as a magnetometer, a telemetered sap-monitoring unit, an autonomous ground penetrating radar, or a smart irrigation system. Prerequisite: CSCI250 or instructor consent.
Course Learning Outcomes

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

GPGN597. SUMMER PROGRAMS. 0-12 Semester Hr.

GPGN598. SPECIAL TOPICS IN GEOPHYSICS. 0-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN598. SPECIAL TOPICS. 0-6 Semester Hr.

GPGN598. SPECIAL TOPICS. 0-6 Semester Hr.

GPGN598. SPECIAL TOPICS. 0-6 Semester Hr.

GPGN599. GEOPHYSICAL INVESTIGATIONS MS. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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GPGN651. ADVANCED SEISMOLOGY. 3.0 Semester Hrs.
In-depth discussion of wave propagation and seismic processing for anisotropic, heterogeneous media. Topics include influence of anisotropy on plane-wave velocities and polarizations, traveltime analysis for transversely isotropic models, anisotropic velocity-analysis and imaging methods, point-source radiation and Green's function in anisotropic media, inversion and processing of multicomponent seismic data, shear-wave splitting, and basics of seismic fracture characterization. Prerequisite: GPGN552, GPGN553.

GPGN658. SEISMIC WAVEFIELD IMAGING. 3.0 Semester Hrs.
(I) Seismic imaging is the process that converts seismograms, each recorded as a function of time, to an image of the earth's subsurface, which is a function of depth below the surface. The course emphasizes imaging applications developed from first principles (elastodynamics relations) to practical methods applicable to seismic wavefield data. Techniques discussed include reverse-time migration and migration by wavefield extrapolation, angle-domain imaging, migration velocity analysis and analysis of angle-dependent reflectivity. Students do independent term projects presented at the end of the term, under the supervision of a faculty member or guest lecturer. Prerequisite: none. 3 hours lecture; 3 semester hours.

GPGN698. SPECIAL TOPICS. 0-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN699. GEOPHYSICAL INVESTIGATION-PHD. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

GPGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

GPGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SYGN501. RESEARCH SKILLS FOR GRADUATE STUDENTS. 1.0 Semester Hr.
(I, II) This course consists of class sessions and practical exercises. The content of the course is aimed at helping students acquire the skills needed for a career in research. The class sessions cover topics such as the choice of a research topic, making a work plan and executing that plan effectively, what to do when you are stuck, how to write a publication and choose a journal for publication, how to write proposals, the ethics of research, the academic career versus a career in industry,

time-management, and a variety of other topics. The course is open to students with very different backgrounds; this ensures a rich and diverse intellectual environment. Prerequisite: None. 1 hour lecture; 1 semester hour.

Course Learning Outcomes

- n/a

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

Professors

John H. Bradford, Vice President for Global Initiatives

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

Yaoguo Li

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

Jeffrey C. Shragge

Ilya D. Tsvankin

University Distinguished Professors

Kamini Singha

Ilya D. Tsvankin

Associate professors

Ge Jin

Eileen Martin

Matthew Siegfried

Assistant Professors

Bia Villas Bôas

Roslynn King

Joint appointments with loci within Geophysics

Eileen Martin, Associate Professor in Applied Mathematics and Statistics

Joint appointments 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

Kamini Singha, Professor, Geology and Geological Engineering

Research Associate Professor

Richard Krahenbuhl

Research Assistant Professor

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Jyoti Behura, Founder & CEO, Seismic Science LLC

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Morgan Moschetti, Research Geophysicist, US Geological Survey

Ryan North, Principal Geophysicist, ISC Geoscience

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