Petroleum Engineering

Degrees Offered

- Master of Engineering in Petroleum Engineering
- Master of Science in Petroleum Engineering
- Doctor of Philosophy in Petroleum Engineering

Program Description

The department offers a choice of a master of science (MS) degree or a master of engineering (ME) degree. For the MS degree, a thesis is required in addition to course work. For the ME degree, no thesis is required, but the coursework requirement is greater than that for the MS degree. The Petroleum Engineering Department also offers Petroleum Engineering (PE) undergraduate students the option of a Combined Undergraduate/Graduate Program. This is an accelerated program that provides the opportunity for PE students to get a head start on their graduate education.

Applications from students with an MS in Petroleum Engineering, or in another complimentary discipline, will be considered for admission to the doctor of philosophy (PhD) program. To obtain the PhD degree, a student must demonstrate unusual competence, creativity, and dedication in the degree field. In addition to extensive course work, a dissertation is required for the PhD degree.

Applying for Admission

All graduate applicants must have taken core engineering, math and science courses before applying to graduate school. For Colorado School of Mines this would be 3 units of Calculus, 2 units of Chemistry with Quantitative Lab, 2 units of Physics, Differential Equations, Statics, Fluid Mechanics, Thermodynamics and Mechanics of Materials. To apply for admission, follow the procedure outlined in the general section of this catalog. Three letters of recommendation must accompany the application. The Petroleum Engineering Department requires the general test of the Graduate Record Examination (GRE) for applicants to all degree levels.

Applicants for the Master of Science and Master of Engineering programs should have a minimum score of 155 or better, and applicants for the PhD program are expected to have 159 or better on the quantitative section of the GRE exam, in addition to acceptable scores in the verbal and analytical sections. The GPA of the applicant must be 3.0 or higher. The graduate application review committee determines minimum requirements accordingly, and these requirements may change depending on the application pool for the particular semester. The applicants whose native language is not English are also expected to provide satisfactory scores on the TOEFL (Test of English as a Foreign Language) exam as specified in the general section of this catalog.

Required Curriculum

A student in the graduate program selects course work by consultation with the faculty advisor and with the approval of the graduate committee. Course work is tailored to the needs and interests of the student. Students who do not have a BS degree in petroleum engineering must take deficiency courses as required by the department as soon as possible in their graduate programs. Depending on the applicant’s undergraduate degree, various basic undergraduate petroleum engineering and geology courses will be required. These deficiency courses are not counted toward the graduate degree; nonetheless, the student is expected to pass the required courses and the grades received in these courses are included in the GPA. Not passing these courses can jeopardize the student’s continuance in the graduate program. It is desirable for students with deficiencies to complete the deficiencies or coursework within the first two semesters of arrival to the program or as soon as possible with the approval of their advisor.

All PE graduate students are required to complete 3 credit hours of course work in writing, research, or presentation intensive classes, such as SYGN683, SYGN684, PEGN681 LICM501, SYGN501, and SYGN600, as agreed to by their graduate advisor.

Fields of Research

Current fields of research include:

- Petroleum data analytics
- Artificial Intelligence applications to porous media
- Rock and fluid properties, phase behavior, and rock mechanics
- Geomechanics
- Formation evaluation, well test analysis, and reservoir characterization
- Oil recovery processes
- IOR/EOR Methods
- Naturally fractured reservoirs
- Analytical and numerical modeling of fluid flow in porous media
- Pore-scale modeling and flow in nanopores
- Development of unconventional oil and gas plays
- Geothermal energy
- Gas hydrates
- Completion and stimulation of wells
- Horizontal and multilateral wells
- Multistage fracturing of horizontal wells
- Drilling management and rig automation
- Fluid flow in wellbores and artificial lift
- Drilling mechanics
- Carbon sequestration and storage
- Environment, health, and safety in oil and gas industry

Research projects may involve professors and graduate students from other disciplines. Projects may include off-campus laboratories, institutes, and other resources.

The Petroleum Engineering Department houses a research institute, a research center, and two consortia.

Research Institute

- Unconventional Natural Gas and Oil Institute (UNGI)

Research Center

- Marathon Center of Excellence for Reservoir Studies (MCERS)

Research Consortia

- Fracturing, Acidizing, Stimulation Technology (FAST) Consortium
- Unconventional Reservoir Engineering Project (UREP) Consortium

Special Features

In the exchange programs with the Petroleum Engineering Departments of the Mining University of Leoben, Austria, Technical University in Delft, Holland, and King Fahd University of Petroleum Minerals (KFUPM) in Dhahran, Saudi Arabia, a student may spend one semester abroad during graduate studies and receive full transfer of credit back to Colorado School of Mines with prior approval of the Petroleum Engineering Department at Colorado School of Mines.

Marquez Hall is home to the Petroleum Engineering Department. A prominent campus landmark, Marquez Hall showcases Mines' long-standing strengths in its core focus areas and our commitment to staying at the forefront of innovation. The building is designed using aggressive energy-saving strategies and is LEED certified. Marquez Hall is the first building on Colorado School of Mines Campus that is funded entirely by donations.

The Petroleum Engineering Department enjoys strong collaboration with the Geology and Geological Engineering Department and Geophysics Department at Colorado School of Mines. Courses that integrate the faculty and interests of the three departments are taught at the graduate levels.

The department is close to oil and gas field operations, oil companies and laboratories, and geologic outcrops of producing formations. There are many opportunities for summer and part-time employment in the oil and gas industry.

Each summer, several graduate students assist with the field sessions designed for undergraduate students. The field sessions in the past several years have included visits to oil and gas operations in Alaska, Canada, Southern California, the Gulf Coast, the northeast U.S., the Rocky Mountain regions, and western Colorado.

The Petroleum Engineering Department encourages student involvement with the Society of Petroleum Engineers, the American Association of Drilling Engineers and the American Rock Mechanics Association. The department provides some financial support for students attending the annual technical conferences for these professional societies.

Program Requirements

Master of Engineering

Candidates for the non-thesis **Master of Engineering** degree must complete a minimum of 30 hours of graduate course credit. At least 15 of the credits must be from the Petroleum Engineering Department. Up to 12 graduate credits can be transferred from another institution. All courses must be approved by the student's advisor and the department head. No graduate committee is required. No more than 6 credits can be earned through independent study.

Master of Science

Candidates for the **Master of Science** degree must complete at least 24 graduate credits of course work, approved by the candidate's graduate committee, and a minimum of 6 hours of research credit. At least 12 of the course credits must be from the Petroleum Engineering Department. Up to 9 credits may be transferred from another institution. For the MS degree, the student must demonstrate ability to observe, analyze, and report original scientific research. For other requirements, refer to the general instructions of the Graduate School in this bulletin.

Doctor of Philosophy

A candidate for the **PhD** must complete at least 48 hours of course credit and a minimum of 30 credits of research beyond the bachelor's degree. A student with a master's degree is allowed to transfer up to 24 hours of course credit from the Master's degree into the PhD program upon approval of the department and the student's thesis committee. Students may additionally transfer up to 21 graduate credits of course work from another institution with the approval of the graduate advisor, under the condition that these hours were not previously used for a degree or a certificate. PhD students must complete at least half of their minimally required course credits from the Petroleum Engineering Department and a minimum of 6 credits of their required course credit outside the Petroleum Engineering Department. The student's faculty advisor, thesis committee, and the department head must approve the course selection. Full-time PhD students must satisfy the following requirements for admission to candidacy within the first two calendar years after enrolling in the program:

1. Have a thesis committee appointment form on file,
2. Complete all prerequisite courses successfully,
3. Demonstrate adequate preparation for and satisfactory ability to conduct doctoral research by successfully completing a series of written and/or oral examinations and fulfilling the other requirements of their graduate committees as outlined in the department's graduate handbook.

Failure to fulfill these requirements within the time limits specified above may result in immediate mandatory dismissal from the PhD program according to the procedure outlined in the section of this Bulletin titled General Regulations—Unsatisfactory Academic Performance—Unsatisfactory Academic Progress Resulting in Probation or Discretionary Dismissal. For other requirements, refer to the general directions of the Graduate School in this bulletin and/or the department's Graduate Student Handbook.

Combined Undergraduate/Graduate Degree Program

Students enrolled in Mines' combined undergraduate/graduate program may double count up to 6 credits of graduate 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.

Courses

PEGN501. APPLICATIONS OF NUMERICAL METHODS TO PETROLEUM ENGINEERING. 3.0 Semester Hrs.
The course will solve problems of interest in Petroleum Engineering through the use of spreadsheets on personal computers and structured FORTRAN programming on PCs or mainframes. Numerical techniques will include methods for numerical quadrature, differentiation, interpolation, solution of linear and nonlinear ordinary differential equations, curve fitting and direct or iterative methods for solving simultaneous equations. Prerequisites: PEGN414 and PEGN424. 3 hours lecture; 3 semester hours.

PEGN502. ADVANCED DRILLING FLUIDS. 3.0 Semester Hrs.
The physical properties and purpose of drilling fluids are investigated. Emphasis is placed on drilling fluid design, clay chemistry, testing, and solids control. Prerequisite: PEGN311. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN503. 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.

PEGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

PEGN505. HORIZONTAL WELLS: RESERVOIR AND PRODUCTION ASPECTS. 3.0 Semester Hrs.
This course covers the fundamental concepts of horizontal well reservoir and production engineering with special emphasis on the new developments. Each topic covered highlights the concepts that are generic to horizontal wells and draws attention to the pitfalls of applying conventional concepts to horizontal wells without critical evaluation. There is no set prerequisite for the course but basic knowledge on general reservoir engineering concepts is useful. 3 hours lecture; 3 semester hours.

PEGN506. ENHANCED OIL RECOVERY METHODS. 3.0 Semester Hrs.
Enhanced oil recovery (EOR) methods are reviewed from both the qualitative and quantitative standpoint. Recovery mechanisms and design procedures for the various EOR processes are discussed. In addition to lectures, problems on actual field design procedures will be covered. Field case histories will be reviewed. Prerequisite: PEGN424. 3 hours lecture; 3 semester hours.

PEGN508. ADVANCED ROCK PROPERTIES. 3.0 Semester Hrs.
Application of rock mechanics and rock properties to reservoir engineering, well logging, well completion and well stimulation. Topics covered include: capillary pressure, relative permeability, velocity effects on Darcy’s Law, elastic/mechanical rock properties, subsidence, reservoir compaction, and sand control. Prerequisites: PEGN423 and PEGN426. 3 hours lecture; 3 semester hours.

PEGN511. ADVANCED THERMODYNAMICS AND PETROLEUM FLUIDS PHASE BEHAVIOR. 3.0 Semester Hrs.
Essentials of thermodynamics for understanding the phase behavior of petroleum fluids such as natural gas and oil. Modeling of phase behavior of single and multi-component systems with equations of states with a brief introduction to PVT laboratory studies, commercial PVT software, asphaltenes, gas hydrates, mineral deposition, and statistical thermodynamics. 3 hours lecture; 3 semester hours. Prerequisites: PEGN312, PEGN305.

Course Learning Outcomes

- Identify the fundamental properties of reservoir rocks and their impact on reservoir behavior, including porosity, saturations, and formation compressibility, for comprehensive understanding in petroleum engineering applications.

PEGN512. ADVANCED GAS ENGINEERING. 3.0 Semester Hrs.
The physical properties and phase behavior of gas and gas condensates will be discussed. Flow through tubing and pipelines as well as through porous media is covered. Reserve calculations for normally pressured, abnormally pressured and water drive reservoirs are presented. Both stabilized and isochronal deliverability testing of gas wells will be illustrated. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN513. RESERVOIR SIMULATION I. 3.0 Semester Hrs.
The course provides the rudiments of reservoir simulation, which include flow equations, solution methods, and data requirement. Specifically, the course covers: equations of conservation of mass, conservation of momentum, and energy balance; numerical solution of flow in petroleum reservoirs by finite difference (FD) and control volume FD; permeability tensor and directional permeability; non-Darcy flow; convective flow and numerical dispersion; grid orientation problems; introduction to finite element and mixed finite-element methods; introduction to hybrid analytical/numerical solutions; introduction to multi-phase flow models; relative permeability, capillary pressure and wettability issues; linear equation solvers; streamline simulation; and multi-scale simulation concept. Prerequisite: PEGN424 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN515. ADVANCED RESERVOIR ENGINEERING. 3.0 Semester Hrs.
Reservoir Engineering overview. Predicting hydrocarbon in place; volumetric method, deterministic and probabilistic approaches, material balance, water influx, graphical techniques. Fluid flow in porous media; continuity and diffusivity equations. Well performance; productivity index for vertical, perforated, fractured, restricted, slanted, and horizontal wells, inflow performance relationship under multiphase flow conditions. Combining material balance and well performance equations. Future reservoir performance prediction; Muskat, Tarner, Carter and Tracy methods. Fetkovich decline curves. Reservoir simulation; fundamentals and formulation, streamline simulation, integrated reservoir studies. 3 hours lecture, 3 semester hours.

PEGN517. ADVANCED DRILLING ENGINEERING. 3.0 Semester Hrs.
Drilling Engineering overview. Subjects to be covered include overall drilling organization, contracting, and reporting; basic drilling engineering principles and equipment; drilling fluids, hydraulics, and cuttings transport; drillstring design; drill bits; drilling optimization; fishing operations; well control; pore pressure and fracture gradients, casing points and design; cementing; directional drilling and horizontal drilling. 3 hours lecture, 3 semester hours.

PEGN518. ADVANCED PRODUCTION ENGINEERING. 3.0 Semester Hrs.
This course provides the fundamental concepts in the production area, including Inflow Performance Relationships (IPR), Outflow Performance Relationship (OPR) (or Multiphase Flow in Wells), and Nodal Analysis. It also teaches the current most widely used artificial lift methods, including Gas Lift, ESP, and Sucker Rod Pump systems, and their design and application/challenges for conventional and unconventional reservoirs. Also covered are the introduction of major flow assurance issues, such as liquid loading, terrain and severe slugging, wax, gas hydrate, and emulsion, and their prevention and mitigation, as well as the surface facilities for gas and oil processing. Students will have the opportunities

to write multiphase flow simulators, which are essential in production design and flow assurance problems prediction and management. Some widely used commercial production design software (PIPESIM and OLGA) will also be taught and the students will use them in the production system design.

Course Learning Outcomes

PEGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.

A detailed review of wireline well logging and evaluation methods stressing the capability of the measurements to determine normal and special reservoir rock parameters related to reservoir and production problems. Computers for log processing of single and multiple wells. Utilization of well logs and geology in evaluating well performance before, during, and after production of hydrocarbons. The sensitivity of formation evaluation parameters in the volumetric determination of petroleum in reservoirs. Prerequisite: PEGN419. 3 hours lecture; 3 semester hours.

PEGN522. ADVANCED WELL STIMULATION. 3.0 Semester Hrs.

(I) Basic applications of rock mechanics to petroleum engineering problems. Hydraulic fracturing; acid fracturing, fracturing simulators; fracturing diagnostics; sandstone acidizing; sand control, and well bore stability. Different theories of formation failure, measurement of mechanical properties. Review of recent advances and research areas. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

PEGN524. PETROLEUM ECONOMICS AND MANAGEMENT. 3.0 Semester Hrs.

Business applications in the petroleum industry are the central focus. Topics covered are: fundamentals of accounting, oil and gas accounting, strategic planning, oil and gas taxation, oil field deals, negotiations, and the formation of secondary units. The concepts are covered by forming companies that prepare proforma financial statements, make deals, drill for oil and gas, keep accounting records, and negotiate the participation formula for a secondary unit. Prerequisite: PEGN422. 3 hours lecture; 3 semester hours.

PEGN530. ENVIRONMENTAL LAW AND SUSTAINABILITY. 3.0 Semester Hrs.

Equivalent with CEEN492,CEEN592,

(II) In this course students will be introduced to the fundamental legal principles that are relevant to sustainable engineering project development. General principles of United States(U.S.) environmental regulation pertaining to air quality, water quality, waste management, hazardous substances remediation, regulation of chemical manufacture and distribution, natural resources, and energy will be discussed parallel with international laws pertaining to environmental protection and human rights. In the context of engineering project design, students will explore legal, societal, and ethical risks, and risk mitigation methodologies. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

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PEGN540. PETROLEUM DATA ANALYSIS. 3.0 Semester Hrs.

This course will take a detailed look at the opportunities, challenges and specific requirements for petroleum data analytics for the energy industry. It starts with an introduction to data analysis and visualization packages. Three projects are assigned in drilling, production, and reservoir data analysis along with data visualization techniques. The student will be required to prepare both oral and written project updates and final results. Prerequisite: PEGN438 or instructor consent.

Course Learning Outcomes

- Contribute toward the significant technical challenges created by large data environments, including architecture, security, integrity, management, scalability, artificial intelligence topics, and distribution.
- Apply the principles and application of informatics, and the goals of enterprise intelligence as applied to the energy industry.
- Prepare and analyze data from various petroleum data streams including drilling, completions, stimulation, production, and reservoir management.
- Interpret petroleum data and derive useful conclusions.
- Demonstrate professionalism through attendance, demeanor, participation, exhibiting integrity, accepting responsibility, taking initiative, team participation and providing leadership as necessary to ensure project success.
- Create formal and informal communications for individual, team, and industry/company use that document and facilitate progress and enhance the impact of the final design.

PEGN547. PHYSICS, MECHANICS AND PETROPHYSICS OF ROCKS. 3.0 Semester Hrs.

(I) This course will discuss topics in rock physics, rock mechanics and petrphysics as outlined below. The class is a combination of lectures, laboratory sessions, and critical reading and discussion of papers. Topics: Stresses, strains, stiffnesses, rock physics, petrophysics: wettability: shale analysis: seismic & log expression of various formations: diagenesis: formation evaluation. 3 hours lecture; 3 semester hours.

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 constitutents 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

PEGN551. PETROLEUM DATA ANALYTICS - FUNDAMENTALS. 3.0 Semester Hrs.

Introduction to advanced data analytics in the Digital Oilfield. Comprehensive overview of the fundamental building blocks of the digital oilfield from the convergence of operational technology (field instrumentation and control systems) with corporate information technology infrastructure. An understanding of the data foundation for a typical oil and gas exploration and production company and the challenges of Big Data to oilfield operations (volumes, variety, velocity, and data quality). Prerequisite: DSCI403, DSCI530 or MATH530 or Instructor Approval.

Course Learning Outcomes

- A review of the objectives and results from the digital oilfield since 2000 and a discussion of what is new today (lower for much longer oil prices and emerging digital technologies)
- Convergence of OT (operational technology) and IT (information technology) systems. From sensors and control systems (SCADA), to remote decision support environments, to workflow automation, to process optimization
- Review of often used analytical techniques (regression analysis, neural networks, machine learning, deep learning). Machine Learning overview with Python programming and Jypter Notebook platform
- Review of Business Intelligence (reporting), Data Visualization (dashboards, data story telling) and Artificial Intelligence approaches, the strengths, and weaknesses of each.

PEGN552. PETROLEUM DATA ANALYTICS - APPLICATIONS. 3.0 Semester Hrs.

A continuation of the advanced data analytics in the Digital Oilfield. This capstone course will be to apply learnings from the previous sequence of courses to drilling/completions improvement, production analysis, reservoir management optimization, and unconventional resource development. The course requires the ability of the student to be able to collect, manage, manipulate, analyze, develop insights, and report using both written and oral means those insights using good data visualizations. Prerequisite: PEGN551 or Instructor Consent.

Course Learning Outcomes

- The application of data computational techniques for developing and measuring key performance indications for oil and gas, geothermal, and other drilling and/or completion operations
- • The application of predictive analytics for optimization of oil and gas production processes.
- • The application of data analysis techniques for determining best practice for the management of sub-surface resource development.
- • The application of data analysis techniques for predicting and optimizing the development and production of unconventional resources – shale development, tight gas sands, enhanced oil recovery, and other esoteric resource development.

PEGN577. WORKOVER DESIGN AND PRACTICE. 3.0 Semester Hrs.

Workover Engineering overview. Subjects to be covered include Workover Economics, Completion Types, Workover Design Considerations, Wellbore Cleanout (Fishing), Workover Well Control, Tubing and Workstring Design, SlicklineOperations, Coiled Tubing Operations, Packer Selection, Remedial Cementing Design and Execution, Completion Fluids, Gravel Packing, and Acidizing. 3 hours lecture, 3 semester hours.

PEGN590. RESERVOIR GEOMECHANICS. 3.0 Semester Hrs.

The course provides an introduction to fundamental rock mechanics concepts and aims to emphasize their role in exploration, drilling, completion and production engineering operations. Basic stress and strain concepts, pore pressure, fracture gradient and in situ stress magnitude and orientation determination and how these properties are obtained from the field measurements, mechanisms of deformation in rock, integrated wellbore stability analysis, depletion induced compaction and associated changes in rock properties and formation strength, hydraulic fracturing and fracture stability are among the topics to be covered in this rock course. Naturally fractured formation properties and how they impact the characteristics measured in the laboratory and in field are also included in the curriculum. Several industry speakers are invited as part of the lecture series to bring practical aspects of the fundamentals of geomechanics covered in the classroom. In addition, Petrel, FLAC3D and FRACMAN software practices with associated assignments are offered to integrate field data on problems including in situ stress magnitude and orientations, pore pressure and fracture gradient prediction and rock property determination using laboratory core measurements, logs, seismic, geological data. Problems are assign for students to use the field and laboratory data to obtain static and dynamic moduli, rock failure criteria, wellbore stress concentration and failure, production induced compaction/subsidence and hydraulic fracture mechanics.

PEGN591. SHALE RESERVOIR ENGINEERING. 3.0 Semester Hrs.

Equivalent with PEGN615,

Fundamentals of shale-reservoir engineering and special topics of production from shale reservoirs are covered. The question of what makes shale a producing reservoir is explored. An unconventional understanding of shale-reservoir characterization is emphasized and the pitfalls of conventional measurements and interpretations are discussed. Geological, geomechanical, and engineering aspects of shale reservoirs are explained. Well completions with emphasis on hydraulic fracturing and fractured horizontal wells are discussed from the viewpoint of reservoir engineering. Darcy flow, diffusive flow, and desorption in shale matrix are covered. Contributions of hydraulic and natural fractures are discussed and the stimulated reservoir volume concept is introduced. Interactions of flow between fractures and matrix are explained within the context of dual-porosity modeling. Applications of pressure-transient, rate-transient, decline-curve and transient-productivity analyses are covered. Field examples are studied. 3 hours lecture; 3 semester hours.

PEGN592. GEOMECHANICS FOR UNCONVENTIONAL RESOURCES. 3.0 Semester Hrs.

A wide spectrum of topics related to the challenges and solutions for the exploration, drilling, completion, production and hydraulic fracturing of unconventional resources including gas and oil shale, heavy oil sand and carbonate reservoirs, their seal formations is explored. The students acquire skills in integrating and visualizing multidiscipline data in Petrel (a short tutorial is offered) as well as assignments regarding case studies using field and core datasets. The role of integrating geomechanics data in execution of the exploration, drilling, completion, production, hydraulic fracturing and monitoring of pilots as well as commercial applications in unlocking the unconventional resources are pointed out using examples. Prerequisite: PEGN590. 3 hours lecture; 3 semester hours.

PEGN593. ADVANCED WELL INTEGRITY. 3.0 Semester Hrs.

Fundamentals of wellbore stability, sand production, how to keep wellbore intact is covered in this course. The stress alterations in near wellbore region and associated consequences in the form of well failures will be covered in detailed theoretically and with examples from deepwater conventional wells and onshore unconventionalwell operations. Assignments will be given to expose the students to the real field data to interpret and evaluate cases to determinepractical solutions to drilling and production related challenges. Fluid pressure and composition sensitivity of various formations will be studied. 3 hours lecture; 3 semester hours.

PEGN594. ADVANCED DIRECTIONAL DRILLING. 3.0 Semester Hrs.

Application of directional control and planning to drilling. Major topics covered include: Review of procedures for the drilling of directional wells. Section and horizontal view preparation. Two and three dimensional directional planning. Collision diagrams. Surveying and trajectory calculations. Surface and down hole equipment. Common rig operating procedures, and horizontal drilling techniques. Prerequisite: PEGN311 or equivalent. 3 hours lecture; 3 semester hours.

PEGN596. ADVANCED WELL CONTROL. 3.0 Semester Hrs.
Principles and procedures of pressure control are taught with the aid of a full-scale drilling simulator. Specifications and design of blowout control equipment for onshore and offshore drilling operations, gaining control of kicks, abnormal pressure detection, well planning for wells containing abnormal pressures, and kick circulation removal methods are taught. Students receive hands-on training with the simulator and its peripheral equipment. Prerequisite: PEGN311. 3 hours lecture; 3 semester hours.

PEGN597. TUBULAR DESIGN. 3.0 Semester Hrs.
Fundamentals of tubulars (casing, tubing, and drill pipe) design applied to drilling. Major topics covered include: Dogleg running loads. Directional hole considerations. Design criteria development. Effects of formation pressures. Stability loads after cementing. Effects of temperature, pressure, mud weights, and cement. Helical bending of tubing. Fishing loads. Micro-annulus problem. Strengths of API tubulars. Abrasive wear while rotating drill pipe. How to design for hydrogen sulfide and fatigue corrosion. Connection selection. Common rig operating procedures. Prerequisites: PEGN311 and PEGN361 or equivalent. 3 hours lecture; 3 semester hours.

PEGN598. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 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.

PEGN598. SPECIAL TOPICS. 0-6 Semester Hr.

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PEGN598. SPECIAL TOPICS. 0-6 Semester Hr.

PEGN598LA. SPECIAL TOPICS LAB. 0-6 Semester Hr.

PEGN598. SPECIAL TOPICS. 0-6 Semester Hr.

PEGN599. INDEPENDENT STUDY. 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.

PEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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PEGN601. APPLIED MATHEMATICS OF FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.
This course is intended to expose petroleum-engineering students to the special mathematical techniques used to solve transient flow problems in porous media. Bessel's equation and functions, Laplace and Fourier transformations, the method of sources and sinks, Green's functions, and boundary integral techniques are covered. Numerical evaluation of various reservoir engineering solutions, numerical Laplace transformation and inverse transformation are also discussed. 3 hours lecture; 3 semester hours.

PEGN604. INTEGRATED FLOW MODELING. 3.0 Semester Hrs.
Students will study the formulation, development and application of a reservoir flow simulator that includes traditional fluid flow equations and a petrophysical model. The course will discuss properties of porous media within the context of reservoir modeling, and present the mathematics needed to understand and apply the simulator. Simulator applications will be interspersed throughout the course. 3 hours lecture; 3 semester hours.

PEGN605. ADVANCED WELL TESTING ANALYSIS. 3.0 Semester Hrs.
Various well testing procedures and interpretation techniques for individual wells or groups of wells. Application of these techniques to field development, analysis of well problems, secondary recovery, and reservoir studies. Productivity, gas well testing, pressure buildup and drawdown, well interference, fractured wells, type curve matching, and shortterm testing. Prerequisite: PEGN426. 3 hours lecture; 3 semester hours.

PEGN608. MULTIPHASE FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.
The factors involved in multiphase fluid flow in porous and fractured media. Physical processes and mathematical models for micro- and macroscopic movement of multiphase fluids in reservoirs. Performance evaluation of various displacement processes in the laboratory as well as in the petroleum field during the secondary and EOR/IOR operations. Prerequisite: PEGN 424, 3 hours lecture; 3 semester hours.

PEGN614. RESERVOIR SIMULATION II. 3.0 Semester Hrs.
The course reviews the rudiments of reservoir simulation and flow equations, solution methods, and data requirement. The course emphasizes multi-phase flow and solution techniques; teaches the difference between conventional reservoir simulation, compositional modeling and multi-porosity modeling; teaches how to construct three-phase relative permeability from water-oil and gas-oil relative permeability data set; the importance of capillary pressure measurements and wetability issues; discusses the significance of gas diffusion and interphase mass transfer. Finally, the course develops solution

techniques to include time tested implicit-pressure-explicitsaturation, sequential and fully implicit methods. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN620. NATURALLY FRACTURED RESERVOIRS -- ENGINEERING AND RESERVOIR SIMULATION. 3.0 Semester Hrs.
The subsurface crust of the Earth is highly fractured which impacts mass and energy transport associated with aquifers, petroleum reservoirs, hydrothermal reservoirs, hot-dry-rock enhanced geothermal systems (EGS), and waste disposal in igneous and metamorphic rocks. The course covers reservoir engineering, well testing, and simulation aspects of naturally fractured reservoirs. Specifics include: fractures in subsurface rocks, connectivity and network; fracture flow properties; physical principles underlying reservoir engineering and modeling naturally fractured reservoirs; local and global effects of viscous, capillary, gravity and molecular diffusion flows; dual-porosity/dual-permeability models; multi-scale fracture models; transient testing with non-Darcy flow effects; tracer injection and breakthrough analysis; geomechanics of fractures; compositional model; coal-bed gas model; oil and gas from fractured shale; improved and enhanced oil recovery in naturally fracture reservoirs. Prerequisites: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge.
Course Learning Outcomes

- Analyze the significance of mass and energy transport models in subsurface energy resources engineering to inform reservoir performance assessments.
- Apply advance engineering strategies to address complex reservoir system challenges, utilizing critical thinking to conduct and communicate research effectively.
- Develop and implement numerical algorithms for solving fluid flow and heat transport equations in fractured rock environments, demonstrating proficiency with data analysis tools.
- Synthesize computational methods to create solutions for non-linear, real-world mass and heat transport problems, enhancing AI-driven models.
- Design practical solutions to real-world engineering problems by integrating coursework, software, and communication skills.

PEGN624. COMPOSITIONAL MODELING - APPLICATION TO ENHANCED OIL RECOVERY. 3.0 Semester Hrs.
Efficient production of rich and volatile oils as well as enhanced oil recovery by gas injection (lean and rich natural gas, CO2, N2, air, and steam) is of great interest in the light of greater demand for hydrocarbons and the need for CO2 sequestration. This course is intended to provide technical support for engineers dealing with such issues. The course begins with a review of the primary and secondary recovery methods, and will analyze the latest worldwide enhanced oil recovery production statistics. This will be followed by presenting a simple and practical solvent flooding model to introduce the student to data preparation and code writing. Next, fundamentals of phase behavior, ternary phase diagram, and the Peng-Robinson equation of state will be presented. Finally, a detailed set of flow and thermodynamic equations for a full-fledged compositional model, using molar balance, equation of motion and the afore-mentioned equation of state, will be developed and solution strategy will be presented. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 hours lecture; 3 semester hours.

PEGN660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION. 3.0 Semester Hrs.
Equivalent with GEOL660,
(II) This course will include keynote lectures and seminars on the reservoir characterization of carbonate rocks, including geologic description, petrophysics and production engineering. Course will focus on the integration of geology, rock physics, and engineering to improve reservoir performance. Application of reservoir concepts in hands-on exercises, that include a reflection seismic, well log, and core data. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1) working knowledge of carbonate sedimentology and diagenesis its use in construction reservoir geometry and pore system architecture to design effective production strategies; 2) working knowledge of production engineering in carbonate reservoirs with a focus on dual porosity media (matrix and fractures), multi-scale physics and geo-mechanics in fractured carbonate reservoirs to help design reservoir stimulation models; and 3) working knowledge of how to integrate geology, geophysics, petrophysics, and engineering to increase reservoir performance.

PEGN681. PETROLEUM ENGINEERING SEMINAR. 1.0 Semester Hr.
Comprehensive reviews of current petroleum engineering literature, ethics, and selected topics as related to research and professionalism. 0 credit hours, except in students' final semester, in which it will be one credit.

PEGN698. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 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.

PEGN698. SPECIAL TOPICS. 0-6 Semester Hr.

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PEGN698. SPECIAL TOPICS. 0-6 Semester Hr.

PEGN699. INDEPENDENT STUDY. 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.

PEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

PEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

PEGN707. 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.

SYGN683. ORAL COMMUNICATION SKILLS. 1.0 Semester Hr.
This course is designed for ME, MS and PhD students and focuses on designing and delivering technical presentations. Course assignments will be based on technical and non-technical material relating to earth, energy, and the environment and will include the topics of professionalism, ethics and diversity. Students will work individually and in multicultural teams on assignments. There are no prerequisites for this

course, however, proficiency with the English language, both oral and written, is expected prior to enrollment.

Course Learning Outcomes

- Identify ethical considerations in technical communication.
- Identify audience considerations in technical communication.
- Prepare and deliver technical presentations.

SYGN684. WRITING SKILLS. 2.0 Semester Hrs.

This course is designed for MS and PhD students and will focus on the research process and the technical writing process. Course assignments will be based on technical and non-technical material relating to earth, energy, and the environment and will include the topics of professionalism, ethics and diversity. Students will work individually and in multicultural teams on assignments. There are no prerequisites for PEGN684, however, proficiency with the English language, both oral and written, is expected prior to enrollment.

Course Learning Outcomes

- Analyze and critique peer-reviewed journal articles
- Organize information and write technical documents including memos, abstracts, proposals, thesis/dissertations, and formal analytical reports.
- Discuss workplace and societal issues including professionalism, ethics, and diversity.

Professors

Hossein Kazemi, Chesebro' Distinguished Chair

Jennifer L. Miskimins, Department Head, F.H. "Mick" Merelli/Cimarex Energy Distinguished Department Head

Erdal Ozkan

Yu-Shu Wu

Associate Professors

Pejman Tahmasebi

Luis E. Zerpa, Associate Department Head, Harry D. Campbell Chair in Petroleum Engineering

Assistant Professors

Parisa Bazazi

Yilan Fan

Serveh Kamrava

Mohamed Khaled

Teaching Professor

Linda A. Battalora

Teaching Associate Professors

Mansur Ermila

Mark G. Miller

Research Professor

Ali Tura

Research Associate Professor

Philip H. Winterfeld

Professor Emeritus

Ramona M. Graves, Professor and Dean Emeritus

Bill Scoggins, President Emeritus

Craig W. Van Kirk, Professor Emeritus

Associate Professor Emeritus

Alfred W. Eustes III, Associate Professor Emeritus

Richard Christiansen, Associate Professor Emeritus