GEOPHYSICAL ENGINEERING (GPGN)

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.

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

- At the completion of the course, students will understand the fundamental principles of probabilistic and deterministic inversion.
- The main methods used to quantify measurement uncertainty.
- The relationships between probabilistic and deterministic solutions to inverse problems; and
- 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

GPGN551. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.

(I, II) Students will probe a range of current methodologies and issues in seismic data processing, and discuss their ongoing and planned research projects. Topic areas include: Statics estimation and compensation, deconvolution, multiple suppression, wavelet estimation, imaging and inversion, anisotropic velocity and amplitude analysis, seismic interferometry, attenuation and dispersion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Every student registers for GPGN551 in only the first semester in residence and receives a grade of PRG. The grade is changed to a letter grade after the student's presentation of thesis research. Prerequisite: none. 1 hour seminar; 1 semester hour.

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. 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 or GPGN 561 and GEOL309 or GEOL314.
Course Learning Outcomes

- NA

GPGN559. RESERVOIR CHARACTERIZATION SEMINAR. 1.0 Semester Hr.
Students will probe a range of current methodologies and issues in integrated reservoir characterization and discuss their ongoing and planned research projects, both in oral presentations and interdisciplinary class discussions. Topic areas include geophysical and geological reservoir characterization, fluid flow and simulation, distributed acoustic and temperature sensing, machine learning and data analytics, compressive sensing for seismic data acquisition, and enhanced oil recovery for unconventionals. Students receive real-time feedback on their research progress and presentations from Geophysics faculty and potentially professionals in the local geophysics community.
Course Learning Outcomes

- Possess a deeper understanding of integrated reservoir characterization
- Become practiced in scientific oral presentations, written abstracts, and poster development
- Develop skills in communicating across interdisciplinary teams

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. 3.0 Semester Hrs.
(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. 1.0 Semester Hr.
(I, II) Attendance at scheduled weekly Heiland Distinguished Lectures during each semester of enrollment. Students must complete one individual presentation during the graduate program, at an approved public venue, before degree is granted. Every thesis-based MS student in Geophysics and Geophysical Engineering registers 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 and successful completion of individual presentation requirement.
Course Learning Outcomes

- Institutional Educational Objectives (1) and (2); Institutional Student Outcomes (1) and (3)

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

GPGN598. SPECIAL TOPICS IN GEOPHYSICS. 6.0 Semester Hrs.
(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.

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.

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.

GPGN681. GRADUATE SEMINAR - PHD. 1.0 Semester Hr.
(I,II) Presentation describing results of PhD thesis research. All students must present their research at an approved public venue before the degree is granted. Every PhD student registers for GPGN681 only in his/ her first semester in residence and receives a grade of PRG. Thereafter, students must attend the weekly Heiland Distinguished Lecture every semester in residence. The grade of PRG is changed to a letter grade after the student's public research presentation and thesis defense are both complete. 1 hour seminar; 1 semester hour.
Course Learning Outcomes

- No change

GPGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(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.

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.