PETROLEUM ENGINEERING

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Petroleum engineers are concerned with the design of processes for energy recovery from oil and gas reservoirs. Included in the design process are characterizing the spatial distribution of reservoir properties, drilling wells, designing and operating production facilities, selecting and implementing methods for enhancing fluid recovery, predicting recovery process performance, monitoring reservoirs, and examining the environmental aspects of petroleum exploration and production. The Department of Petroleum Engineering curriculum provides a sound background in basic sciences and their application to practical problems to address the complex and changing nature of the field. Course work includes the fundamentals of chemistry, computer science, engineering, geology, geophysics, mathematics, and physics. Applied courses cover most aspects of petroleum engineering and some related fields like geothermal engineering and geostatistics. The curriculum emphasizes the fundamental aspects of fluid flow in the subsurface. These principles apply equally well to optimizing oil recovery from petroleum reservoirs and remediating contaminated groundwater systems.

Faculty and graduate students in the department conduct research in a variety of areas including: enhanced oil recovery by thermal means, gas injection, and the use of chemicals; flow of fluids in pipes; geostatistical reservoir characterization and mathematical modeling; geothermal engineering; natural gas engineering; optimization; properties of petroleum fluids; reservoir simulation using computer models; and well test analysis. Undergraduate students are encouraged to participate in research projects. Graduate programs lead to the degrees of Master of Science (M.S.), Engineer, and Doctor of Philosophy (Ph.D.) in Petroleum Engineering.

M.S., Engineer, and Ph.D. degrees may be awarded with field designations for students who follow programs of study in the fields of geostatistics, geothermal, crustal fluids, or environmental specialties.

The department is housed in the Green Earth Sciences Building and it operates laboratories for research in various enhanced oil recovery processes and geothermal engineering. Students have access to a variety of computers for research and course work. Computers available for instruction and research include eight UNIX workstations and three multi-processor multi-user NT servers within the department, as well as extensive campus-wide computer clusters. Each graduate student office has one X-terminal per student.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

The four-year program leading to the B.S. degree provides a foundation for careers in many facets of the energy industry. The curriculum includes basic science and engineering courses that provide sufficient depth for a wide spectrum of careers in the energy and environmental industries.

One of the goals of the program is to provide experience integrating the skills developed in individual courses to address a significant design problem. In Petroleum Engineering 180, taken in the senior year, student teams design facilities for a real petroleum reservoir to meet specific management objectives.

PROGRAM

The requirements for the B.S. degree in Petroleum Engineering are similar to those described in the "School of Engineering" section of this bulletin. Students must satisfy the University general education, writing, and language requirements. The normal Petroleum Engineering undergraduate program automatically satisfies the University General Education Requirements (GERs) in area 2a (Natural Sciences), area 2b (Technology and Applied Sciences), and area 2c (Mathematics). Engineering fundamentals courses and petroleum engineering depth and elective courses must be taken for a letter grade.

In brief, the credit and subject requirements are:

Subject	*Minimum Units*
Engineering fundamentals	25
General Education, writing, language, and electives	68-69
Mathematics	23
Petroleum engineering depth	39-40
Science	26
Total	181

The following courses constitute the normal program leading to a B.S. in Petroleum Engineering. The program may be modified to meet a particular student's needs and interests with the adviser's prior approval.

MATHEMATICS

Course No. and Subject	*Units*
Math. 41. Single Variable Calculus	5
and Math. 42. Single Variable Calculus	5
or	
Math. 19. Calculus	3
and Math. 20. Calculus	3
and Math. 21. Calculus	4
Math. 51. Linear Algebra and Differential Calculus of Several Variables	5
Math. 52. Integral Calculus of Several Variables	5
Math. 130. Ordinary Differential Equations	3
or Mech. Engr. 100. Differential Equations in Engineering	3
Total	23

SCIENCE

Chem. 31. Chemical Principles	4
Chem. 33. Structure and Reactivity	4
Chem. 171. Physical Chemistry	3
Geol. & Envir. Sci. 1. Fundamentals of Geology	5
Physics 41. Mechanics	3
Physics 43. Electricity	3
Physics 45. Magnetism	3
Physics 46. Electricity and Magnetism Laboratory	1
Total	26

ENGINEERING FUNDAMENTALS

Comp. Sci. 106A. Programming Methodology	5
or Comp. Sci. 106X. Programming Methodology and Abstractions	5
Engr. 14. Applied Mechanics: Statics and Deformables	5
and Engr. 15. Dynamics	5
Engr. 30. Engineering Thermodynamics	3
Mech. Engr. 33. Introductory Fluids Engineering	4
Engr. 60. Engineering Economy	3
Total	25

ENGINEERING DEPTH

The following courses constitute the core program in Petroleum Engineering:

Chem. Engr. 120A. Fluid Mechanics	3
or Chem. Engr. 180. Chemical Engineering Plant Design	3
Chem. Engr. 185A. Chemical Engineering Laboratory	3
Chem. Engr. 185B. Chemical Engineering Laboratory	3
Geol. & Envir. Sci. 111. Structural Geology and Rock Mechanics	3
Geol. & Envir. Sci. 151. Sedimentary Geology and Petrography: Depositional Systems	4
Pet. Engr. 120. Reservoir Engineering	3
Pet. Engr. 121. Fundamentals of Multiphase Flow	3
Pet. Engr. 130. Well Log Analysis I	3
Pet. Engr. 140. Drilling and Completion Technology	3

Pet. Engr. 175. Well Test Analysis	3
Pet. Engr. 280. Oil and Gas Production Engineering	3
Pet. Engr. 260. Groundwater Pollution and Oil Spills	3
Total	40

A list of suggested electives and sample course programs are available in the Department of Petroleum Engineering, room 65, Green Earth Sciences Building. It is important to start mathematics courses in the first year and engineering and geology early in the second year. Computers are used extensively in most petroleum engineering courses. Students must develop programming skills through appropriate course work and self-study and are expected to achieve fluency in the use of FORTRAN, C, or C++ by their junior year.

MINORS

To be recommended for a B.S. degree with Petroleum Engineering as a minor subject, a student must take the following courses in addition to those required by the major department or program: Pet. Engr. 120, 121, 130, 175, 180; Geol. & Envir. Sci. 111 and 151. In some programs, Geol. & Envir. Sci. 111 or 151 may also satisfy major requirements.

HONORS PROGRAM

A limited number of undergraduates may be admitted to the honors program at the beginning of their senior year.

To be admitted, the student must have a grade point average (GPA) of at least 3.0 in all course work in the University. In addition to the minimum requirements for the B.S. degree, the student must complete 6 units of advanced petroleum engineering courses and at least 3 units of research (Pet. Engr. 193).

Students who wish to be admitted to the honors program should consult with their adviser before the start of their senior year. Those who do not meet all of the formal requirements may petition the department for admission. Those completing the program receive the B.S. degree in Petroleum Engineering with Honors. An overall 3.5 GPA is required in all petroleum engineering courses for graduation with honors.

COTERMINAL B.S. AND M.S. PROGRAM

The coterminal B.S./M.S. program offers a unique opportunity for Stanford University students to pursue a graduate experience while completing the B.S. degree in any relevant major. Petroleum Engineering graduate students generally come from a variety of backgrounds such as chemical, civil, or mechanical engineering; geology or other earth sciences; or physics or chemistry. Students should have a background at least through Mathematics 130 and Computer Science 106 before beginning graduate work in this program.

The two types of M.S. degrees, the course work only degree, and the research degree, as well as the courses required to meet degree requirements are described below in the M.S. section. Both degrees require 45 units and may take from one to two years to complete depending on various circumstances unique to each student.

Requirements to enter the program are two letters of recommendation from faculty members or job supervisors, a statement of purpose, scores from the GRE general test, and a copy of Stanford University transcripts. While the department does not require any specific GPA or GRE score, potential applicants are expected to compete favorably with graduate student applicants.

A Petroleum Engineering master's degree can be used in a variety of ways. It is considered a terminal professional degree which prepares the student to obtain a professional job in the petroleum or geothermal industry, or in any related industry where analyzing flow in porous media or computer simulation skills are required. It can also be a stepping stone to a Ph.D. degree, which usually leads to a professional research job or an academic position.

Students should apply to the program any time after they have completed 105 undergraduate units, and in time to take Petroleum Engineering 120, the basic introductory course in Autumn Quarter of the year they wish to begin the program. Contact the Department of Petroleum Engineering to obtain additional information.

GRADUATE PROGRAMS

The University's basic requirements for M.S., Engineer, and Ph.D. degrees are discussed in the "Graduate Degrees" section of this bulletin.

The energy industry provides a variety of employment opportunities for petroleum engineers with advanced training. A balanced master's degree program including both engineering course work and research requires a minimum of one maximum tuition academic year beyond the baccalaureate to meet the University residence requirements. Most full-time students spend at least one additional summer to complete the research requirement. An alternative master's degree program based only on course work is available that also requires at least one maximum tuition academic year to meet University residence requirements.

Students who anticipate continuing in the Ph.D. program should follow the research option. M.S. students receiving financial aid normally require two academic years to complete the degree. Such students must take the research option and are limited to a 9-unit course load per quarter.

The degree of Engineer requires a comprehensive maximum tuition two-year program of graduate study. This degree permits more extensive course work than the master's degree, with an emphasis on professional practice. All Engineer's degree students receiving financial aid are also limited to a 9-unit course load per quarter and need at least ten quarters of work to complete the degree.

The Ph.D. degree is awarded primarily on the basis of completion of significant, original research. Extensive course work and a minimum of three maximum tuition years of graduate work beyond the master's degree is required. Doctoral candidates planning theoretical work are encouraged to gain experimental research experience in the M.S. program. Ph.D. students receiving financial assistance are limited to 9 units per quarter and often require more than three years to complete the Ph.D.

In special cases, the M.S., Engineer, and Ph.D. degrees may be awarded with field designations for students who follow programs of study in the particular fields of (1) geostatistics, (2) geothermal, (3) crustal fluids, or (4) environmental. For example, students may be awarded the degree Master of Science in Petroleum Engineering (Geothermal).

MASTER OF SCIENCE

The objective is to prepare the student for professional work in the energy industry through completion of fundamental courses in the major field and in related sciences as well as independent research.

Students entering the graduate program are expected to have an undergraduate-level petroleum engineering background. Competence in computer programming in a high-level language (Computer Science 106X or the equivalent) and knowledge of petroleum engineering and geological fundamentals (Petroleum Engineering 120, 130, 140, and Geological and Enviromental Sciences 151) are prerequisites for taking most graduate courses.

The candidate must fulfill the following requirements:

1. Register as a graduate student for at least three quarters at maximum tuition or the equivalent of partial-tuition quarters.
2. Submit a Program Proposal for the Master's Degree approved by the adviser during the first quarter of enrollment.
3. Complete 45 units with at least a grade point average (GPA) of 3.0. This requirement is satisfied by taking the Core Sequence, selecting one of the seven elective sequences, an appropriate number of additional courses from the list of technical electives, and completing 6 units of master's level research. Students electing the "course work only" M.S. degree are strongly encouraged select an additional elective sequence in place of the research requirement. Students interested in continuing for a Ph.D. are expected to choose the research option and enroll in 6 units of Petroleum Engineering 361. All courses must be taken for a letter grade.
4. Students entering without an undergraduate degree in Petroleum Engineering must make up deficiencies in previous training. Not more than 10 units of such work may be counted as part of the minimum total of 45 units toward the M.S. degree.

Research subjects include certain groundwater hydrology and environmental problems, energy industry management, flow of non-Newtonian fluids, geothermal energy, natural gas engineering, oil and gas recovery, pipeline transportation, production optimization, reservoir characterization and modeling, reservoir engineering, reservoir simulation, and transient well test analysis.

RECOMMENDED COURSES AND SEQUENCES

The following list is recommended for most students. With the prior special consent of the student's adviser, courses listed under technical electives may be substituted based on interest or background.

CORE SEQUENCE

Course No. and Subject	*Units*
Mech. Engr. 200A. Mathematical & Computational Methods in Engineering	3
Mech. Engr. 200B. Mathematical Methods in Engineering	3
Pet. Engr. 175. Well Test Analysis	3
or Pet. Engr. 130. Well Log Analysis	3
Pet. Engr. 221. Fundamentals of Multiphase Flow	3
Pet. Engr. 222. Reservoir Engineering†	3
Pet. Engr. 246. Reservoir Characterization and Flow Modeling with Outcrop Data	3
Pet. Engr. 251. Thermodynamics of Equilibria*	3
Total	21

* Optional for students taking the Geostatistics and Reservoir Modeling sequence.
† Students taking the Environmental sequence may substitute Pet. Engr. 227.

ELECTIVE SEQUENCE

Choose one of the following:

Crustal Fluids:	
Geol. & Envir. Sci. 230. Physical Hydrogeology	5
Geol. & Envir. Sci. 231. Contaminant Hydrogeology	4
Geophys. 170. Fluids in the Earth's Crust	3
Total	12
Environmental:	
Geol. & Envir. Sci. 231. Contaminant Hydrogeology	4
Pet. Engr. 227. Enhanced Oil Recovery	3
Plus two out of the following courses:	
Civ. & Envir. Engr. 270. Movement, Fate, and Effect of Contaminants in Surface Water and Groundwater	3
Civ. & Envir. Engr. 274A. Environmental Microbiology	3
Geol. & Envir. Sci. 230. Physical Hydrogeology	3
Geol. & Envir. Sci. 264. Low Temperature Aqueous Geochemistry	3
Pet. Engr. 240. Geostatistics	3-4
Pet. Engr. 260. Environmental Problems in Petroleum Engineering	3
Total	13-14
Enhanced Recovery:	
Pet. Engr. 225. Theory of Gas Injection Processes	3
Pet. Engr. 226. Thermal Recovery Methods	3
Pet. Engr. 227. Enhanced Oil Recovery	3
Total	9
Geostatistics and Reservoir Modeling:	
Geophys. 182. Reflection Seismology	3
Pet. Engr. 240. Geostatistics for Spatial Phenomena	3-4
Pet. Engr. 241. Practice of Geostatistics	3-4
Total	9-11
Geothermal:	
Chem. Engr. 120B. Energy and Mass Transport	4
Mech. Engr. 250. Introduction to Heat Transfer	3
Pet. Engr. 269. Geothermal Reservoir Engineering	3
Total	10
Reservoir Performance:	
Geophys. 202. Reservoir Geomechanics	3
Pet. Engr. 223. Resevoir Simulation	3-4
Pet. Engr. 280. Oil and Gas Production Engineering	3
Total	9-11
Simulation and Optimization:	
Pet. Engr. 223. Reservoir Simulation	3-4
Pet. Engr. 224. Modeling Flow in Heterogeneous Reservoirs	3
Pet. Engr. 284. Optimization	3
Total	9-10

RESEARCH SEQUENCE

Pet. Engr. 361. Master's Degree Research in Petroleum Engineering*	6
Total units required for M.S. degree	45

* Students selecting the company sponsored "course work only" for the M.S. degree may substitute an additional elective sequence in place of the research.

TECHNICAL ELECTIVES

Technical electives from the following list of advanced-level courses usually complete the M.S. program. In unique cases, when justified and approved by the adviser prior to taking the course, courses listed here may be substituted for courses listed above in the elective sequences.

Geophys. 170. Fluids in the Earth's Crust	3
Geophys. 182. Reflection Seismology	3
Geophys. 190. Environmental and Applied Geophysics	4
Geophys. 202. Reservoir Geomechanics	3
Mech. Engr. 200C. Mathematical & Computational Methods in Engineering	3
Pet. Engr. 130. Well Log Analysis	3
Pet. Engr. 211. Computer Applications for Petroleum Engineers	1
Pet. Engr. 224. Modeling Flow in Heterogeneous Reservoirs	3
Pet. Engr. 230. Advanced Topics in Well Logging	3
Pet. Engr. 260. Environmental Aspects of Petroleum Engineering	3
Pet. Engr. 269. Geothermal Reservoir Engineering	3
Pet. Engr. 273. Special Topics in Petroleum Engineering	1-3
Pet. Engr. 280. Oil & Gas Production Engineering	3
Pet. Engr. 281. Applied Mathematics in Reservoir Engineering	3
Pet. Engr. 284. Optimization	3

ENGINEER

The objective is to broaden training through additional work in engineering and the related sciences and by additional specialization.

Basic requirements include registering for at least six quarters at maximum tuition or the equivalent of partial-tuition quarters; completion of 90 units of course work including 15 units of research (Petroleum Engineering 362), and including all course requirements of the department's master's degree (39 units, excluding research). If the candidate has received credit for research in the M.S. degree, this credit ordinarily would be transferable to the Engineer degree, in which case a total of 9 additional research units would be required. No more than 10 of the 90 required units can be applied to overcoming deficiencies in undergraduate training.

At least 30 units in engineering and closely allied fields must be taken in advanced work, that is, work beyond the master's degree requirements and in addition to research (Petroleum Engineering 362). These may include courses from the Ph.D. degree list below or advanced-level courses from other departments with prior consent of the adviser. All courses must be taken for a letter grade. The student must have a grade point average (GPA) of at least 3.0 in courses taken for the degree of Engineer. A thesis based on 15 units of research must be submitted and approved by the adviser, another faculty member, and the University Committee on Graduate Studies.

DOCTOR OF PHILOSOPHY

The Ph.D. degree is conferred upon demonstration of high achievement in independent research and by presentation of the research results in a written dissertation and oral defense.

Basic requirements include a minimum of nine quarters of registration at maximum tuition or the equivalent in partital-tuition quarters of satisfactorily completed graduate study. Students must take at least 72 units beyond the 45 units required for the master's degree. The 72 units are composed of 36 units of research and 36 units of course work. The student's record must indicate outstanding scholarship. The student must pass the department's qualifying examination, submit an approved research proposal, fulfill the requirements of the minor department if a minor is elected, and pass the University oral examination, which is a defense of the dissertation. The student must prepare a dissertation based on independent research and that makes a significant contribution to the field.

The specification of 36 units of course work is a minimum; in some cases the research adviser may specify additional requirements to strengthen the student's expertise in particular areas. The 36 units of course work does not include teaching experience (Pet. Engr. 359), which is a requirement for the Ph.D. degree, nor any units in research seminars, which students are required to attend. All courses must be taken for a letter grade, with an average grade point average (GPA) of at least 3.25 in the 36 units of course work. The 36 units of course work may include graduate courses in petroleum engineering (numbered 200 and above) and courses selected from the following list. Other courses may be substituted with prior approval by the adviser. In general, non-technical courses are not approved.

MATH AND APPLIED MATH

Course No. and Subject	*Units*
Aero. & Astro. 210A. Fundamentals of Compressible Flow	3
Aero. & Astro. 214A. Numerical Methods in Fluid Mechanics	3
Aero. & Astro. 214B. Numerical Computation of Compressible Flow	3
Chem. Engr. 300. Applied Mathematics in Chemical Engineering	3
Civ. & Envir. Engr. 268. Groundwater Flow	3-4
Comp. Sci. 106X. Programming Methodology and Abstractions	5
Comp. Sci. 137. Introduction to Scientific Computing	3-4
Comp. Sci. 193D. C++ and Object Oriented Programming	4
Comp. Sci. 193U. Software Engineering in C	3
Comp. Sci. 237A,B,C. Advanced Numerical Analysis	3 ea.
Manage. Sci. & Engr. 111. Introduction to Optimization	4
Manage. Sci. & Engr. 211. Linear and Non-Linear Optimization	3
Math. 106. Introduction to Theory of Functions of a Complex Variable	3
Math. 113. Linear Algebra and Matrix Theory	3
Math. 114. Linear Algebra and Matrix Theory	3
Math. 115. Fundamental Concepts of Analysis	3
Math. 131. Partial Differential Equations I	3
Math. 132. Partial Differential Equations II	3
Math. 220A,B,C. Partial Differential Equations of Applied Mathematics	3 ea.
Mech. Engr. 200A,B,C. Mathematical and Computational Methods in Engineering	3 ea.
Mech. Engr. 234A,B,C. Finite Element Methods in Fluid Mechanics	3 ea.
Mech. Engr. 235A,B,C. Finite Element Analysis	3 ea.
Stat. 110. Statistical Methods in Engineering and Physical Sciences	4
Stat. 116. Theory of Probability	4
Stat. 201. Statistical Methods	3
Stat. 202. Data Analysis	3

SCIENCE

Geol. & Envir. Sci. 231. Contaminent Hydrogeology	4
Geol. & Envir. Sci. 253. Petroleum Geology and Exploration	3
Geophys. 182. Reflection Seismology	3
Geophys. 190. Environmental and Applied Geophysics	3-4
Geophys. 262. Rock Physics	3

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Chem. Engr. 110. Equilibrium Thermodynamics	3
Chem. Engr. 120A. Fluid Mechanics	3
Chem. Engr. 120B. Energy and Mass Transport	3
Chem. Engr. 310A. Microscale Transport in Chemical Engineering	3
Chem. Engr. 310B. Connective Transport and Reaction Engineering	3
Engr. 298. Seminar in Fluid Mechanics	1
Mech. Engr. 250. Heat Transfer	4
Mech. Engr. 252C. Convective Heat Transfer	3

Ph.D. students are required to take the doctoral qualifying examination at the beginning of the second year of study. Students receiving a master's degree from the Department of Petroleum Engineering and continuing on for a Ph.D. are required to take the qualifying examination at the first opportunity after the completion of the requirements for the master's degree.

The qualifying examination consists of both a written and an oral section. The written part consists of three or four three-hour examinations on different subjects. The oral part is a three-hour examination in which members of the department faculty question the student. Students are required to apply for candidacy for the Ph.D. degree after passing the department's qualifying examination.

Within a year of passing the qualifying examination, the student must prepare a short written report that contains a literature review and a research proposal. This proposal must be approved after oral examination by a committee made up of the student's adviser and two other faculty, one of whom must be from the department.

The dissertation must be submitted in its final form within five calendar years from the date of admission to candidacy. Candidates who fail to meet this deadline must submit an Application for Extension of Candidacy for approval by the department chair if they wish to continue in the program.

Ph.D. MINOR

To be recommended for a Ph.D. degree with Petroleum Engineering as a minor subject, a student must take 20 units of selected graduate-level lecture courses in the department. These courses must include Pet. Engr. 221 and 222. The remaining courses should be selected from Pet. Engr. 175, 223, 224, 225, 227, 280, 281, and 284.

COURSES

(WIM) indicates that the course meets the Writing in the Major requirements.

(AU) indicates that the course is subject to the University Activity Unit limitations (8 units maximum).

101. Energy and the Environment—(Same as Earth Systems 101.) Where the energy that powers society comes from, acknowledging that most current energy is generated from fossil resources. Case studies consider the consequences of current energy use patterns. Focus is on energy definitions, use patterns, resource estimation, pollution. Recommended: Mathematics 21 or 42, Engingeering 30.

3 units, Spr (Kovscek)

110Q. Stanford Introductory Seminar: Soap Bubbles, Raindrops, and Inkjets—Preference to sophomores. The behavior of bubbles and drops whose shapes are controlled by surface tension. Readings of Newton, Young, Laplace, and Plateau show how thinking about curved surfaces occupied scientists and mathematicians of the 18th and 19th centuries. A mathematical picture of a curved surface permits prediction of the shape of a bubble surface. The properties of curved surfaces determine many phenomena of daily life. Simple experiments and theory explore the physical manifestations of these curved liquid surfaces: the distribution of raindrops on a spider web, why sand grains stick together when damp, the design of a disposable diaper and the stability of a liquid jet in an inkjet printer. Prerequisite: Mathematics 42. GER:2b (DR:6)

3 units (Orr) alternate years, not given 2001-02

120. Fundamentals of Petroleum Engineering—(Same as Engineering 120.) Lectures, problems, field trip. Basic engineering topics in petroleum recovery; origin, discovery, and development of oil and gas. The chemical, physical, and thermodynamic properties of oil and natural gas. Material balance equations and reserve estimates using volumetric calculations. Gas laws. Single phase and multiphase flow through porous media.

3 units, Aut (Horne)

121. Fundamentals of Multiphase Flow—See 221.

3 units, Win (Hewett)

130. Well Log Analysis—For earth scientists and engineers. Interdisciplinary, providing a practical understanding of the interpretation of well logs. Lectures, problems using real field examples: methods for evaluating the presence of hydrocarbons in rock formations penetrated by exploratory and development drilling. The fundamentals of all types of logs, including electric and non-electric logs.

3 units, Aut (Lindblom)

140. Drilling and Completion Technology—The principles applied to the drilling and completion of oil, gas, and geothermal wells for off- and onshore operations. Rig mechanics, drilling fluid technology (drilling hydraulics, clay chemistry, and pressure control), cementing technology, bit mechanics, casing design, and directional drilling.

3 units (Staff) not given 2000-01

155. Undergraduate Report on Energy Industry Training—Provides on-the-job practical training under the guidance of experienced, on-site supervisors geared to undergraduate level students. A concise report detailing work activities, problems, assignments and key results is required. Prerequisite: written consent of instructor.

1 unit, any quarter (Staff)

175. Well Test Analysis—Lectures, problems. Application of solutions of unsteady flow in porous media to transient pressure analysis of oil, gas, water, and geothermal wells. Pressure buildup analysis and drawdown. Design of well tests. Computer-aided interpretation. Prerequiste: 120 or equivalent.
3 units, Spr (Horne)

178. Solar Energy Thermal Processes—(Same as Earth Systems 178.) The nature and availability of solar radiation. Radiation and convection heat transfer, radiation characteristics of opaque materials, absorptance, emittance, and reflectance. Radiation transmission through glazing. The design and performance of flat-plate solar collectors and concentrating collectors. Energy storage. Systems design for solar space and water heating. Industrial process heat.
3 units, Aut (Hewett)

180. Oil and Gas Production Engineering—See 280. (WIM)
3 units, Aut (Kovscek, Aziz)

192. Undergraduate Teaching Experience—Leading field trips, preparing lecture notes, quizzes under supervision of the instructor.
1-3 units, any quarter (Staff)

193. Undergraduate Research Problems—Original and guided research problems with comprehensive report.
1-3 units, any quarter (Staff)

194. Special Topics in Energy and Mineral Fluids—Lectures, problems.
1-3 units, any quarter (Staff)

202. Reservoir Geomechanics—(Enroll in Geophysics 202.)
3 units, Win (Zoback)

211. Computer Applications for Petroleum Engineers—Lectures, seminars, and class projects. Provides "seed" knowledge of the software and hardware available to petroleum engineering students, effective use of computer resources, and some software tools. X-Windows, use of graphics, interlanguage communication, and user interfaces.
1 unit (Horne) not given 2000-01

221. Fundamentals of Multiphase Flow—(Same as 121.) Lectures, problems. Multiphase flow in porous media. Wettability, capillary pressure, imbibition and drainage, Leverett J-function, transition zone, vertical equilibrium. Relative permeabilities, Darcy's law for multiphase flow, fractional flow equation, effects of gravity, Buckley-Leverett theory, recovery predictions, volumetric linear scaling, JBN and Jones-Rozelle determination of relative permeability. Frontal advance equation, Buckley-Leverett equation as frontal advance solution, tracers in multiphase flow, adsorption, three phase relative permeabilities.
3 units, Win (Hewett)

222. Advanced Reservoir Engineering—Lectures, problems. Single-phase flow equations, tensor permeabilities, steady state and succession of steady state solutions. Radial flow and skin. Injectivity during fill-up of a depleted reservoir, injectivity for liquid-filled reservoirs, pattern elements. Flow potential and gravity forces, coning. Two-phase flow equations. Displacements in layered reservoirs, streamlines. Transient flow equation, primary drainage of a cylindrical reservoir, line source solution, pseudosteady state, pressure drawdown tests. Prerequisite: 221.
3 units, Spr (Durlofsky)

223. Reservoir Simulation—Lectures, problems, and class project provide a thorough understanding of the fundamentals of petroleum reservoir simulation. Development of equations for multicomponent, multiphase flow between gridblocks comprising a petroleum reservoir. Relationships between black-oil and compositional models. Various techniques for developing black-oil, compositional, thermal, and dual-porosity models. Practical considerations in the use of simulators for predicting reservoir performance. Prerequisite: 221 and 246, or consent of instructor. Recommended: Mechanical Engineering 200C.
3-4 units, Win (Durlofsky, Aziz, Edwards)

224. Modeling Flow in Heterogeneous Reservoirs—Lectures, problems. Overview of characterization of reservoir heterogeneity, univariate statistics, spatial continuity measures, stochastic simulation. Dispersion in heterogeneous porous media, scale effects, fingering vs. channeling, heuristic fractional flow models. The influence of lamina scale heterogeneities, capillary cross-flow, rate dependent recoveries. Effective flow properties for coarse grid simulation, permeability averaging, permeability tensors, pseudofunctions for multiphase flow. Approximate streamtube methods for calculating flow in heterogeneous media. Flexible gridding. Prerequisites: 223, and 240 or 246.
3 units, Spr (Hewett) alternate years, not given 2001-02

225. Theory of Gas Injection Processes—Lectures, problems. Theory of multicomponent, multiphase flow in porous media. Miscible displacement: diffusion and dispersion, convection-dispersion equation and its solutions. Method of characteristic calculations of chromatographic transport of multi-component mixtures. Development of miscibility and interaction of phase behavior with heterogeneity. Prerequisite: Mechanical Engineering 200A.
3 units (Orr) alternate years, given 2001-02

226. Thermal Recovery Methods—Lectures, problems. Theory and practice of thermal recovery methods: steam drive, cyclic steam injections, and in-situ combustion. Models of combined mass and energy transport. Estimates of heated reservoir volume and oil recovery performance. Wellbore heat losses, recovery production, and field examples.
3 units, Spr (Castanier) alternate years, not given 2001-02

227. Enhanced Oil Recovery—Lectures, problems. Introduction to the physics, theories, and methods of evaluating chemical, miscible, and thermal enhanced oil recovery projects. Existing methods and screening techniques, and analytical and simulation based means of evaluating project effectiveness. Dispersion-convection-adsorption equations, coupled heat, and mass balances and phase behavior provide requisite building blocks for evaluation.
3 units (Kovscek) alternate years, given 2001-02

230. Advanced Topics in Well Logging—(Same as Geophysics 230.) Designed to follow a course in standard well logging, and assumes knowledge of standard practice and application of electric well logs. Guest lectures on state-of-the-art tools and analyses; and the technology, rock physical basis, and applications of each measurement. Hands-on computer-based analyses illustrate instructional material. Prerequisite: 130 or equivalent.
3 units, Spr (Lindblom)

240. Geostatistics for Spatial Phenomena—(Same as Geological and Environmental Sciences 240.) Probabilistic modeling of spatial and/or time dependent phenomena. Kriging and cokriging for gridding and spatial interpolation. Integration of heterogeneous sources of information. Stochastic imaging of reservoir/field heterogeneities. Introduction to GSLIB software. Case studies from the oil and mining industry and environmental sciences. Prerequisites: introductory calculus and linear algebra, Statistics 116 or equivalent.
3-4 units, Win (Caers)

241. Practice of Geostatistics and Seismic Data Integration—(Same as Geological and Environmental Sciences 241, Geophysics 241.) Students build a synthetic 3D fluvial channel reservoir model with layer depths, channel geometry, and facies-specific petrophysic and seismic properties, stressing the physical significance of geophysical data. Reference data set is sparsely sampled, providing the sample data typically available for an actual reservoir assessment. Geostatistical reservoir modeling uses well and seismic data, with results checked against

reference database. All software provided (Gslib and SRBtools). Recommended; basic prior experience with Unix, Matlab/Fortran programming. Prerequisites: 240.
3-4 units, Spr (Caers, Mukerji)

242. Topics in Advanced Geostatistics—(Same as Geological and Environmental Sciences 242A.) Conditional expectation theory and projections in Hilbert spaces; parametric vs. non-parametric geostatistics; Boolean, Gaussian, fractal, indicator, annealing approaches to stochastic imaging; multiple point statistics inference and reproduction; neural net geostatistics; Bayesian methods for data integration; techniques for upscaling hydrodynamic properties. May be repeated for credit. Prerequisites: 240, advanced calculus, Fortran/Unix.
3 units, Aut (Journel) alternate years, not given 2001-02

246. Reservoir Characterization and Flow Modeling with Outcrop Data—(Same as Geological and Environmental Sciences 246.) Project provides earth science students with an understanding of how to use outcrop observations in quantitative geological modeling and flow simulation, and addresses a specific reservoir management problem by studying a suitable outcrop analog (weekend field trip), constructing geostatistical reservoir models, and performing flow simulation. An introduction, through an applied example, to the relationship between the different disciplines. A different reservoir management question and outcrop analog is studied each year.
3 units, Aut (Aziz, Graham, Journel)

251. Thermodynamics of Equilibria—Lectures, problems. The volumetric behavior of fluids at high pressure. Equation of state representation of volumetric behavior. Thermodynamic functions and conditions of equilibrium, Gibbs and Helmholtz energy, chemical potential, fugacity. Phase diagrams for binary and multicomponent systems. Calculation of phase compositions from volumetric behavior for multicomponent mixtures. Experimental techniques for phase equilibrium measurements.
3 units, Aut (Kovscek)

255. Master's Students' Report on Energy Industry Training—Provides on-the-job training for master's degree students under the guidance of experienced, on-site supervisors. Students must submit a concise report detailing work activities, problems, assignments, and key results. Prerequisite: consent of adviser.
1 unit, Sum (Staff)

260. Groundwater Pollution and Oil Spills: Environmental Problems in the Petroleum Industry—Sources and types of wastes in petroleum operations. Partitioning of hydrocarbons in soil. Review of single phase flow. Multiphase flow of oil, water, and air. Movement of hydrocarbons in the vadose zone and in the groundwater. Remediation and cleanup techniques: air stripping and sparging, bioremediation, steam flooding, and solvent and surfactant injection. Drilling wastes. The physical processes affecting the spread of oil slicks at sea. Methods for containing and removing the spill and cleaning of polluted beaches.
3 units (Staff) not given 2000-01

268. Seminar in Petroleum Engineering
1 unit, any quarter (Staff)

269. Geothermal Reservoir Engineering—Conceptual models of heat and mass flows within geothermal reservoirs. The fundamentals of fluid/heat flow in porous media; convective/conductive regimes, dispersion of solutes, reactions in porous media, stability of fluid interfaces, liquid and vapor flows. Interpretation of geochemical, geological, and well data to determine reservoir properties/characteristics. Geothermal plants and the integrated geothermal system.
3 units, Spr (Horne) alternate years, not given 2001-02

273. Special Topics in Petroleum Engineering—Lectures, problems.
1-3 units, any quarter (Staff)

280. Oil and Gas Production Engineering—(Same as 180.) Design and analysis of production systems for oil and gas reservoirs. Topics: well completion, single-phase and multi-phase flow in wells and gathering systems, artificial lift and field processing, well stimulation, inflow performance. Prerequisite: 120. Recommended: 130. (WIM)
3 units, Aut (Kovscek, Aziz)

281. Applied Mathematics in Reservoir Engineering—Lectures, problems. The philosophy of the solution of engineering problems. Methods of solution of partial differential equations: Laplace transforms, Fourier transforms, wavelet transforms, Green's functions, and boundary element methods. Prerequisites: Mechanical Engineering 200B or Mathematics 131, and consent of instructor.
3 units (Horne) alternate years, given 2001-02

284. Optimization: Deterministic and Stochastic Approaches—Deterministic and stochastic methods for optimization in earth sciences and engineering. Linear and nonlinear regression, classification and pattern recognition using neural networks, simulated annealing and genetic algorithms. Deterministic optimization using non-gradient-based methods (simplex) and gradient-based methods (conjugated gradient, steepest descent, Levenberg-Marquardt, Gauss-Newton), eigenvalue and singluar value decomposition. Applications in petroleum engineering, geostatistics, and geophysics. Prerequisite: Mechanical Engineering 200A or consent of instructor. Recommended: introduction to probability theory.
3 units, Aut (Caers)

285A,B,C,D,E,F,G. Research Seminars—Focused study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Prerequisite: consent of instructor.

285A. Research Seminar: Enhanced Oil Recovery—Current research in the SUPRI-A group. Thermal and enhanced oil recovery. (AU)
1 unit, Aut, Win, Spr (Kovscek, Castanier, Brigham)

285B. Reservoir Simulation—Current research in SUPRI-B (Reservoir Simulation) program. (AU)
1 unit, Aut, Win, Spr (Aziz, Durlofsky, Edwards)

285C. Research Seminar: Gas Injection Processes—Current research in the SUPRI-C group. (AU)
1 unit, Aut, Win, Spr (Orr)

285D. Research Seminar: Well-Test Analysis—Current research in the SUPRI-D well test analysis group. (AU)
1 unit, Aut, Win, Spr (Horne)

285F. Research Seminar: Geostatistics—Current research in the SCRF (Stanford Center for Reservoir Forecasting) program. (AU)
1 unit, Aut, Win, Spr (Journel, Hewett, Caers)

285G. Research Seminar: Geothermal Reservoir Engineering—Current research in the geothermal energy group. (AU)
1 unit, Aut, Win, Spr (Horne)

285H. Research Seminar: Horizontal Well Technology—Current research in SUPRI-HW (productivity and injectivity of horizontal wells) program. (AU)
1 unit, Aut, Win, Spr (Aziz, Durlofsky)

355. Doctoral Report on Energy Industry Training—Provides on-the-job training for doctoral students under the guidance of experienced, on-site supervisors. Students must submit a concise report detailing work activities, problems, assignments, and key results. Prerequisite: consent of adviser.
1 unit, Sum (Staff)

359. Teaching Experience in Petroleum Engineering—On-the-job training in teaching petroleum engineering. Student prepares and presents several lectures, problem sets, grades problems, and prepares lab experiments under the supervision of regular instructor. Performance is

evaluated by students and the regular instructor.
1-3 units, any quarter (Staff)

360. Advanced Work in Petroleum Engineering—Graduate-level work in experimental, computational, or theoretical research.
1-9 units, any quarter (Staff)

361. Master's Report Research in Petroleum Engineering—Graduate-level work in experimental, computational, or theoretical research. Advanced technical report writing. Limited to 6 units total.
1-6 units, any quarter (Staff)

362. Engineer's Thesis Research in Petroleum Engineering—Graduate-level work in experimental, computational, or theoretical research. Advanced technical report writing. Limited to 15 units total, or 9 units total if 6 units of 361 were previously credited.
1-9 units, any quarter (Staff)

363. Doctoral Dissertation Research in Petroleum Engineering—Graduate-level work in experimental, computational, or theoretical research. Advanced technical report writing.
1-9 units, any quarter (Staff)

365. Special Research in Petroleum Engineering—Graduate-level research work not related to report, thesis, or dissertation.
1-15 units, any quarter (Staff)