College of Engineering and Applied Science

Robert Ettema, Dean
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Web site: wwweng.uwyo.edu

Engineering is a profession that truly makes a difference. Engineers constantly discover how to improve lives by creating new solutions to real world problems and needs. From small villages to large cities, engineers are involved in innovative improvements to all aspects of life from health care, to energy production, to protecting and rehabilitating the environment, to developing the newest technological device. The broad background of communication, mathematical, scientific, and problem solving skills provided at the University of Wyoming will prepare engineering graduates to pursue careers in engineering, construction, environmental policy, even medicine or law. The possibilities are endless! The creativity and innovative thinking developed in engineering enables students to lead rewarding lives, work with inspiring people, and give back to their communities.

Computer science is a profession that is closely affiliated with engineering. At the University of Wyoming, degrees in computer science are awarded through the College of Engineering and Applied Science. The technology trends in this industry are also advancing at a tremendous rate. This requires that computer science education be at the forefront of new computing technologies, software languages, and networking.

Mission

The University of Wyoming's College of Engineering and Applied Science will provide excellent education, research, and service in chosen fields of engineering and applied science. The College emphasizes connectivity with society, life-long learning, and the essential problem-solving and collaborative skills needed to address the frontier challenges facing Wyoming, the nation and the world.

Design Experiences

In direct support of the goals of the individual departments within the College of Engineering and Applied Science, the design process is consistently developed and integrated throughout the curriculum from the freshman year through the senior year. Within the engineering science program, design elements such as basic analysis skills, communication skills, experimental skills, computational skills, problem solving skills, and design methodology are taught. At the departmental level, these skills are developed further and the concepts of design methodology are reinforced. The design process culminates in a comprehensive design experience within the student's major.

Accreditation

The following undergraduate programs are accredited by the Engineering Accreditation Commission of ABET: architectural engineering, chemical engineering, civil engineering, computer engineering, electrical engineering, energy systems engineering, mechanical engineering, and petroleum engineering.

Various options within different engineering programs are accredited as part of the primary major. That is, the electrical engineering/bioengineering option is accredited as an electrical engineering degree, and the chemical engineering/petroleum option is accredited as a chemical engineering degree.

The Bachelor of Science in Computer Science is accredited by the Computer Accreditation Commission of ABET.

Programs of Study

Undergraduate Degrees

Bachelor of Science in Architectural Engineering
Bachelor of Science in Chemical Engineering
Bachelor of Science in Chemical Engineering (petroleum engineering option)
Bachelor of Science in Civil Engineering
Bachelor of Science in Computer Engineering
Bachelor of Science in Computer Science
Bachelor of Science in Computer Science (business option)
Bachelor of Science in Electrical Engineering
Bachelor of Science in Electrical Engineering (Francis M. Long bioengineering option)
Bachelor of Science in Energy Systems Engineering
Bachelor of Science in Mechanical Engineering
Bachelor of Science in Petroleum Engineering

Graduate Degrees

Master of Science
- Atmospheric science
- Chemical engineering
- Civil engineering
- Civil engineering/water resources
- Computer science
- Computer science professional
- Electrical engineering
- Environmental engineering
- Mechanical engineering
- Petroleum engineering

Doctor of Philosophy
- Atmospheric science
- Chemical engineering
- Civil engineering
- Computer science
- Electrical engineering
- Mechanical engineering
- Petroleum engineering

Candidates for the various master's degrees in engineering are required to do a full year's work in residence either under Plan A or Plan B.

Students should understand that a strong background in mathematics is necessary to actively pursue an engineering curriculum. Credit toward an engineering degree is not allowed for algebra and trigonometry.

Coursework in all four-year curricula stresses the mastery of subjects fundamental to all fields of engineering. The balance of the program is divided between cultural context and courses applying to the particular field selected. The aim is to provide the student with such groundwork that the general principles acquired may be used successfully in any one of the several specialized fields he or she may follow after graduation.

Depending on the major, a minimum of 125 to 132 semester hours of credit is required for the bachelor's degree from the College of Engineering and Applied Science. All course work must be selected with prior approval. Detailed outlines of curricula are presented later under headings of the various departments of the college. Since most engineering programs are similar during the first year, students may change an engineering major during this time with little or no loss in credit.

The electives in cultural context must be selected such that the student meets all university studies requirements not covered by specific courses in the detailed curriculum outlines.

Degree candidates must meet the academic requirements of the university and must have a grade point average of 2.0 (C) or above in all engineering courses attempted at this university.

Students may not take a course for S/U credit to satisfy any requirement for a degree from the College of Engineering and Applied Science, unless the course is offered for S/U credit only.

All undergraduate engineering programs within the College of Engineering and Applied Science use the Fundamentals of Engineering Exam as one of their methods of outcomes assessment. As a graduation requirement, students must complete the exam, with a good faith effort, within one year prior to their expected graduation.

Preparation for the profession of engineering requires diligent work in the various curricula. The required credit hours can be completed in a four-year program, but because of the rigorous nature of some of the courses involved, some students may require additional time to complete degree requirements.

All engineering curricula are subject to minor program changes. The published curricula are general guides. Prospective students should consult the individual departments for current information.

Graduate Study

The College of Engineering and Applied Science offers coursework and research opportunities leading to the following master's degrees: master of science in atmospheric science, chemical engineering, civil engineering, computer science, electrical engineering, environmental engineering, mechanical engineering, and petroleum engineering. Candidates for the various master's degrees in engineering are required to do a full year's study in residence either under Plan A or Plan B.

Only graduates with satisfactory GPAs in programs accredited by ABET are granted full admission to graduate study. In addition, graduates with satisfactory GPAs in undergraduate disciplines of meteorology, physics, mathematics, or related fields can be granted full admission to graduate studies in atmospheric science. Other engineering graduates can be admitted on a provisional basis.

The College of Engineering and Applied Science offers coursework and research opportunities leading to the following doctoral degrees: doctorate in atmospheric science, chemical engineering, civil engineering, computer science, electrical engineering, mechanical engineering, and petroleum engineering. Interdisciplinary programs of study and research leading to one of the above disciplinary degrees can be developed.

Engineering Science

Program Director: Steven F. Barrett, Ph.D., P.E.
2076 Engineering Building, 766-6181
FAX: (307) 766-4444

Engineering Science offerings present the fundamental engineering concepts upon which most engineering analysis and design work is based. Faculty are drawn from all of the academic departments in the college. These core courses represent the majority of engineering offerings at the freshman and sophomore level.

Courses in engineering science have their roots in mathematics and physical science, extending knowledge toward creative application. Thus, students must take their courses in calculus, chemistry, physics, and engineering science in a timely manner. Details are given in the published curriculum for each program. **A grade of C or better must be earned in all courses that are prerequisite to any required engineering science course.**

Engineering Science (ES)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

1000. Orientation to Engineering Study. 1. [F1◆▶I, L] Skills and professional development related to engineering. Involves problem solving, critical thinking and ethics, as well as activities to help transition to university environment. Required of all freshmen entering engineering curricula. Students with credit in UNST 1000 may not receive credit for this course. (Normally offered both semesters)

1002. Introduction to Engineering Information Literacy. 0.5. [(none)◆▶L] Offers transfer students the opportunity to satisfy the College of Engineering and Applied Science requirements for the Information Literacy and the initial O component of the University Studies Program. *Prerequisites:* none.

1060. Introduction to Engineering Problem Solving. 3. An overview of the methodology and tools used in the engineering profession for analyzing problems. Example problems are solved using spreadsheet tools and structured programming language. Laboratory. *Prerequisite:* MATH 2200 or concurrent enrollment.

1061. Engineering Problem Solving with Spreadsheets. 1. An introduction to engineering problem solving through the use of computer spreadsheets. Topics include functions, referencing, conditional statements, graphs, trendlines, and iterative solvers. *Prerequisite:* MATH 1400 or MATH 1450 or ACT Math Score of 25 or Math Placement Exam score of 4.

1062. Introduction to Structured Programming. 1. Introduction to structured programming through the use of computer applications. Topics include built-in functions, user functions, logical operators, flowcharts, pseudo code, selection structures, repetition structures, and plotting. *Prerequisite:* ES 1061.

1063. Graphical Communication and Solid Modeling. 1. An introduction to solid models and graphical communication. Topics include geometric relationships, solid parts, solid assemblies, constraints, orthogonal projection, multiview represation, dimensioning, and drawing annotation. *Prerequisite:* MATH 1400 or MATH 1450 or ACT Math Score of 25 or Math Placement Exam score of 4.

2110. Statics. 3. [M3◆▶(none)] Vector statics of particles and rigid bodies, including equilibrium in two and three dimensions, center of gravity, centroids, distributed loads, truss analysis, simple structures and machines, friction, and internal actions. *Prerequisites:* MATH 2205 or concurrent enrollment. (Offered fall, spring and summer)

2120. Dynamics. 3. Vector dynamics of particles and rigid bodies, including impulse-momentum and work-energy. *Prerequisites:* ES 2110 and MATH 2205; PHYS 1210 or concurrent enrollment. (Offered fall, spring and summer)

2210. Electric Circuit Analysis. 3. Basic concepts of electric circuit theory, dependent sources, network theorems, first and second order circuits, phasors, three-phase circuits. Laboratory. *Prerequisite:* MATH 2205. (Offered fall, spring and summer)

2215. Electric Circuit Analysis Lecture. 2. Basic concepts of electric circuit theory, dependent sources, network theorems, first and second order circuits, phasers, three-phase circuits. No laboratory. Available for Outreach students only. *Prerequisite:* MATH 2205.

2216. Electric Circuit Analysis Laboratory. 1. Laboratory activities focusing on basic concepts of electric circuit theory, dependent sources, network theorems, first and second order circuits, phasers, three-phase circuits. *Prerequisite:* ES 2215.

2310. Thermodynamics I. 3. Macroscopic systems involving energy and its various forms. Fundamental concepts including energy, mass

and entropy balances. Pure substances and availability. Reversible and irreversible processes. *Prerequisites:* (ES 2120 or PHYS 1210), MATH 2210. (Offered fall and spring)

2330. Fluid Dynamics. 3. Incompressible flow of ideal and real fluids. Potential and stream functions; similitude and dimensional analysis. *Prerequisite:* (ES 2120 or PHYS 1210), MATH 2210. (Offered fall, spring and summer)

2410. Mechanics of Materials. 3. Mechanics of deformable bodies, including energy methods. *Prerequisite:* ES 2110 and MATH 2205. (Offered fall and spring)

4910. Survey of Engineering Management. 3. Offers a survey of a variety of topics related to engineering management. The objective is to introduce students to some of the non-technical aspects of engineering practice and management. *Prerequisite:* junior standing in an engineering degree program.

4965. EPSCoR Research. 1. Seminar for undergraduates selected for EPSCoR research. Topics include graduate school, entrepreneurship, presentations. *Prerequisite:* selection for EPSCoR research.

4970. Engineering CO-OP. 1 (Max. 6). Provides a mechanism for students on engineering co-op to maintain continuous registration and have the co-op experience reflected on their transcript. Credit earned will not normally count toward graduation credit. Offered S/U only. *Prerequisite:* must be involved in an engineering co-op experience.

Department of Atmospheric Science

6034 Engineering Building, 766-3245
FAX: (307)766-2635
Web site: www.atmos.uwyo.edu
Department Head: Alfred R. Rodi

Professors:

TERRY DESHLER, B.A. University of Wyoming 1969; M.S. 1975; Ph.D. 1982; Professor of Atmospheric Science 1999, 1991.

BART GEERTS, Licenciaat Physical Geography Katholieke University, Belgium 1984; Engineer in Irrigation Sciences 1986; Ph.D. University of Washington 1992; Professor of Atmospheric Science 2011, 1999.

ROBERT D. KELLY, B.A. University of Wyoming 1973; M.S. 1978; Ph.D. University of Chicago 1982; Professor of Atmospheric Science 1990, 1984.

THOMAS R. PARISH, B.S. University of Wisconsin 1975; M.S. 1977; Ph.D. 1980; Professor of Atmospheric Science 1990, 1980.

ALFRED R. RODI, B.S. University of Chicago 1967; M.S. 1969; Ph.D. University of Wyoming 1981; Professor of Atmospheric Science 1993, 1981.

JEFFERSON R. SNIDER, B.S. University of Oregon 1979; M.S. University of Arizona 1982; Ph.D. University of Wyoming 1989; Professor of Atmospheric Science 2004, 1990.

Associate Professors:

DEREK C. MONTAGUE, B.Sc. University of Southampton (UK) 1964; Ph.D. 1967; Associate Professor of Atmospheric Science 1988.

ZHIEN WANG, B.S. Anhui Normal University (China) 1990; M.S. Chinese Academy of Sciences 1994; Ph.D. University of Utah 2000; Associate Professor of Atmospheric Science 2009, 2004.

Assistant Professors:

SHANE MURPHY, B.S. University of Colorado 2000; Ph.D. California Institute of Technology 2009; Assistant Professor of Atmospheric Science 2011.

Professors Emeritus:

John D. Marwitz, Gabor Vali

Atmospheric Science is a rapidly developing discipline in which meteorology, physics, chemistry, biology, engineering, mathematics and computer science are all being applied in an effort to better understand the earth's atmosphere. The entire development of atmospheric science demonstrates how progress can result from the application of knowledge developed in the basic sciences to a complex environmental system. Concurrently, atmospheric scientists develop many observational and analytical techniques unique to the study of the atmosphere. Over the past decades, atmospheric science developed vigorously, stimulated by the availability of the latest satellite, ground-based and aircraft observations, as well as the availability of large computers for numerical simulations of atmospheric processes. At the same time, the importance of the atmosphere as a crucial resource in the welfare and survival of humankind is being recognized, as knowledge about how the atmosphere behaves is obtained.

The Department of Atmospheric Science offers graduate programs leading to the M.S. and Ph.D. degrees.

In these graduate programs, great emphasis is placed on the active research involvement of students both during the academic year and during the summer months. The low student to faculty ratio in the department ensures an atmosphere of vital cooperation among students, faculty and staff. Student theses form integral parts of the department's research productivity and almost always lead to publishable results.

Research interests in the department center around cloud and precipitation physics, cloud and mesoscale atmospheric dynamics, boundary layer processes, tropospheric and stratospheric aerosols and chemistry, ozone depletion, wind energy, global change, instrumentation and air quality. These interests are also reflected in the department's academic program, which has the breadth and depth necessary to give students a background for entering into many different types of employment upon graduation.

A number of unique research tools are available in the department. Prominent among these is the King Air research aircraft which carries extensive instrumentation and computer-directed data acquisition systems. The department maintains a well-equipped observatory at the peak of 11,000 foot Elk Mountain. The tropospheric and stratospheric balloon launch facility is used to sample aerosols, volcanic plumes, clouds and ozone in Laramie, and in both the north and south polar regions. Excellent laboratory facilities are available in the department's spacious quarters. These laboratories focus on aerosol and nucleation research, on atmospheric optics, remote sensing, and atmospheric chemistry. Well-equipped electronic and mechanical construction and design facilities are conducive for work in instrumentation development. A wide range of computer facilities are available, providing excellent support both in hardware and software for research activities and for learning.

A prerequisite for admission to the graduate program is a bachelor's degree in meteorology, engineering, physics, chemistry, mathematics or a similar relevant discipline. Graduate assistantships are available by application to the department and are awarded on the basis of past record and promise for achievement.

For material containing further details on curriculum and research programs, write to the graduate admissions coordinator or visit the web site at www.uwyo.edu/atsc/.

Graduate Study

The Department of Atmospheric Science offers degree programs leading to the master of science (Plan A only) and doctor of philosophy degrees.

The department has strong research programs in the following areas: cloud physics and dynamics; tropospheric aerosols and clouds; stratospheric aerosol and ozone; boundary layer processes; remote sensing; and airborne- and balloon-borne instrumentation. The department's observational facilities are: 1) the King Air research aircraft (UWKA); 2) the Wyoming Balloon Launch Facility; 3) the Elk Mountain Observatory at 11,000 ft altitude; 4) the Wyoming Cloud Radar (WCR) and Wyoming Cloud Lidar (WCL) for the study of cloud structure and composition; and 5) the Keck Aerosol Laboratory. The UWKA, WCR, and WCL are designated Lower Atmospheric Observing Facilities by the National Science Foundation (NSF).

Please refer to the departmental homepage at www.atmos.uwyo.edu for programmatic updates, or contact the department directly.

Program Specific Admission Requirements

Admission based on the university minimum requirements. Admissions are competitive.

Program Specific Graduate Assistantships

Assistantships are offered for both the M.S. and Ph.D. tracks.

Program Specific Degree Requirements

Master's Program

Approval of research plan by the graduate committee (at the end of year one)
Colloquium and oral defense of M.S. thesis
Approval of M.S. thesis by the graduate committee
Requires a minimum of 26 hours of acceptable graduate coursework and four hours of thesis research and a thesis (final written project).
21 in-residence coursework hours

Doctoral Program

Qualifying assessment exam
Approval of research plan by the graduate committee
At least one colloquium presentation per year
Preliminary exam (at least 15 weeks before dissertation defense)
Oral defense of Ph.D. dissertation
Approval of Ph.D. dissertation by the graduate committee
Ph.D. requires a minimum of 72 graduate hours, but at least 42 hours must be earned in formal coursework.
42 hours of formal graduate coursework including appropriate coursework from a master's degree.
Additional credits toward the 72 credit hour requirement may include dissertation research hours, internship hours, or additional coursework.
24 in-residence coursework hours

Required Courses

These courses are required for both master's and doctoral programs.

ATSC 5880: Ethics and Research Methods. 1.
ATSC 5001. Atmospheric Energetics. 2.
ATSC 5002. Atmospheric Radiation. 3.
ATSC 5003. Problems in Energetics and Radiation. 1.
ATSC 5100. Atmospheric Dynamics I. 3.
ATSC 5004. Problems in Dynamic Meteorology. 1.
ATSC 5005. Microphysics. 2.
ATSC 5006. Problems in Microphysics. 1.
ATSC 5160. Synoptic Meteorology. 2.
ATSC 5007. Problems in Synoptic Meteorology. 1.
ATSC 5008. Mesoscale Meteorology. 2.
ATSC 5020. Physical Meteorology Lab. 1.
ATSC 5210. Cloud and Precipitation Systems. 3.
UW Elective(s) to be determined by committee. 3 minimum
ATSC Elective(s). To be determined by committee. 3 minimum

Atmospheric Science (ATSC)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

2000. Introduction to Meteorology. 4. [S3◆▶SE] First course in meteorology for students with minimal background in math and science. Provides general and practical understanding of weather phenomena. Emphasizes observational aspects of the science, meteorological view of the physical world and the impact the science has on life and society. Includes three hours of lecture and one laboratory per week. Includes atmospheric composition and structure, radiation, winds and horizontal forces, stability and vertical motions, general circulation, synoptic meteorology, clouds and precipitation, severe storms and atmospheric optics.

2100. Atmospheric Change: Composition and Climate. 3. Introduces non-specialists to a broad overview of global, regional and local atmospheric impacts of mankind's activities and natural phenomena, and their consequences. Includes global warming and potential for climate change, atmospheric ozone depletion, acid rain, urban air pollution and problem alleviating mitigating strategies.

3032. Weather Analysis and Forecasting. 3. Students learn to access, display, and interpret meteorological data including surface, upper air, satellite, and radar data, and become familiar with NWP models and weather predictability. They gain a basic understanding of dynamic and physical meteorology through real-time applications, and are introduced to meteorological data display software applications. *Prerequisites:* MATH 2205 and PHYS 1310 or equivalent.

4001. Modeling the Earth System. 4. Takes a modeling approach to demonstrate how the Earth is integrated into an interconnected system through exchanges of energy and matter, and how Earth system functioning is susceptible to human alteration. Unifying concepts focus on quantitative interactions between the Earth and the Sun, and between the Earth's lithosphere, hydrosphere, biosphere and atmosphere. Cross listed with BOT/ESS/GEOL. *Prerequisites:* MATH 2205 or equivalent and [ESS 2000 or GEOL 2000].

4007. Problems in Synoptic Meteorology. 1. Laboratory supplement to ATSC 5160. Analysis of weather systems using operational observations and numerical model output. Real-time weather briefings. Numerical simulation of select weather phenomena. Dual listed with ATSC 5007. *Prerequisites:* ATSC 4130, 5130; 4160, 5160 or concurrent enrollment and permission of instructor.

4008. Mesoscale Meteorology. 2. Fundamental dynamics of mesoscale motions including departures from hystrostatic balance. Mesoscale energy sources. Boundary layer circulations. Convective initiation. Structure and dyanmics of deep convection and mesoscale organized convection. Atmoospheric waves. Orograpically modified flow. Dual listed with ATSC 5008. *Prerequisites:* ATSC 4160, 4007, 5160, 5007 and permission of the instructor.

4031. Atmospheric Dynamics. 3. Atmospheric statics, development and interpretation of Newton's Second Law of Motion as applied to the atmosphere, scales of motion, atmospheric motion types, thermal wind equation, circulation and vorticity, boundary layer motions, introduction to quasi-geostrophic theory. *Prerequisites:* MATH 2210, PHYS 1320, ATSC 4010.

4033. Atmospheric Remote Sensing. 3. Satellite ground-based remote sensing from UV to microwave including the principles of atmospheric radiative transfer, descriptions

of important satellite orbits and sensors, the retrieval of atmospheric forecast and air quality monitor. *Prerequisites:* MATH 2210 or 2310, and PHYS 1310 & 1320 or equivalent.

4035. Atmospheric Processes II. 3. Starts with physical-meteorology concepts necessary for a first-time examination of cloud microphysics – aerosol physical properties, Mie and Rayleigh radiative transfer, moisture variables, conserved temperatures, saturation vapor pressure – finishes with water and ice nucleation, diffusional and collection hydrometeor growth, and radiative forcing by clouds. *Prerequisites:* ATSC 4010 and ATSC 4031.

4160. Synoptic Meteorology. 2. Structure and evolution of the extratropic cyclone, identification and development of fronts, jet streams and associated weather features; theories of cyclogenesis; role of topography. Climatology of formation and movement of a cyclone. Mesoscale circulation features; ingredients of severe weather. Dual listed with ATSC 5160. *Prerequisites:* ATSC 4031, 5001, 5003, 5100, 5004 5031 and permission of instructor.

4320. The Ocean Environment. 3. Focuses on the ocean as a system. Objective is the development of interdisciplinary understanding of marine processes, especially those processes occurring along coastal margins. Emphasis is on the development of quantitative models and their use in understanding anthropogenic impact on ocean resources. Dual listed with ATSC 5320. *Prerequisites:* MATH 2310, PHYS 1310, CHEM 1030, ES 3060 (or ES 3070), LIFE 1010, senior standing or higher.

4400. The Physical Basis of Climate. 3. Global atmospheric and oceanic circulations, radiation balance, water balance and hydrologic cycle, energy balance, energy and moisture transport, evaporation and evapotranspiration, energetic processes, and theories of climate change. Dual listed with ATSC 5400. *Prerequisites:* MATH 2200, PHYS 1310, and CHEM 1020.

4410 [4330]. Introduction to Micrometeorology. 3. Quantitative and descriptive study of processes effecting exchanges of energy, momentum, gases, and particles between the atmosphere and the bio/geosphere, including the effects of plant cover, land use changes, diurnal and seasonal cycles, turbulence, boundary layer structure, local weather, and climate. Instrumentation and techniques also discussed. *Prerequisites:* ATSC 4010 and LIFE 2023.

4650. Undergraduate Research in Atmospheric Science. 2-6 (max 9). Course Description and *Prerequisites:* Independent research in atmospheric science under supervision of an atmospheric science faculty member. Projects are possible in the fields of cloud and aerosol physics, radar meteorology, mesoscale dynamics, and stratospheric chemistry. Participation in field work, involving the UW aviation or stratospheric ballooning facilities, is a possibility. Research results are summarized in a report. *Prerequisites:* ATSC 4000 and 4100, plus consent from advsing faculty.

4900. Problems in Atmospheric Science. 1-3 (Max. 10). Independent study of a particular problem or phrase of atmospheric science, or presentation of reviews and discussion of current advances in atmospheric science investigations. *Prerequisites:* ATSC 4010, 4031, and 4035.

5001. Atmospheric Energetics. 2. First and second laws of thermodynamics applied to energy transformations in the atmosphere. Investigated are: air saturating processes, conserved temperatures, dry air entrainment into clouds, and first and second law applications in atmospheric models. *Prerequisites:* MATH 2210, PHYS 1310 and 1320 (or equivalent).

5002. Atmospheric Radiation I. 3. Covers the principles of atmospheric radiative transfer. Conceptual and theoretical frameworks are provided for the understanding of radiative measurement systems (e.g., satellite, lidar and radar), blackbody radiation, the planetary radiative budget, and the propagation of both longwave and shortwave radiation. *Prerequisites:* MATH 2210, PHYS 1310 and 1320 (or equivalent).

5003. Problems in Energetics and Radiation. 1. Proficiency in the use of tools for assimilation, analysis and presentation of quantitative information is fostered. Also considers solutions to problems developed theoretically in ATSC 5001 and 5002. These consist of solution to thermodynamic and radiative transfer governing equations. *Prerequisites:* ATSC 5001 and 5002, or concurrent enrollment in each.

5004. Problems in Dynamic Meteorology I. 1. Focuses on computational solutions to problems developed theoretically in ATSC 5100. In addition, students gain proficiency in interpretation and analysis of weather data, including surface and upper level maps, and sounding data, which will be used to understand static stability. Data visualization software is also introduced and used to develop understanding of dynamical processes. *Prerequisite:* ATSC 5100 or concurrent enrollment in ATSC 5100.

5005. Microphysics. 2. Microphysical observations of clouds and precipitation are first briefly surveyed. Thermodynamic equilibria in multiphase microphysical systems are then examined, as are homogeneous and heterogeneous nucleation, and diffusional and collisional processes leading to time-dependent changes in hydrometeor size. Embedded in these discussions are elementary considerations of single particle mechanics and hydrodynamics. *Prerequisites:* ATSC 5001, 5002 and 5003.

5006. Problems in Microphysics. 1. Atmospheric processes altering the hydrometeor size distribution are examined using computer algorithms developed by the student. Condensational and collisional growth processes, in warm and cold clouds, are examined. Data from hydrometer size spectrometers are used to initialize the problems. *Prerequisite:* ATSC 5005 or concurrent enrollment.

5007. Problems in Synoptic Meteorology. 1. Laboratory supplement to ATSC 5160. Analysis of weather systems using operational observations and numerical model output. Real-time weather briefings. Numerical simulation of select weather phenomena. Dual listed with ATSC 4007. *Prerequisites:* ATSC 4130, 5130; 4160, 5160 or concurrent enrollment and permission of instructor.

5008. Mesoscale Meteorology. 2. Fundamental dynamics of mesoscale motions including departures from hystrostatic balance. Mesoscale energy sources. Boundary layer circulations. Convective initiation. Structure and dyanmics of deep convection and mesoscale organized convection. Atmoospheric waves. Orograpically modified flow. Dual listed with ATSC 4008. *Prerequisites:* ATSC 4160, 4007, 5160, 5007 and permission of the instructor.

5020. Physical Meteorology II Lab. 1. Laboratory course concerned with physical processes in the atmosphere. Approximately eight experiments are conducted examining phenomena related to atmospheric radiation, gas expansions, phase transitions, and nucleation. *Prerequisites:* ATSC 5005, ATSC 5006 or concurrent enrollment.

5100. Atmospheric Dynamics I. 3. Development and interpretation of the atmospheric equations of motion, scales of motion, horizontal atmospheric winds, thermal wind equation, circulation and vorticity. Introduction to planetary boundary layer flows. *Prerequisite:* MATH 2210, PHYS 1310 and 1320 (or equivalent).

5160. Synoptic Meteorology. 2. Structure and evolution of the extratropic cyclone, identification and development of fronts, jet streams and associated weather features; theories of cyclogenesis; role of topography. Climatology of formation and movement of a cyclone. Mesoscale circulation features; ingredients of severe weather. Dual listed with ATSC 4160. *Prerequisites:* ATSC 4031, 5001, 5003, 5100, 5004 5031 and permission of instructor.

5210. Cloud and Precipitation Systems. 3. Types of clouds and precipitation systems, and the precipitation mechanisms in those systems; structure of convective, orographic, and frontal systems and severe storms. Schematic and numerical models of clouds and storms with emphasis on hailstorms. *Prerequisite:* ATSC 5005 and 5100.

5310. Atmospheric Dynamics II. 3. Introduction to the dynamic energetics of the atmosphere, wave motions, atmospheric instabilities. Introduction to numerical modeling, applications. *Prerequisite:* ATSC 5100.

5320. The Ocean Environment. 3. Focuses on the ocean as a system. Objective is the development of interdisciplinary understanding of marine processes, especially those processes occurring along coastal margins. Emphasis is on the development of quantitative models and their use in understanding anthropogenic impact on ocean resources. Dual listed with ATSC 4320. *Prerequisite:* MATH 2310, PHYS 1310, CHEM 1030, ES 3060 (or ES 3070), LIFE 1010, senior standing or higher.

5330. Boundary Layer Meteorology. 3. A quantitative and descriptive study of the thermodynamics and dynamics of the planetary boundary layer, including budgets (heat, moisture, momentum, turbulent kinetic energy, radiation), stability, turbulence and turbulent fluxes, convection, terrain effects, phenomenology, and measurement and analysis techniques. *Prerequisite:* ATSC 5001, 5100.

5340. Radar Meteorology. 3. The theory of radar and the application of radars to studies of the atmosphere, including basic radar design, distributed targets, attenuation, polarization, Doppler velocities, analysis techniques, and examples of radar studies of clear air, clouds, and precipitation. *Prerequisite:* ATSC 5002 and 5005.

5350. Atmospheric Chemistry. 3. Origin and composition of the atmosphere. Sources, lifetimes, transport of gases and aerosols. Cycles of C, S, N and trace elements. Removal processes: precipitation, and dry deposition. Homogenous and Heterogeneous kinetics. Anthropogenic influences: effect of air pollution on radiation balance and cloud processes. *Prerequisite:* graduate standing in a physical science or engineering.

5370. Meteorological Instrumentation. 3. Physical principles of instruments, their response characteristics and their proper use. Error analysis and interpretation of data. Classical instruments. Introduction to modern methods and instrumentation. Remote sensing, such as by radar and lidar. Instrument systems, such as on aircraft, and remote platforms, such as satellites and buoys. Laboratory experience with a large variety of instruments will be part of the course. *Prerequisite:* graduate standing in a physical science or engineering.

5400. The Physical Basis of Climate. 3. Global atmospheric and oceanic circulations, radiation balance, water balance and hydrologic cycle, energy balance, energy and moisture transport, evaporation and evapotranspiration, energetic processes, and theories of climate change. Dual listed with ATSC 4400. *Prerequisite:* MATH 2200, PHYS 1310, and CHEM 1020.

5500. Atmospheric Radiation and Optics. 3. Overview of atmospheric radiation, basic definitions, and basic laws of radiation. Nature of solar and terrestrial radiation, and atmospheric transmission. Derivation and analytic solutions to the equation of radiative transfer. Radiative transfer models at solar and terrestrial wavelengths, net radiation, and effects of polarization. Radiative properties of molecules, aerosols, and clouds (Rayleigh and Mie scattering). Inadvertent climate modification. Atmospheric refraction, diffraction and polarization phenomenon. *Prerequisite:* ATSC 5002.

5600. Advanced Cloud Micophysics. 3. Analysis of the processes involved in cloud and precipitation formation. Detailed treatments of the condensation, ice nucleation, vapor growth, and collection processes. Emphasis is on reviewing the current state of knowledge in the field and on surveying directions of research. *Prerequisite:* ATSC 5005.

5880. Atmospheric Science Problems. 1-3 (Max. 6). A special course for graduate students in atmospheric science only, designed to make possible the study and investigation of problems or phases of atmospheric science selected to fit the needs of students.

5890. Atmospheric Science Seminar. 1-3 (Max. 6). A seminar-type class furnishing motivation for advanced study of current problems by means of library research, study of current literature, and carefully guided class discussions. *Prerequisite:* consent of department head.

5900. Practicum in College Teaching. 1-3 (Max. 3). Work in classroom with a major professor. Expected to give some lectures and gain classroom experience. *Prerequisite:* graduate status.

5920. Continuing Registration: On Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5940. Continuing Registration: Off Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5959. Enrichment Studies. 1-3 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

5960. Thesis Research. 1-12. (Max. 24). Designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. *Prerequisites:* enrolled in a graduate degree program.

5980. Dissertation Research. 1-12 (Max. 48). Graduate level course designed for students who are involved in research for their dissertation project. Also used for students whose coursework is complete and are writing their dissertation. *Prerequisite:* enrolled in a graduate level degree program.

5990. Internship. 1-12 (Max. 24). *Prerequisite:* graduate standing.

Department of Chemical and Petroleum Engineering

4055 Engineering Building, 766-2500
FAX: (307) 766-6777
Web site: wwweng.uwyo.edu/chemical
Department Head: David Bagley

Professors:

DAVID M. BAGLEY, B.S. Colorado School of Mines 1984; M.S. Cornell University 1989; Ph.D. 1993; Professor and Department Head, Chemical and Petroleum Engineering 2011, 2005.

H. GORDON HARRIS, B.S. University of Texas 1961; M.S. 1962; Ph.D. University of California 1968; Professor of Petroleum Engineering 1984.

NORMAN R. MORROW, B.Sc. University of Leeds, England 1959; Ph.D. 1962; Professor of Petroleum Engineering 1992.

MACIEJ RADOSZ, M.S. Cracow University of Technology 1972; Ph.D. 1977; Professor of Chemical Engineering 2000.

MRITYUNJAI P. SHARMA, B.Sc. B.I.T.T. in Dhanbad, India 1967; M.Tech. I.I.T. in Kampur, India 1970; Ph.D. Washington State University 1977; Professor of Petroleum Engineering 1992, 1982.

BRIAN F. TOWLER, B.E. University of Queensland 1972; Ph.D. 1978; Professor of Petroleum Engineering 2006, 1988.

Associate Professors:

HERTANTO ADIDHARMA, B.Sc. Institute of Technology, Surabaya 1987; Ph.D. Louisiana State University 1999; Associate Professor of Chemical Engineering 2011, 2005.

VLADIMIR ALVARADO, B.Sc. Universidad Central de Venezuela 1987; M.S. Institut Francais du Pétrole 2002; Ph.D. University of Minnesota 1996; Associate Professor of Petroleum Engineering 2012, 2006.
DAVID A. BELL, B.S. University of Washington 1976; M.S. Rice University 1979; Ph.D. Colorado State University 1992; Associate Professor of Chemical Engineering 2000, 1993.
MAOHONG FAN, B.S. Wuhan University of Science and Engineering 1984; M.S. Beijing University of Science and Tech., 1992; Ph.D. Chinese Academy of Sciences 1997; Ph.D. Iowa State University 2000; Ph.D. Osaka University 2003; Associate Professor of Chemical Engineering 2008.
JOSEPH HOLLES, B.S. Iowa State University 1990; M.E. University of Virginia 1998; Ph.D. 2000; Associate Professor of Chemical Engineering 2010.
PATRICK JOHNSON, B.S. Lehigh University 1992; M.S. University of Virginia 1994; Ph.D. Columbia University 2004; Associate Professor of Chemical Engineering 2012,2006.
MOHAMMAD PIRI, B.Sc. Azad University, Arak 1995; M.Sc. Azad University, Tehran 1998; M.Sc. Imperial College, London 2000; Ph.D. 2004; Associate Professor of Petroleum Engineering 2011, 2005.

Assistant Professors:
LAMIA GOUAL, B.Sc. Ecole Nationale Polytechnique 1993; M.Sc. Imperial College London 1998; Ph.D. 2003; Assistant Professor of Chemical and Petroleum Engineering 2007.
DONGMEI (KATIE) LI, B.S. Shandong University of Technology 1994; M.S. Tianjin University 1997; M.S. University of Colorado at Boulder 1999; Ph.D. 2003; Assistant Professor of Chemical Engineering 2011.
JOHN OAKEY, B.S. The Pennsylvania State University 1997; M.S. Colorado School of Mines 1999; Ph.D. 2003; Assistant Professor of Chemical Engineering 2010.
SHUNDE YIN, B.S. Shijiazhuang Railway University, China 1999; M.S. Chinese Academy of Sciences 2003; Ph.D. University of Waterloo 2008; Assistant Professor of Petroleum Engineering 2008.

Assistant Lecturer:
John Myers

Adjunct Professors:
John Ackerman
Morris Argyle
Jill Buckley
Geoffrey Mason
Youqing Shen
John Schabron
Koichi Takamura
Karen Wawrousek

Professors Emeriti:
Chang Yul Cha
Harry A. Deans
Jack Evers
Henry W. Haynes

Chemical Engineering

Chemical Engineering is one of the most versatile of the engineering programs. It prepares students for employment in many diverse fields, such as petroleum refining, production of pharmaceuticals, petrochemicals, polymers and plastics, semiconductors, heavy industrial chemicals, and synthetic fuels. Chemical engineers also work in metallurgy, corrosion control, enhanced oil recovery, environmental engineering and biological engineering. Undergraduate chemical engineering training has been found to be an excellent background for graduate work not only in engineering, but also in a number of other fields, including medicine, law, business, and the natural sciences.

The chemical engineering curriculum is based on a sound background in chemistry, mathematics, physics, and biology. The essentials of engineering are added to this foundation, including fluid dynamics and thermodynamics. In order to develop the individual's social consciousness and to broaden the student's educational background, an integrated program of study in the humanities and social sciences is included in the curriculum. Chemical engineering courses in multicomponent thermodynamics, transport phenomena, kinetics, process control and process design are concentrated in the junior and senior years. This program provides training for engineers to enter production, research, product and process development, process design, technical sales and engineering management positions. Training in chemical engineering equips the graduate to solve many of the problems facing society today: human health, energy shortages, synthetic fuels production, water and air pollution, toxic chemical control, and food production. Furthermore, our program prepares students interested in a career in medicine or the life sciences and is suitable for premed and pre-dental students.

The department offers a 18-credit-hour block of approved electives and encourages concentration in an area of interest. At least one of the elective courses must be CHE. Students can elect to concentrate in Biomaterials and Polymers, Biomedical Engineering, Biotechnology, Chemistry, Environmental Engineering, International Engineering, Math, and Petroleum Engineering for which elective courses are approved by the department. Finally, students can design their own self-directed 18-credit-hour block of electives to reflect individual interests.

Chemical Engineering degree candidates must meet the academic requirements of the college and, in addition, must have a GPA of 2.0 in Chemical Engineering courses attempted at UW that are applied toward graduation for the B.S. degree from the department.

Chemical Engineering Program Educational Objectives

Three to six years after graduation, graduates who choose to practice in Chemical Engineering should:

- Successfully practice the profession of Chemical Engineering;
- Demonstrate successful career growth

Chemical Engineering Program Outcomes

During the course of study in Chemical Engineering, the student should develop:

- 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 design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
- an ability to function on multidisciplinary teams;
- an ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- a recognition of the need for, and ability to engage in life-long learning;
- a knowledge of contemporary issues;
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Chemical Engineering Curriculum

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
ES	1000	1
MATH	2200	4
CHEM	1050	4
ES	1060	3
LIFE	1010	4
PEAC	1001	1
	Total Hrs.	**17**

FRESHMAN YEAR: Spring		Hrs.
US & Wyoming Constitutions		3
MATH	2205	4
CHEM	1060	4
PHYS	1210[1]	4
ENGL	1010	3
	Total Hrs.	**18**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2210	4
CHEM	2420	4
PHYS	1220	4
CHE	2005	3
	Total Hrs.	**15**

SOPHOMORE YEAR: Spring		Hrs.
CHE	2060	3
MATH	2310	3
CHEM	2440	4
ES	2310	3
ES	2330	3
	Total Hrs.	**16**

JUNIOR YEAR: Fall		Hrs.
CHE	3015	3
CHE	3025	3
CHEM	4507	3
Elective [2]		3
USP Cultural Context		3
	Total Hrs.	**15**

JUNIOR YEAR: Spring		Hrs.
CHE	3030	3
CHE	3070	3
CHE	4060	3
Elective[2]		3
Elective[2]		3
	Total Hrs.	**15**

SENIOR YEAR: Fall		Hrs.
CHE	3040	3
CHE	4070	3
CHE	4090	3
USP Cultural context		3
Elective[2]		3
	Total Hrs.	**15**

SENIOR YEAR: Spring		Hrs.
CHE	4050	3
CHE	4080	5
Cultural context		3
Elective[2]		3
Elective[2]		3
	Total Hrs.	**17**

Notes:

1. The ES 2110/ES 2120 sequence can be substituted for PHYS 1210.
2. Six electives are required. At least one elective must be an upper level CHE course.

Areas of Concentration

Biological Engineering: MOLB 2021 General Microbiology (4), CHE 4100 Biochemical Engineering (3), CHE 4160 Biomedical Engineering (3) + approved electives.

Biological Engineering Pre-medicine Sequence (satisfies pre-med requirements): MOLB 2021 General Microbiology (4), MOLB 3610 (4); [Alternative: [MOLB 4600 (3) and MOLB 4610 (3)], LIFE 3050 Genetics (4), LIFE 3600 Cell Biology (3) + CHE 4160 Biomedical Engineering (3). Students should contact the Preprofessional Advising Office for pre-med and pre-dental advising.

Concurrent Chemistry Major (Plan-1BS): CHEM 4000 Seminar (1) + CHEM 4110 Introduction to Inorganic Chemistry (3) + CHEM 4100 Inorganic Chemistry Lab (2) + CHEM 4508 Physical Chemistry II (3) + CHEM 4530 Physical Chemistry Lab (1) + CHEM 4930 Undergraduate Research (2) + 3 credits of upper-division Chemistry electives. If the Adviser and Chemistry Department's Undergraduate Studies Committee approve a research plan, CHE 3900 (Undergraduate Research) can substitute for CHEM 4930.

Environmental: MOLB 2021 General Microbiology (4) + CE 3400 Introduction to Environmental Engineering (3) + CHE 4110 Air Pollution for Chemical Engineers (3) + CHE 4100 Biochemical Engineering (3) or approved elective.

International: 15 hours of foreign language and a semester abroad, which satisfies 9 hrs of cultural context (CA, CH, CS, D, G). Hence 15 - 9 = 6 hrs are available for electives.

Math: *Math Minor:* MATH 2250 Elementary Linear Algebra (3) + MATH 2800 Math Seminar (2) or MATH 2850 Putnam Seminar (2) + programming class (for example, COSC 1010 or COSC 1030) + two MATH 3000-plus electives (for example, Math 3310 and CHE 5140/ MATH 5310).

Petroleum Engineering: PETE 2050 Introduction to Petroleum Engineering (3), PETE 3200 Reservoir Mechanics (3), PETE 4060 Flow through Porous Media (3), GEOL 4190 Petroleum Geology (3) or approved elective.

Self-directed: Individual Elective plan approved by adviser.

Concentration definitions may change to reflect the most recent class offerings. Please consult with your adviser.

Graduate Study

The Department of Chemical and Petroleum Engineering offers graduate programs leading to the M.S. and Ph.D. degrees in chemical engineering and in petroleum engineering. The M.S. degree is offered under Plan A and Plan B. In addition, an environmental engineering program, run jointly by the Department of Chemical and Petroleum Engineering and the Department of Civil and Architectural Engineering, offers graduate programs leading to an M.S. in environmental engineering under either Plan A or Plan B.

Program Specific Admission Requirements

A. Admission Process and Requirements

Standard Admission

Admission is open to students with at least a bachelor's degree who meet the minimum requirements:

1. A GPA of 3.0 (A = 4), or equivalent;

2. A GRE score of 305 (combined verbal and quantitative sections)*

3. For international applicants who did not attend an English-speaking program in an English-speaking country for all years of their highest degree:

A TOEFL score of 600 (paper-based), 250 (computer-based), or 80 (Internet based) or an IELTS score of 6.0.

*GRE requirement may be waived if the applicant has already obtained an MS degree, subject to approval by the Graduate Committee.

Complete official transcripts of all prior college-level coursework and recommendations from three references must be submitted as parts of the application.

The deadline to submit application credentials is February 1 (to be considered for Fall semester), and October 1 (to be considered for Spring semester).

The application will not be processed until all the necessary documents have been submitted.

B. Graduate Study Guidelines

All incoming Ph.D. and M.S. Plan A students who have not been assigned to an adviser are required to meet with all the faculty members (and obtain their signatures) in their

program to get information regarding their research projects and evaluate the possibility of joining one of the research groups.

All incoming M.S. Plan B students must have an adviser. The student is responsible for contacting faculty members in order to find an adviser.

All Chemical Engineering graduate students must take the following Chemical Engineering Core courses:

1. Thermodynamics (CHE 5020)
2. Transport Phenomena (CHE 5010)
3. Reaction Kinetics (CHE 5030)
4. Mathematical Methods in Chemical Engineering (CHE 5355)

	Credit Hours
Total (from above)	12
A graduate level course in mathematics, statistics, or computing	3
CHE/PETE 5960 Thesis Research	4
Electives	11
Total	30

All Petroleum Engineering graduate students must take at least four out of the following Petroleum Engineering Core courses:

1. Mathematical Methods in Chemical Engineering (PETE 5355)
2. Thermodynamics (PETE 5020)
3. Transport Phenomenon (PETE 5010)
4. Fundamentals of Enhanced Oil Recovery (PETE 5310)
5. Flow Thru Porous Media (PETE 5060)
6. Reservoir Simulation (PETE 5300).

	Credit Hours
Total (from above)	12
A graduate level course in mathematics, statistics, geology, or computing	3
CHE/PETE 5960 Thesis Research	4
Electives	11
Total	30

Plan B (non-thesis)

The coursework requirements are the same as the M.S. Plan A requirements except that Thesis Research (CHE, PETE 5960) is not required. Plan B students take an additional 4 hours of elective course credits (total of 30 hours required).

M.S. Plan B students must write a paper on a topic assigned by the adviser. This paper must be submitted to the student's graduate committee for approval.

Doctoral Program

	Credit Hours
M.S. Plan A list (except CHE, PETE 5960); petitions allowed	26
Dissertation Research (CHE or PETE 5980)	30
Electives (no internship 5990)	16
Total	72

M.S. and Ph.D. Seminar Requirements

All chemical and petroleum engineering graduate students must enroll in CHE/PETE 5890, Chemical and Petroleum Engineering Seminar, every semester. All seminars, including the required presentations described below, must be scheduled by the seminar coordinator. Registered off-campus graduate students can be exempt from having to enroll in CHE/PETE 5890.

Ph.D. Preliminary Examination

All Ph.D. students must pass a preliminary examination no later than the end of the student's fifth full semester in the graduate program and a least 15 weeks prior to the dissertation defense. Prior to attempting the Ph.D. preliminary examination, students must have completed all required core classes no later than the end of their fourth semester in the graduate program. Students must file a program of study prior to attempting the preliminary examination.

The goal of the preliminary exam is for the student to demonstrate his or her research progress to-date and present the research proposition that will be investigated and lead to his or her final dissertation. The preliminary exam consists of three components: a written document provided to each member of the student's graduate committee at least one week prior to the oral presentation; a public oral presentation; and a private examination by the student's graduate committee immediately following the oral presentation.

The written document may be in any format but must concisely provide a survey of the relevant literature, a summary of the student's progress to-date, and a clear, detailed plan for the successful completion of the proposed work. The preliminary exam oral presentation should be consistent with the written document. It should provide an appropriate literature background, demonstrate proficiency with proposed experimental/computational techniques, identify details of the experiments to be performed, and provide a timeline to final defense.

The student's committee will pass or fail the student on the strength of the preliminary examination, with and option to conditionally pass the student while requiring an interim committee meeting prior to the final Ph.D. examination. A form sent by the student's adviser to the Office of the Registrar reports the results of the examination.

M.S. Thesis or Ph.D. Final Examination (Dissertation Defense)

All M.S. Plan A and Ph.D. students must orally defend their thesis or dissertation at a public final examination. If, for any reason, a student's Ph.D. research goals are substantially changed after successful completion of the preliminary examination, the student must arrange a subsequent meeting to provide their committee with an accurate and current overview of their proposed work. The final examination consists of a public thesis defense in oral presentation format. At least two weeks before the examination, the student must provide each member of the graduate committee with a copy of the written thesis of Ph.D. dissertation and provide the department and announcement of their defense for advertisement by bulletin board, e-mail, or other means. The results of the examination are reported on the Completion of Requirements form. Often, graduate committee members request changes in the thesis or dissertation, and they may postpone signing the form until they are satisfied that those changes have been made.

Publication of Thesis or Dissertation

After the defense, an electronic copy (in PDF format) of the thesis or dissertation must be uploaded in accordance with the directions provided on the Graduate Student Resources web site. This copy will be rejected if the format standards specified by the Thesis and Dissertation Format Guide are not met. This guide allows for a publication-ready format. If required by the department and/or committee, additional printed copies should be delivered to the University Store for binding. A bound copy must be submitted to the Department of Chemical and Petroleum Engineering for the departmental library. Most students will want one or more copies for their own use. Students should consult with the adviser to determine if the adviser wants a copy of the thesis, dissertation, or other research documentation.

Chemical Engineering (CHE)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

2005 [3000]. Chemical Process Analysis. 3. Introduces analysis of chemical processes using stoichiometry, material and energy balances, thermodynamics and economics. Introduces analysis of safety, health, and environment. *Prerequisite:* C or better in MATH 2205 and either CHEM 1050 or CHEM 1020. (Normally offered fall semester)

2060. Introduction to Chemical Engineering Computing. 3. Introduces chemical engineering problems, develops computational skills needed to solve them, and reinforces a computational tool that will be useful for other CHE classes. *Prerequisites:* Grade of C or better in ES 1060 and concurrent enrollment in MATH 2310. (Normally offered spring semester)

3015 [3010]. Multicomponent Thermodynamics. 3. Introduces mixture properties, such as chemical potentials, excess properties, partial molar properties, heats of mixing, fugacities, and practical tools for estimating them from solution theories and equations of state. These tools and concepts are applied to phase and chemical equilibria. Cross listed with PETE 3015. *Prerequisite*: ES 2310, CHE 2060 or PETE 2060. (Normally offered fall semester)

3025 [3020]. Transport Phenomena. 3. Introduces energy and mass transfer concepts and the development of mathematical models of physical phenomena, including convection, diffusion, conduction and radiation, applicable to the analysis and design of chemical processes. Cross listed with PETE 3025. *Prerequisites:* C or better in ES 2330 and CHE 2005. (Normally offered fall semester)

3030. Unit Operations. 3. Applies transport and equilibrium concepts and models to the analysis and design of unit operations, such as distillation, absorption, extraction, crystallization, membrane, and heat exchange processes. Cross listed with PETE 3030. *Prerequisites:* CHE 2005, 3015, and 3025. (Normally offered spring semester)

3040. Unit Operations Laboratory I. 3. [W3◆▶WB] Illustrates fluid-flow and heat-transfer principles with experiments, for example, on pipe flow, fluid viscosity and convective heat transfer. Emphasizes experimental-error analysis and technical communication, both written and oral. *Prerequisite:* WA, CHE 3025. (Normally offered fall semester)

3070. Process Simulation and Economics. 3. Introduces the process simulation software used in the chemical industry and its applications, including examples of heat and material balances, physical properties, phase and chemical equilibria, equilibrium-stage separations and costs and profitability analysis. *Prerequisites:* concurrent enrollment in CHE 3015 and CHE 3030.

3900. Undergraduate Research. 1-6 (Max. 6). Students carry out research appropriate to undergraduates, under faculty supervision. May be taken more than once. *Prerequisite:* junior standing in chemical engineering. (Normally offered each semester)

4000. Environment, Technology and Society. 3. [C2, G1◆▶(none)] Explores relationships among technology, the environment and society. Examines social and humanistic aspects of using current and future technology to understand and solve environmental problems. Cross listed with PETE 4000. *Prerequisites:* junior standing and completion of two university studies science courses (SB, SP, SE).

4050. Unit Operations Laboratory II. 3. [W3◆▶(none)] Illustrates mass-transfer principles with experiments, for example, on extraction, gas absorption, and distillation. Emphasizes experiment planning and technical communication, both written and oral. *Prerequisite:* CHE 3030. (Normally offered spring semester)

4060. Reaction Engineering. 3. Introduces chemical process kinetics, catalysis and reactor design. Includes homogeneous and heterogeneous reaction kinetics; design of batch, stirred-tank and tubular reactors; and non-isothermal operation. *Prerequisites:* CHE 3015 and 3025. (Normally offered spring semester)

4070. Process Design I. 3. Encompasses engineering design of chemical processes. Introduces engineering economics, process safety management and environmental management. *Prerequisites:* CHE 3030, 3070 and 4060 or concurrent enrollment. (Normally offered fall semester)

4080. Process Design II. 5. [(none)◆▶WC] Intended for the last semester of the senior year. Applies all previous courses to the design of safe, economical and environmentally benign chemical processes. *Prerequisite:* CHE 3040, 4070.

4090. Process Dynamics and Control. 3. Encompasses analysis and design control systems for the chemical process industry including steady-state approximation, types of controllers, simple unsteady-state analysis, use of mathematical models and process dynamics under control. *Prerequisites:* CHE 3025, 3030 and 4060. (Normally offered spring semester)

4100. Biochemical Engineering. 3. Applies chemical engineering principles to the analysis and design of biological processes widely used in the pharmaceutical, food and environmental remediation industries. Topics include kinetics of enzyme-catalyzed reactions, cellular growth and metabolism, bioreactor design and mass transfer considerations. Dual listed with CHE 5100. *Prerequisites:* MOLB 2021 or concurrent enrollment and CHE 4060 or concurrent enrollment.

4110. Air Pollution for Chemical Engineers. 3. Focuses on strategies and technologies for complying with air pollution control regulations. Introduces atmospheric mixing and dispersion modeling to describe impact of process air emissions on the environment. Examines chemistries of pollutant production and atmospheric fate of air pollutants. *Prerequisite:* CHE 2005.

4160. Biomedical Engineering-Transport Processes. 3. Focuses on chemical and physical transport processes with applications toward the development of drug delivery systems, artificial organs, bioartificial organs and tissue engineering. Involves topics covering body fluids, capillary solute transport, physical and flow properties of blood, tissue oxygen transport, pharmacokinetic models and cell physiology. *Prerequisites:* consent of instructor and grade of C or better in at least three courses counting no more than two from CHEM 1020, CHEM 1030, CHEM 1050, LIFE 1010, LIFE 1020 and at least one from LIFE 2022, MATH 2200, KIN 2040, MOLB 2021, MOLB 2240, CHE 3000, ES 2310.

4170. Polymeric Materials Synthesis. 3. An introduction to the polymer technology, with emphasis on the synthesis of polymeric materials and on the polymerization processes. Applications cover commodity polymers, such as polyolefins and advanced materials, such as nanomaterials, aerospace materials and biomaterials for drug delivery, artificial tissues and organs. *Prerequisite:* CHEM 2340 or 2440.

4190. Polymeric Materials: Characterization and Properties. 3. Intended for science and engineering students, an introduction to the characterization and properties of polymeric materials. Introduces synthesis, architecture, molecular microstructure analysis, molecular weight determination, solution properties, thermal properties and mechanical properties of polymeric materials. Dual listed with CHE 5190. *Prerequisite:* CHEM 4507.

4200. Industrial Chemical Production. 3. Integration of chemical engineering and chemistry as practiced in modern industry. Engineering of chemical reactions and processes for commodity chemicals, petroleum-based

fuels, petrochemicals, intermediates, specialty chemicals, pharmaceuticals, and engineered materials. Environmental strategies for waste minimization and pollution prevention. *Prerequisites:* CHEM 2420 and CHE 3015 (may be taken concurrently).

4210. Natural Gas Processes and Modeling. 3. After a quick introduction to the Hysys simulation program, the main chemical processes used to convert well-head gas to products will be reviewed and modeled (fractionation train, sulfur recovery, tail gas clean-up, dehydration, refrigeration, nitrogen rejection) in high detail, including appropriate property models to use. *Prerequisite*: CHE 3070.

4270. Advanced Process Simulation. 3. Advanced topics for a commercial process simulation software that is routinely used in industry will be covered. Topics will include: electrolyte systems, physical property methods and regression of parameters, petroleum industry component selection and distillation, solids handling capabilities including coal processing, advanced recycle stream convergence techniques, and equation-oriented solution methods. *Prerequisite*: CHE 3070.

4340. Numerical Analysis. 3. Considers computer methods and their accuracy for applied mathematics. Topics include machine arithmetic, analysis of rounding error, solution methods for linear systems and nonlinear equations, interpolations, numerical differentiation, and numerical solution of differential equations. Includes some programming. *Prerequisites:* grade of C or better in COSC 1010, MATH 2310, and either MATH 2250 or 3310.

4970. Internship in Chemical Engineering. 1-6 (Max. 6). Enables credit for students in appropriate engineering activities while serving as interns in an industrial, government, or other setting. *Prerequisite:* must be involved in a chemical engineering co-op/internship experience.

4990. Topics in Chemical Engineering. 1-6 (Max. 6). Features topics not included in regularly offered classes. Section I is individual study. Other sections are group study by seminar or in class format. *Prerequisite:* CHE 3000 or concurent enrollment.

5010. Transport Phenomena. 3. Examines the modeling of momentum, heat and mass transport. Cross Listed with PETE 5010. *Prerequisite:* ES 2330, MATH 2310, and graduate standing in Chemical or Petroleum Engineering.

5020. Thermodynamics. 3. Examines molecular thermodynamics of pure materials and mixtures, including phase equilibria and the use of equations of state. Cross listed with PETE 5020. *Prerequisite:* ES 2310 or CHEM 4505.

5030. Reaction Kinetics. 3. An analysis of reactions involving phase boundaries, heterogeneous catalysis, gas-solid systems, and gas-liquid systems. Cross listed with PETE 5030. *Prerequisite:* CHE 4060.

5045. Reactor Design. 3. Examines reactor design techniques, including the use of thermodynamics, kinetics, heat transfer, and mass transfer. Cross listed with PETE 5045. *Prerequisite:* CHE 4060.

5050. Structure and Properties of Porous Media. 3. Introduction to porous materials, pore structure and mineralogy of reservoir rocks. Fundamentals of porosity, permeability, and capillary properties of porous materials. Application to hydrocarbon reservoirs. Cross listed with PETE 5050. *Prerequisite:* graduate standing.

5060. Flow Thru Porous Media. 3. Review of properties of porous media. Relationships of permeability to porosity. Formulation of the Fundamental Flow equation. Constant Rate Solutions. Constant Pressure Solutions. The Principle of Superposition. Transient well testing of oil and gas reservoirs, including drawdown, build-up faulted systems, interference, drillstem tests, and isochronal test analysis. Dual listed with PETE 5060. *Prerequisite:* PETE 3200 and graduate standing.

5070. Multiphase Flow. 3. A thorough background in the methods of analysis and current developments in gas-liquid, gas-solid, liquid-solid, and gas-liquid-solid flows. Introduction to multiphase flow instrumentation. Identical to PETE 5070. *Prerequisite:* ME 3360 or CHE 3025.

5080. Interfacial Phenomena. 3. Introduction to surface and colloid chemistry, coagulation and flocculation, surface energy and thermodynamics of surfaces, adsorption at interfaces, surface tension, capillarity and wetting, spontaneous imbibition, applications to hydrocarbon reservoirs and oil recovery. Cross listed with PETE 5080. *Prerequisite:* graduate standing.

5100. Biochemical Engineering. 3. Applies chemical engineering principles to the analysis and design of biological processes widely used in the pharmaceutical, food and environmental remediation industries. Topics include kinetics of enzyme-catalyzed reactions, cellular growth and metabolism, bioreactor design and mass transfer considerations. Dual listed with CHE 4100. *Prerequisite:* MOLB 2021 or concurrent enrollment and CHE 4060 or concurrent enrollment.

5130. Staged Operations. 3. Thermodynamic and mathematical analysis of stagewise mass transfer operations. Distillation, absorption, and extraction are discussed. *Prerequisite:* CHE 3030, CHE 5040 or concurrent enrollment.

5140. Computational Methods I. 3. First semester of a three-semester computational methods series. Review of iterative solutions of linear and nonlinear systems of equations, polynomial interpolation/approximation, numerical integration and differentiation, and basic ideas of Monte Carlo methods. Comparison of numerical techniques for programming time and space requirements, as well as convergence and stability. Identical to COSC 5310 and MATH 5310. Cross listed with PETE/ME/CE 5140. *Prerequisite:* MATH 3310, COSC 1010.

5150. Topics in Chemical Engineering. 1-3 (Max. 12). Selected topics in chemical engineering. Cross listed with PETE 5150. *Prerequisite:* consent of instructor.

5160. Biomedical Engineering - Transport Processes. 3. Focuses on chemical and physical transport processes with applications toward the development of drug delivery systems, artificial organs, bioartificial organs and tissue engineering. This will involve topics covering body fluids, capillary solute transport, physical and flow properties of blood, tissue oxygen transport, pharmacokinetic models and cell physiology. Dual listed with CHE 4160. *Prerequisite:* consent of instructor and grade of C or better in at least 3 courses counting no more than 2 from CHEM 1020, CHEM 1030, CHEM 1050, LIFE 1010, LIFE 1020 and at least one from LIFE 2022, MATH 2200, KIN 2040, MOLB 2021, MOLB 2240, CHE 3000, ES 2310, graduate standing.

5170. Polymeric Materials Synthesis. 3. An introduction to the polymer technology, with emphasis on the synthesis of polymeric materials and on the polymerization processes. Applications will cover commodity polymers such as polyolefins, and advanced materials, such as nanomaterials, aerospace materials and biomaterials for drug delivery, artificial skin and organs. Dual Listed with CHE 4170. *Prerequisite:* CHEM 2340 or CHEM 2440, graduate standing.

5180. Molecular Biophysics. 3. Organized into five sections that cover 1) Confrontation of biopolymers 2) Dynamics of biopolymers 3) Hydration of biopolymers 4) Biopolymers as poly-electrolytes and 5) Association between molecules with topics to include equilibrium studies and ligand/receptor binding and linkage. *Prerequisite:* MOLB 4600/5600 or CHEM 4507.

5190. Polymetric Materials: Characterization and Properties. 3. Intended for science and engineering students, is an introduction to the characterization and properties of polymeric materials. Introduces synthesis, architecture, microstructure analysis, molecular weight determination, solution properties, thermal properties and mechanical properties of polymeric materials. Dual listed with CHE 4190. *Prerequisite:* CHEM 4507.

5355. Mathematical Methods in Chemical Engineering. 3. Covers mathematical modeling: conservation laws and constitution relationships; partial differential equations (PDEs): the types and analytical solution techniques; applied linear algebra; matrices and Eigen-analysis; numerical solution techniques: finite difference and finite element methods, Newton-Raphson method, and temporal discretization techniques, and linear solution techniques: direct and iterative methods. Cross listed with PETE 5355. *Prerequisites:* MATH 2210, CHE/PETE 3025 or equivalent.

5410. Advanced Biological Wastewater Treatment. 3. Theory and practice of advanced biological treatment processes for municipal and industrial wastewaters, sludges, groundwater bioremediation and solid waste. Emphasis is on fundamental principles applied to the design and control of existing processes and the development of innovative systems. Cross listed with CE/ENVE 5410. *Prerequisites:* consent of instructor.

5440. Fluid Mechanics. 3. Lagrangian and Eulerian coordinates, Navier-Stokes equations, momentum balance, fluid statics, strain rate and vorticity, irrotational flow, and laminar viscous flow including exact solutions and boundary layers. Cross listed with ME 5440. *Prerequisites:* none.

5442. Advanced Fluid Mechanics. 3. Introduction to inviscid and viscous hydrodynamic stability; closure in turbulent flows; vorticity and vortex dynamics; theoretical aerodynamics; numerical simulations of viscous flows; experimental methods in fluid flows. *Prerequisite:* ME 5440.

5530. Advanced Mass Transfer. 3. Consideration of diffusional phenomena and processes. Topics include flux laws, diffusion coefficient prediction, steady and unsteady state diffusion in non-flowing systems (with and without chemical reaction), convective diffusion, and diffusion-based separation processes.

5700. Fundamentals of Coal Utilization. 3. Following introduction to coal structure, constituents and classification, fundamental principles of coal utilization technologies will be examined. The topics to be covered include behavior of coal stockpiles, drying, pyrolysis, combustion/gasification of coal. Reactor models for utilization of coal will be discussed with reference to current environmental issues and remediation. *Prerequisite:* graduate standing.

5710. Advances in Fluidization Technology. 3. Covers particle classification, hydrodynamics, advanced modeling strategies, and technical applications of fluidization. *Prerequisite:* graduate level.

5870. Mathematical Modeling of Processes. 3. Introduction to techniques in the process of constructing mathematical models. Application of the techniques to areas such as petroleum reservoir simulation, chemical process industry operations and plant start-up. Identical to MATH 5320. *Prerequisite:* CHE/PETE 5140 and graduate standing.

5880. Problems in Chemical Engineering. 1-6 (Max. 6). A special course designed to make possible the study and investigation of problems or phases of chemical engineering selected to fit the needs of the student. *Prerequisite:* graduate standing in engineering.

5890. Chemical and Petroleum Engineering Seminar. 1 (Max. 9). Departmental seminar on current research with formal training for student presentation of technical papers. Satisfactory/unsatisfactory only. Cross listed with PETE 5890. *Prerequisite:* graduate standing.

5900. Practicum in College Teaching. 1-3 (Max. 3). Work in classroom with a major professor. Expected to give some lectures and gain classroom experience. *Prerequisite:* graduate status.

5920. Continuing Registration: On Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5940. Continuing Registration: Off Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5959. Enrichment Studies. 1-3 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

5960. Thesis Research. 1-12 (Max. 24). Graduate level course designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. *Prerequisites:* enrolled in a graduate degree program.

5980. Dissertation Research. 1-12 (Max. 48). Graduate level course designed for students who are involved in research for their dissertation project. Also used for students whose coursework is complete and are writing their dissertation. *Prerequisite:* enrolled in a graduate level degree program.

5990. Internship. 1-12 (Max. 24). *Prerequisite:* graduate standing.

Petroleum Engineering

Petroleum Engineering trains students for Wyoming's largest industries, the production of crude oil and gas. With the recognition of the state's and nation's vast reserves of natural gas, the curriculum emphasizes the production and processing of this important resource. Because of American predominance in petroleum technology, career opportunities are available throughout most of the world.

The curriculum in petroleum engineering is based upon sound preparation in fundamental sciences, mathematics, physics, chemistry, and geology. The essentials of engineering are added to this foundation: computer programming, statics, dynamics, materials science, hydraulics, and thermodynamics. To aid in developing individuals' social potential and broaden their educational background, an integrated program in humanities and social sciences is included in the curriculum. Petroleum engineering courses, which are primarily concerned with application of previously acquired knowledge to problems of the oil and gas industry, are concentrated in the junior and senior years.

Petroleum Engineering degree candidates must meet the academic requirements of the college and, in addition, must have a GPA of 2.0 in Petroleum Engineering courses attempted at UW that are applied toward graduation for the B.S. degree from the department. For approved electives, students must have prior approval of their adviser and department head. Courses must be chosen from a list provided by the department.

Petroleum Engineering Program Educational Objectives

Three to six years after graduation, graduates who choose to practice in Petroleum Engineering should:

- Successfully practice the profession of Petroleum Engineering;
- Demonstrate successful career growth

Petroleum Engineering Program Outcomes

During the course of study in Petroleum Engineering, the student should develop:

- 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 design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
- an ability to function on multidisciplinary teams;
- an ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- a recognition of the need for, and ability to engage in life-long learning;
- a knowledge of contemporary issues;
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Petroleum Engineering Curriculum

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
ES	1000	1
ES	1060	3
CHEM	1020	4
GEOL	1100	4
MATH	2200	4
	Total Hrs.	**16**

FRESHMAN YEAR: Spring		Hrs.
CHEM	1030	4
ES	2110	3
MATH	2205	4
ENGL	1010	3
US & Wyoming Constitution		3
	Total Hrs.	**17**

SOPHOMORE YEAR: Fall		Hrs.
PHYS	1220	4
MATH	2210	4
ES	2410	3
ES	2120	3
PETE	2050	3
	Total Hrs.	**17**

SOPHOMORE YEAR: Spring		Hrs.
MATH	2310	3
ES	2310	3
ES	2330	3
CHEM	2300	4
USP Cultural Context		3
	Total Hrs.	**16**

JUNIOR YEAR: Fall		Hrs.
PETE	2060	3
PETE	3100	2
PETE	3255	3
USP Cultural Context		3
PETE Elective		3
PEAC	1001	1
	Total Hrs.	**15**

JUNIOR YEAR: Spring		Hrs.
PETE	3200	3
PETE	3265	2
PETE	3725	3
PETE	3715	3
PETE	4320	3
	Total Hrs.	**14**

SENIOR YEAR: Fall		Hrs.
PETE	3015	3
PETE	4720	3
PETE	4225	2
PETE	4340	3
Approved Elective		3
USP Cultural Context		3
	Total Hrs.	**17**

SENIOR YEAR: Spring		Hrs.
PETE	4735	4
GEOL	4190	3
Approved Elective		3
Approved Elective		3
Approved Elective		3
	Total Hrs.	**16**

Petroleum Engineering (PETE)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

2050 [3000]. Introduction to Petroleum Engineering. 3. General introduction to petroleum engineering, including physical properties of reservoir rock, single phase fluid flow through porous media, surface forces, fluid saturation's, drilling fundamentals, methods of production, completion technology and petroleum reservoir field data. *Prerequisites:* MATH 2205.

2060. Introduction to Petroleum Engineering Computing. 3. Introduces Petroleum Engineering problems and principles, develops computational skills needed to solve them, and reinforces a computational tool that will be useful for other Petroleum Engineering classes. *Prerequisites:* grade of C or better in ES 1060, concurrent enrollment in MATH 2310.

3015 [3010]. Multicomponent Thermodynamics. 3. Introduces mixture properties, such as chemical potentials, excess properties, partial molar properties, heats of mixing, fugacities, and practical tools for estimating them from solution theories and equations of state. These tools and concepts are applied to phase and chemical equilibria. Cross listed with CHE 3015. *Prerequisite*: ES 2310, CHE 2060 or PETE 2060. (Normally offered fall semester)

3025 [3020]. Transport Phenomena. 3. Introduces energy and mass transfer concepts and the development of mathematical models of physical phenomena, including convection, diffusion, conduction and radiation, applicable to the analysis and design of chemical processes. Cross listed with CHE 3025. *Prerequisites:* C or better in ES 2330 and CHE 2005. (Normally offered fall semester)

3030. Unit Operations. 3. Applies transport and equilibrium concepts and models to the analysis and design of unit operations, such as distillation, absorption, extraction, crystallization, membrane, and heat exchange processes. Cross listed with CHE 3030. *Prerequisites:* CHE 2005, 3015, and 3025.

3100. Rock and Fluids Lab. 2. Provides understanding of principles of rock and fluid properties and their measurement as part of conventional and special core analysis, as well as PVT characteristics of reservoir fluids. Students are expected to understand how to measure important rock and fluid properties using laboratory equipment, as part of reservoir characterization routines, formation damage evaluations and well log calibration protocols. Students are also expected to learn how to write succinct and organized reports. *Prerequisites:* PETE 2050.

3200 [4010]. Reservoir Mechanics. 3. Examines use of material balance equation. Studies principles of fluid mechanics applied to single and multiphase flow of fluids in porous media and decline curve analysis. *Prerequisite:* PETE 2050. (Normally offered spring semester)

3255. Basic Drilling Engineering. 3. Principles and practices of oil and gas well rotary drilling, including rock mechanics, drilling hydraulics, drilling fluids, and hold deviation. Drilling equipment analysis, casing design, and drilling fluid properties. Application of modern computer-based analysis and design methods. *Prerequisites:* ES 2310, ES 2330, or consent of the instructor.

3265. Drilling Fluids Laboratory. 2. Measurements of physical and chemical properties of drilling fluids and computer simulations of drilling operations. Includes experiments on drilling fluid rheological properties, mud weight, water loss, and gel strength. Filtration at high temperature and pressures. *Prerequisites:* ES 2310, 2330, PETE 3255 (concurrently).

3715. Production Engineering. 3. Provides elements for design and analysis of surface production processes, including fluid separation, pumping and compression, measurement and treatment of production fluids, basic design of artificial lift system, and analysis and optimization of production systems. *Prerequisites:* PETE 2050, ES 2310, ES 2330.

3725. Well Bore Operations. 3. Covers many facets of completion and intervention technology. The material progresses through each of the major design, diagnostic and intervention technologies, ending with effect of operations on surface facilities and finally plug and abandonment requirements. *Prerequisites:* PETE 2050, ES 2410.

3900. Undergraduate Research in Petroleum Engineering. 1-6 (Max. 6). Students carry out research appropriate to undergraduates, under faculty supervision. May be taken more than once. *Prerequisites:* junior standing in petroleum engineering or consent of instructor.

4000. Environment, Technology and Society. 3. [C2, G1◆▶(none)] Explores relationships among technology, the environment and society. Studies social and humanistic aspects of using current and future technology to understand and solve environmental problems. Cross listed with CHE 4000. *Prerequisites:* junior standing and completion of two university studies science courses (SB, SP, SE).

4030 [3010]. Rock and Fluid Properties. 3. Reservoir rocks - mineralogy, deposition, diagenesis, porosity, permeability, pore space imaging. Coring and core analysis. Intermolecular forces and fluid properties. Fundamentals of wetting and capillarity. Hydrocarbon distribution. Chemistry of crude oils. Oil-brine-rock interactions, formation damage, reservoir wettability, and oil recovery. *Prerequisite:* PETE 2050**.**

4060 [4220]. Flow Through Porous Media. 3. Review of properties of porous media. Relationships of permeability to porosity. Formulation of Fundamental Flow Equation. Constant Rate Solutions. Constant Pressure Solutions. The Principles of Superposition. Transient well testing of oil and gas reservoirs, including drawdown, build-up, faulted systems, interference, drillstem tests, isochronal test analysis. Dual listed with PETE 5060. *Prerequisite:* PETE 3200. (Normally offered fall semester)

4200. Natural Gas Engineering. 3. Studies development of natural gas reservoirs for normal production and as storage fields. Includes back pressure tests, hydrates, pipeline problems, cycling and use of the material balance equation. Also processing of natural gas, including compression, expansion, refrigeration, separation, sour gas treating, sulfur recovery, LNG production and carbon dioxide separation. *Prerequisites:* PETE 2050. (Normally offered fall semester)

4215. Rock Mechanics. 3. Covers rock mechanical properties, stress and strain in rock and rock masses, rock failure mechanisms, thermal-hydraulic-mechanical-chemical (THMC) coupling, and their applications to ground surface subsidence/uplift, borehole instability, and hydraulic fracturing. Dual listed with PETE 5215. *Prerequisites:* ES 2330 and 2410.

4225. Well Test Analysis. 2. Aims to present the fundamental concepts of well test analysis. The mathematical formulations presented are a critical facet of the methodology used in the interpretation. The formation gathered from the interpretation will help analyze, improve, and forecast the potential of the well and the reservoir. *Prerequisite:* PETE 3200.

4250 [3250]. Drilling Engineering. 3. Principles and practices of rotary drilling, including rock mechanics, hydraulics, drilling fluids and hole deviation. Oil and gas drilling equipment models. Drilling fluid tests, casing design. *Prerequisite:* PETE 2050.

4320. Well Log Interpretation. 3. Studies use of various types of open hole logs for quantitative evaluation of formations. *Prerequisites:* PETE 2050. (Normally offered spring semester)

4340. Petroleum Economics. 3. Applies principles of economics to petroleum properties. Studies taxation, present worth, rate of return, payout and decisions under uncertainty. *Prerequisite:* PETE 3200. (Normally offered fall semester)

4720. Petroleum Engineering Design I. 3. [(none)◆▶WB, O] Design and development of petroleum reservoirs using principles and skills learned in the Petroleum Engineering program. Application of software for design and analysis of the drilling, reservoir and production of petroleum fields. *Prerequisites:* PETE 3200, 3255, 3715 and 3725.

4735. Petroleum Engineering Design II. 4. [(none)◆▶WC, O] Design and development of petroleum reservoirs using principles and skills learned in the Petroleum Engineering program. Application of software for design and analysis of the drilling, reservoir and production of petroleum. A continuation of PETE 4720. *Prerequisite:* PETE 4720.

4810. Unconventional Gas Production. 3. Study of resource base, drilling, completion and production technology, and reservoir characteristics for tight gas sands. Devonian shales, coalbed methane, geopressured aquifers, and hydrates. Case histories and economics are presented in each of these. Dual listed with PETE 5810. *Prerequisite:* graduate status or consent of instructor.

4830. Thermal Recovery. 3. Objective of this course is to examine and explore in depth the theoretical and applied aspects of thermal recovery process of producing hydrocarbons including state-of-the-art review. Dual listed with PETE 5830. *Prerequisite:* Senior standing in petroleum or chemical engineering.

4970. Internship in Petroleum Engineering. 1-6 (Max. 6). Enables credit for students in appropriate engineering activities while serving as interns in an industrial, government, or other setting. *Prerequisites:* Must be involved in a petroleum engineering co-op/internship experience; consent of instructor.

4990. Topics in Petroleum Engineering. 1-6 (Max. 6). Features topics not included in regularly offered classes. Section I is individual study. Other sections are group study by seminar or in class format. *Prerequisites:* PETE 2050 or concurent enrollment.

5010. Transport Phenomena. 3. Examines the modeling of momentum, heat and mass transport. Cross listed with CHE 5010. *Prerequisite:* ES 2330, MATH 2310, and graduate standing in Chemical or Petroleum Engineering.

5015. Secondary Recovery. 3. Conventional secondary recover practices, including: flood patterns, gas injection, waterflooding, and water treatment for water flooding. *Prerequisite:* PETE 3200.

5020. Thermodynamics. 3. Examines molecular thermodynamics of pure materials and mixtures, including phase equilibria and the use of equations of state. Cross listed with CHE 5020. *Prerequisite:* ES 2310 or CHEM 4505.

5030. Reaction Kinetics. 3. An analysis of reactions involving phase boundaries, heterogeneous catalysis, gas-solid systems, and gas-liquid systems. Cross listed with CHE 5030. *Prerequisite:* CHE 4060.

5045. Reactor Design. 3. Examines reactor design techniques, including the use of thermodynamics, kinetics, heat transfer, and mass transfer. Cross listed with CHE 5045. *Prerequisite:* CHE 4060.

5050. Structure and Properties of Porous Media. 3. Introduction to porous materials, pore structure and mineralogy of reservoir rocks. Fundamentals of porosity, permeability, and capillary properties of porous materials. Application to hydrocarbon reservoirs. Cross listed with CHE 5050. *Prerequisite:* graduate standing.

5060. Flow in Porous Media. 3. Review of properties of porous media. Relationships of permeability to porosity. Formulation of the Fundamental Flow equation. Constant Rate solutions. Constant Pressure Solutions. The Principle of Superposition. Transient well testing of oil and gas reservoirs, including drawdown, build-up, faulted systems, interference, drillstem tests, and isochronal test analysis. Dual listed with PETE 4060; cross listed with CHE 5060. *Prerequisite:* PETE 3200 and graduate standing.

5070. Multiphase Flow. 3. A thorough background in the methods of analysis and current developments in gas-liquid, gas-solid, liquid-solid, and gas-liquid-solid flows. Introduction to multiphase flow instrumentation. Identical to CHE 5070. *Prerequisite:* ME 3360 or CHE 3020.

5080. Interfacial Phenomena. 3. Introduction to surface and colloid chemistry, coagulation and flocculation, surface energy and thermodynamics of surfaces, adsorption at interfaces, surface tension, capillarity and wetting, spontaneous imbibition, applications to hydrocarbon reservoirs and oil recovery. Cross listed with CHE 5080. *Prerequisite:* graduate standing.

5100. Topics. 1-3 (Max. 12). Selected topics in petroleum engineering. *Prerequisite:* consent of instructor.

5140. Computational Methods I. 3. First semester of a three-semester computational methods series. Review of iterative solutions of linear and nonlinear systems of equations, polynomial interpolation/approximation, numerical integration and differentiation, and basic ideas of Monte Carlo methods. Comparison of numerical techniques for programming time and space requirements, as well as convergence and stability. Identical to ME 5140, CE 5140, CHE 5140, COSC 5310 and MATH 5310. *Prerequisite:* MATH 3310, COSC 1010.

5150. Topics in Chemical Engineering. 1-3 (Max. 12). Selected topics in chemical engineering. Cross listed with CHE 5150. *Prerequisite:* consent of instructor.

5200. Problems in Petroleum Engineering. 1-3 (Max. 6). Selected topics in petroleum engineering. *Prerequisite:* doctoral student and consent of instructor.

5215. Rock Mechanics. 3. Covers rock mechanical properties, stress and strain in rock and rock masses, rock failure mechanisms, thermal-hydraulic-mechanical-chemical (THMC) coupling, and their applications to ground surface subsidence/uplift, borehole instability, and hydraulic fracturing. Dual listed with PETE 4215. *Prerequisites:* ES 2330 and 2410.

5255. Advanced Drilling Engineering. 3. Principles and practices of advanced topics in oil and gas drilling engineering including advances in directional and horizontal drilling, drilling fluid hydraulics and cuttings transport. Non-Newtonian Fluid Flow Analysis, pore pressures and fracture resistance estimation methods. Application of modern computer-based analysis and design methods. *Prerequisites:* PETE 4250.

5300. Reservoir Simulation. 3. Simulation of petroleum reservoirs, formulation of equations, finite difference methods of solution, data preparation and input, history matching case studies. Dual listed with PETE 4300. *Prerequisite:* PETE 3200 MATH 4440, 2210.

5310. Fundamentals of EOR. 3. The application of physical principles to increasing the recovery from reservoirs. Miscible fluid flooding in-situ combustion, and thermal recovery. Dual listed with PETE 4310. *Prerequisite:* PETE 3200.

5355. Mathematical Methods in Chemical Engineering. 3. Covers mathematical modeling: conservation laws and constitution relationships; partial differential equations (PDEs): the types and analytical solution techniques; applied linear algebra; matrices and Eigen-analysis; numerical solution techniques: finite difference and finite element methods, Newton-Raphson method, and temporal discretization techniques, and linear solution techniques: direct and iterative methods. Cross listed with CHE 5355. *Prerequisites:* MATH 2210, CHE/PETE 3025 or equivalent.

5600. Air Pollution Control. 3. Coverage includes science and engineering of air pollution sources, formation mechanisms, and removal of pollutants including discussion on air pollution effects. Cross listed with CHE 5600. *Prerequisite:* CHEM 1060 or CHEM 1030, MATH 2310.

5810. Unconventional Gas Production. 3. Study of resource base, drilling, completion and production technology, and reservoir characteristics for tight gas sands. Devonian shales, coalbed methane, geopressured aquifers, and hydrates. Case histories and economics are presented in each of these. Dual listed with PETE 4810. *Prerequisite:* graduate status or consent of instructor.

5830. Thermal Recovery. 3. Objective of this course is to examine and explore in depth the theoretical and applied aspects of thermal recovery process of producing hydrocarbons including state-of-the-art review. Dual listed with PETE 4830. *Prerequisite:* Senior standing in petroleum or chemical engineering.

5840. Miscible Processes. 3. Objective is to examine and explore in depth the theoretical and applied aspects of miscible processes of producing hydrocarbons including state-of the-art review. *Prerequisite:* PETE 4010, 5310.

5850. Chemical Enhanced Oil Recovery Processes. 3. Objective is to examine and explore in depth the theoretical and applied aspects of the classification of enhanced oil recovery processes called chemical processes. *Prerequisite:* consent of instructor.

5890. Chemical and Petroleum Engineering Graduate Seminar. 1 (Max. 9). Departmental seminar on current research with formal training for student presentation of technical papers. Cross listed with CHE 5890. *Prerequisite:* graduate standing.

5900. Practicum in College Teaching. 1-3 (Max. 3). Work in classroom with a major professor. Expected to give some lectures and gain classroom experience. *Prerequisite:* graduate status.

5920. Continuing Registration: On Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

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5959. Enrichment Studies. 1-3 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

5960. Thesis Research. 1-12 (Max. 24). Designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. Prerequisite: enrollment in a graduate degree program.

5980. Dissertation Research. 1-12 (Max. 48). Designed for students who are involved in research for their dissertation project. Also used for students whose coursework is complete and are writing their dissertation. *Prerequisite:* enrollment in a graduate level degree program.

5990. Internship. 1-12 (Max. 24). *Prerequisite:* graduate standing.

Department of Civil and Architectural Engineering

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Adjunct Faculty:

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Professors Emeriti:

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Civil Engineering

The mission of the Department of Civil and Architectural Engineering at the University of Wyoming is to:

1. Educate civil and architectural engineers to design, build, operate and manage sustainable human habitat and infrastructure systems for Wyoming and the world.

2. Develop the technical solutions to support sustainable human habitat and infrastructure systems through research, innovation, application, design, and technology transfer.

The civil engineering curriculum begins with a basic education in the physical, engineering, mathematical and computer sciences. This foundation supports further development of engineering topics that prepare the engineer to address critical societal needs. To meet these needs, the civil engineer designs and builds bridges, buildings, dams and hydraulic structures, pipelines and canals, power plants, transportation facilities, sanitary and environmental engineering facilities, surveying and mapping systems, space and ocean platforms, as well as numerous other engineering systems. The civil engineer must also be aware of the social, humanistic, and political aspects of their projects. Therefore, course work in the humanities and social sciences is required to better understand the social aspects of public works. During the last two years of their program, students may pursue several areas of civil engineering or, depending upon their interests, more specialized courses in one or more of the specific technical areas listed below. All students must have a comprehensive design experience.

Civil engineering degree candidates must meet the academic requirements of the college and in addition must have an average GPA of 2.0 (C) in civil and architectural engineering courses attempted at this university.

Structural engineering: Analysis and design of structural systems including buildings, bridges, towers and other structures. Structural engineering also includes the study of solid mechanics and advanced structural materials.

Environmental engineering: Analysis, design and development of engineering systems to provide potable water supplies, treat municipal, industrial and hazardous wastes and protect human health and the environment.

Water resource engineering: Planning, analysis and design of hydraulic and hydrologic systems with respect to watersheds, municipalities, irrigation and drainage, and flood control. Conservation and management of groundwater and surface water are emphasized.

Transportation engineering: Planning, analysis and design of highways, traffic engineering and control, traffic safety, and pavement maintenance, design and rehabilitation.

Geotechnical engineering: Design and analysis of foundations, dams, embankments, slope stability and construction practices in soil and rock.

The civil engineering curriculum prepares the graduate to engage in professional practice, and upon completion of post-graduate requirements, to obtain registration as a Professional Engineer. It also provides the graduate with an excellent preparation for graduate studies in engineering, business or law.

International Engineering Option

Engineering is a global profession and today's engineers must be able to work and interact in a variety of diverse cultural and technical environments. The international engineering option gives civil engineering students an opportunity to study culture and foreign language at the same time as they pursue their engineering degrees.

The option includes at least one semester of study abroad with courses taken in a foreign language. In addition, students may participate in a four-to-five month international internship. Foreign language skills can be earned through a variety of means, including formal university coursework, intensive summer language programs, and previous education.

Foreign language education and the study-abroad experience satisfy the cultural context requirements of the University Studies Program.

CE Objectives

Three to six years after graduation, graduates of the University of Wyoming Civil Engineering Program will:

CE-OB1 Be able to successfully practice the profession of Civil Engineering.

CE-OB2 Be prepared and motivated to accept challenging assignments and responsibilities.

CE-OB3 Demonstrate successful career growth.

CE Outcomes

University of Wyoming Civil Engineering graduates shall:

CE-OT01 Solve problems in mathematics (through differential equations), in calculus-based physics, chemistry, and one additional area of science, and in engineering science.

CE-OT02 Design or select a civil engineering laboratory test to meet a need; conduct the test, and analyze and interpret the results.

CE-OT03 Design a complex system or process to meet desired needs within constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.

CE-OT04 Function effectively as a member of a multi-disciplinary team.

CE-OT05 Solve well-defined engineering problems in four technical areas in Civil Engineering.

CE-OT06 Analyze a complex situation involving conflicting professional and ethical interests, to determine an appropriate course of action.

CE-OT07 Develop and deliver effective verbal, written, and graphical communications.

CE-OT08 Based on a broad education, determine the global, economic, environmental and societal impacts of a specific, relatively constrained engineering solution.

CE-OT09 Demonstrate the ability to learn independently, without the aid of formal instruction.

CE-OT10 Incorporate contemporary issues into the identification, formulation, and solution of engineering problems.

CE-OT11 Apply relevant techniques, skills, and engineering tools to solve problems.

CE-OT12 Explain key concepts and problem-solving processes used in management.

CE-OT13 Explain key concepts and problem-solving processes used in business, public policy, and public administration.

CE-OT14 Explain the role of the leader, leadership principles, and attitudes conducive to effective professional practice of civil engineers.

Civil Engineering Curriculum[4]

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
MATH	2200	4
CHEM	1020	4
ES	1000	1
ES	1060	3
ENGL	1010	3
PEAC	1001	1
	Total Hrs.	**16**

FRESHMAN YEAR: Spring		Hrs.
MATH	2205	4
GEOL 1100, 1500, or LIFE 1010		4
US and WY Constitutions[1]		3
University Studies [(CH, CS, CA)/C, O][2]		3
ES	2110	3
	Total Hrs.	**17**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2210	4
ES	2410	3
ES	2120	3
CE	2070	3
University Studies [(CH, CS, CA)/C, O][2]		3
	Total Hrs.	**16**

SOPHOMORE YEAR: Spring		Hrs.
MATH	2310	3
PHYS	1220	4
ES	2310	3
ES	2330	3
CE	2100	3
	Total Hrs.	**16**

JUNIOR YEAR: Fall		Hrs.
STAT	4220	3
Select four (4) from CE 3100, 3200 3210, 3300, 3400, 3500 3600, 3900		12
University Studies [(CH, CS, CA)/C, O][2]		3
	Total Hrs.	**18**

JUNIOR YEAR: Spring		Hrs.
Math/Science/Technical Electives[3]		3
Select four (4) from CE 3100, 3200 3210, 3300, 3400, 3500 3600, 3900		12
	Total Hrs.	**15**

SENIOR YEAR: Fall		Hrs.
CE	4260	3
ENGL	4010	3
Math/Science/Technical electives[3]		5
Professional development electives[3]		6
	Total Hrs.	**17**

SENIOR YEAR: Spring		Hrs.
Math/Science/Technical electives[3]		5
Professional development electives[3]		9
University Studies [(CH, CS, CA)/C, O][2]		3
	Total Hrs.	**17**

[1]ECON 1200, HIST 1211, HIST 1221, HIST 1251, POLS 1000, or other approved V course.

[2]Elective selection is governed by the approved list in effect when the course is taken. Cultural Context courses [CH/C, CS/C, CA/C] selected must meet University Studies requirements. Requirements for Global Studies [G], Writing [WB], and Diversity [D] may be satisfied concurrently with Cultural Context requirements if an appropriate selection of courses is made. Consult your academic adviser for further information.

[3]To be selected from appropriate department-approved lists. Must include one course that is designated as a Comprehensive Design Experience.

[4]All civil and architectural engineering classes require a grade of C or better in prerequisite courses.

International Engineering Option Curriculum

FRESHMAN YEAR: Fall		Hrs.
MATH	2200	4
CHEM	1020	4
ES	1000	1
ES	1060	3
ENGL	1010	3
	Total Hrs.	**15**

FRESHMAN YEAR: Spring		Hrs.
MATH	2205	4
GEOL 1100, 1500, or LIFE 1010		4
PEAC	1001	1
US and WY Constitutions		3
ES	2110	3
	Total Hrs.	**15**

SUMMER AFTER FRESHMAN YEAR		
First-year foreign language I		4
First-year foreign language II		4
	Total Hrs.	**8**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2210	4
CE	2070	3
ES	2120	3
PHYS	1220	4
Second-year foreign language I		4
	Total Hrs.	**18**

SOPHOMORE YEAR: Spring		Hrs.
MATH	2310	3
ES	2310	3
CE	2100	3
ES	2410	3
Math/Science Technical Elective*		3
Second-year foreign language II		3
	Total Hrs.	**18**

SUMMER AFTER SOPHOMORE YR		
CE	3900	3
ES	2330	3
	Total Hrs.	**6**

JUNIOR YEAR: Study Abroad		Hrs.
CE	3100	3
CE	3200	3
CE	3300	3
CE	3400	3
	Total Hrs.	**12**

JUNIOR YEAR: Internship		Hrs.
International internship		3
ENGL	4010	3
	Total Hrs.	**6**

SENIOR YEAR: Fall		Hrs.
STAT	4220	3
CE	3210	3
CE	3500	3
CE	3600	3
Math/Science/Technical electives*		3
CE	4260	3
	Total Hrs.	**18**

SENIOR YEAR: Spring	Hrs.
Math/Science/Tech Electives*	2
Prof Development Electives*	12
CE 4900	3
Total Hrs.	**17**

*To be selected from the appropriate departmentally approved lists.

Graduate Study

Graduate Programs

An advanced degree in civil engineering is professionally and economically attractive. Advanced degrees are important for professional civil engineers in many specialized areas of civil engineering. Many consulting firms and industrial design groups require advanced knowledge gained from graduate studies. Engineers in such firms often work at the forefront of their profession. UW alumni are involved in design and construction of major projects worldwide.

An advanced degree is also required for careers in university teaching and research. A university career is highly recommended for those motivated students who are interested in becoming leaders in education and in the development of new concepts, processes and inventions.

The Department of Civil and Architectural Engineering offers programs leading to the degrees of master of science and doctor of philosophy. Areas of study in the M.S. and Ph.D. programs include: building mechanical systems engineering, environmental engineering, geotechnical engineering, structural engineering, transportation engineering, and water resources engineering. The department also offers a master of science in environmental engineering in cooperation with the Department of Chemical and Petroleum Engineering. Additional information is available from the department or from the Web page.

Program Specific Admission Requirements

Admission is open to all students holding a bachelor's degree with at least a 3.0 GPA from an accredited engineering curriculum and a GRE combined minimum score of 291 on the quantitative and verbal reasoning, with a minimum score of 148 on the verbal reasoning.

Ph.D. applicants are reviewed with regard to stated interests, objectives and the ability of the department to provide a quality experience for the applicant.

International students must achieve a TOEFL score of 550 on the paper-based, a minimum of 76 on the internet-based or a minimum of 6.0 on the IELTS.

MSCE Quick Start Program

The MSCE Quick Start program in Civil and Architectural Engineering (CAE) is designed to present highly qualified UW students with the opportunity to begin graduate study while they complete their bachelor of science (B.S.) degree in civil engineering or architectural engineering. These students may apply for admission to the Quick Start program during the second semester of their junior year or during their senior year.

This program allows for early planning of the graduate portion of a student's education and provides more flexibility in the number of required courses and the order in which they are taken. The more efficient and better-planned use of time should result in reduction of the time required for obtaining the master of science in civil engineering (MSCE) degree. Students who enter the Quick Start program must accept the primary responsibility for actively planning their programs of study to assure timely completion of their coursework and research programs.

The Quick Start program contains two essential elements:

Qualified students may receive provisional admission to the civil engineering graduate program prior to completing the normal application process. This provisional admission will permit students to make their long-term educational plans earlier in their studies, thus providing enhanced opportunities for course selection and involvement in research.

Students in the program may apply up to six credit hours of 5000-level courses toward both the B.S. and M.S. degree programs. By completing successfully up to six credit hours of graduate classes during their senior year, these students will have demonstrated their ability to do graduate-level coursework as undergraduates, easing their transition to the civil engineering graduate program.

For additional information and an application form, please contact the CAE graduate program coordinator at (307) 766-2390 or stop by 3074 Engineering Building.

Program Specific Degree Requirements

Master's Program

Areas of study in the master of science program include: building mechanical systems engineering, environmental engineering, geotechnical engineering, structural engineering, transportation engineering, and water resources engineering. The master of science degree in each of these areas requires completion of 12 to 18 hours of engineering courses related to the particular program area.

Plan A (thesis)

The degree of master of science, Plan A, requires a minimum of 26 hours of coursework and a minimum of 4 hours thesis research in addition to the minimum requirements set forth in this bulletin.

Early in the program, the student must submit a program of study listing coursework for approval by the departmental graduate studies committee (CEGS), and the department head.

Plan A is required of all state or contract supported graduate assistants.

Plan B (non-thesis)

Requires a minimum of 30 hours of coursework and a Plan B paper, in addition to the minimum requirements set forth in this bulletin.

Early in the program, the student must submit a program of study listing coursework and the course number that the Plan B paper covers for approval by the CEGS and the department head.

Doctoral Program

Areas of study in the doctor of philosophy program include: building mechanical systems engineering, environmental engineering, geotechnical engineering, structural engineering, transportation engineering, and water resources engineering.

Minimum of 56 hours of coursework beyond the baccalaureate, 44 hours of which must be 5000-level (graduate-level) courses or the equivalent, and concentrated independent research leading to an acceptable dissertation.

In addition to expertise in the specific dissertation topic, the candidate must demonstrate competence in two or more research areas that will help to insure a high-quality dissertation acceptable to the student's graduate committee.

Subject to department and university requirements, the student's coursework is arranged by consultation between the student, his or her adviser, and his or her committee, and must also be approved by the CEGS and by the department head.

Coursework is defined in a program of study that should be filed by the end of the second semester of the Ph.D. program.

At a time near the completion of formal coursework, the student is required to take and pass a preliminary examination on the Ph.D. coursework and, as a part of the examination, is required to present a written and oral dissertation proposal to his or her committee for approval.

Finally, the student must demonstrate research competence in an oral defense of the dissertation and must submit an acceptable written version of the dissertation to his or her graduate committee in a timely manner to meet deadlines. In addition, the student is to meet the minimum requirements set forth in this bulletin.

Civil Engineering (CE)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

2050. Real Property Law. 3. Covers all major areas of real property law, including the nature of real property, types of ownership, real estate contracts, title and insurance, financing, landlord and tenant, land use, environmental law and regulation. An understanding of real property law is fundamental to understanding boundary law. *Prerequisites:* none.

2070. Engineering Surveying. 3. Principles of measurements of distances, elevation and angles. Basic error theory in measurement and calculations. Traverse field techniques and office calculations. Basic principles of surveying and map making. *Prerequisite:* significant surveying experience or ES 1060.

2072. Engineering Surveying Lecture. 2. Principles of measurements of distances, elevation and angles. Basic error theory in measurement and calculations. Basic principles of surveying and map making. *Prerequisite:* a working knowledge of algebra and trigonometry.

2073. Engineering Surveying Laboratory. 1. Field surveying activities consisting of traversing, differential leveling, construction staking and gathering topographic data. *Prerequisite:* CE 2072.

2074. Ethics for the Professional Surveyor. 1. Introduction to the common ethical and moral issues facing professional surveyors in modern practice. *Prerequisite:* CE 2070.

2076. Records Research for Surveyors. 3. Introduced to the public, quasi-public, and private depositories of recorded and non-recorded documents that establish land ownership boundaries, easement boundaries, and land use rights and restrictions in both the Public Land Survey System and the Colonial States. Assignments will require work to be conducted during depositories' normal business hours. **Prerequisites**: none.

2083. GIS for Surveyors. 3. Covers the basic concepts of geographic information systems, the methods and software used to implement them, and their applications to surveying and analysis of other surveying problems. *Prerequisites:* ES 1060 or 1061 and either CE 2070 or CE 2072.

2085. Public Land Surveys. 3. Basic fundamentals of the Public Land Survey System (PLSS), dependent and independent resurveys, survey plats, "bono fide rights", riparian boundaries, non-rectangular entities, corner evidence and the role of the modern day surveyor. *Prerequisites:* CE 2070 or equivalent.

2088. Writing Land Descriptions. 2. Historical and current issues for land description writing and usage for the practicing surveyor. Relationship between written descriptions and field survey data, interpreting old descriptions and the structure principles of description. *Prerequisite:* CE 2070.

2089. Basic Geodesy for Today's Land Surveyor. 2. The history of geodesy including measurement techniques, coordinate systems, ellipsoids, and datums is reviewed. The modern geodetic and Cartesian coordinates systems, as well as the differences between grid and ground coordinates systems, and the current geodetic and Cartesian coordinate systems available today are discussed. *Prerequisites:* none.

2090. GPS for Land Surveyors. 4. From fundamental theory to practical application and advanced technologies, this class covers all aspects of GPS needed to understand and use GPS as a land surveyor including the basics of GPS technology, common hardware, surveying methods, survey design, planning and observing, real-time kinematics and DGPS. *Prerequisites:* CE 2089.

2100. Civil Engineering Systems. 3. The practice of civil engineering is used as a model to introduce how the different areas of civil engineering are interested. Uses examples from several civil engineering projects to introduce computer-aided drafting and design. *Prerequisites:* ES 2110 and CE 2070.

3100. Civil and Architectural Engineering Practice. 3. Civil and architectural engineering practice from project inception through construction documentation. Topics include: codes, marketing, specifications, budgeting, contracts, subcontracting, registration, construction planning, scheduling, bidding, liability, insurance, and bonding. Cross listed with ARE 3100. *Prerequisites:* CE 2100 or ARE 2100.

3200. Structural Analysis I. 3. [(none)◆▶WB] Introductory design and analysis topics in loads on building, stress and displacement analysis of structures, including beams, trusses and frames, classical flexibility and stiffness methods. Cross listed with ARE 3200. *Prerequisite:* ES 2410.

3210 [2210]. Civil Engineering Materials. 3. [(none)◆▶WB] Laboratory investigation and design of materials used in civil engineering: metals, masonry, concrete and timber. Nondestructive evaluation of materials. Analysis and presentation of data, including various types of written reports and oral presentations. Cross listed with ARE 3210. *Prerequisites:* WA and ES 2410.

3300 [4320]. Hydraulic Engineering. 3. Develops analysis, design and modeling techniques for incompressible pipe flow, steady uniform and gradually varied open channel flow, and hydraulic structures. *Prerequisite:* ES 2330.

3400. Introduction to Environmental Engineering. 3. An introduction to the major topics in environmental engineering. Focus areas include water supply, wastewater treatment, air pollution control and solid and hazardous waste management. Quantitative aspects and engineering solutions to problems are emphasized. *Prerequisites:* MATH 2205 and CHEM 1020 or equivalent.

3500 [4500]. Transportation Engineering. 3. Introduction to the major topics in Transportation Engineering. Focus areas include roadway and non-motorized facility design, traffic operations, transportation planning, and pavement materials and design. *Prerequisite:* CE 2070.

3600 [4600]. Soil Mechanics I. 3. A study of soil and the properties which influence its usefulness as an engineering material. Principles governing movement of soil, water and propagation of stresses through soil masses are studied. *Prerequisite:* ES 2410.

3710 [4710]. Route Surveying. 3. Principles of route location and design. The theory of circular, parabolic and spiral curves; highway and railway geometric design; area and volumes of earthwork; and mass diagrams. *Prerequisite:* CE 2070 or equivalent.

3720 [4720]. Advanced Surveying. 4. Advanced topics in surveying computations and procedures, including traverse error analysis, topographic surveying, mapping, astronomical observations, coordinate geometry applications, introduction to geodesy, state plane coordinates and concepts of least squares analysis of survey adjustments. *Prerequisite:* CE 2070 or equivalent.

3740. Survey Boundary Control and Legal Principles. 2. This course in boundary law addresses the fundamental principles of real property as applied to land surveying and related professions. Discussion and applications center on practical situations and concepts commonly encountered while conducting boundary surveys and the determination of the extent of ownership rights. Students explore the scope of the surveyors' judiciary role in real property ownership. Primarily offered through the Outreach School. *Prerequisite:* CE 2070 or equivalent.

3750. Surveying Evidence and Procedures for Boundary Location. 2. A practical and working guide to understanding survey evidence and the laws of boundary location for efficient, accurate boundary determination. This material aids in the elimination of errors in location of land boundaries. The surveyor's liability and statutes of limitations are explored in depth. Also included are discussions of the surveyor's role in court. Normally offered only through the Outreach School. *Prerequisite:* CE 2070 or equivalent.

3760. Applied Least Squares Adjustments. 4. The use of applied statistics in land surveying, error propagation in polygon and link traverses, discussion of positional tolerances and an introduction to least squares adjustments using StarNet and VectorNT software. *Prerequisite:* CE 3720.

3900 [4900]. Engineering Economics and Professional Ethics. 3. A study of decision making based on economic criteria. Includes time value of money, present value, annual value and rate of return methods; incremental graphics, depreciation methods, income tax evaluations; replacement and sensitivity analysis; and governmental financing. A review of social and professional ethics. Includes the engineer in society, business and profession with case studies of professional responsibility and ethics decisions. *Prerequisite:* junior standing.

4100. Civil Engineering Applications in GIS. 3. Concepts of Geographic Information Systems, the methods and software used to implement them, and their applications to solve civil engineering problems. *Prerequisites:* CE 2070 and senior standing.

4200. Structural Analysis II. 3. Stress and displacement of indeterminate structures. Determination of loads on buildings. Matrix stiffness methods. Cross listed with ARE 4200 *Prerequisite:* ARE/CE 3200.

4250. Structural Steel Design. 3. Design of structural components and applications utilizing steel. Cross listed with ARE 4250. *Prerequisite:* ARE/CE 4200 or concurrent enrollment.

4260. Structural Concrete Design. 3. Design of structural components and applications utilizing reinforced concrete. Cross listed with ARE 4260. *Prerequisite:* ARE/CE 3200.

4280. Reinforced Masonry Design. 3. Design of structural components in reinforced masonry buildings, including walls, columns, beams and connections. Particular attention is paid to current codes, specifications and analysis. Cross listed with ARE 4280. *Prerequisites:* ARE/CE 4260 and concurrent enrollment in ARE/CE 4200.

4290. Structural Timber Design. 3. Design of structural components and applications utilizing timber. Cross listed with ARE 4290. *Prerequisite:* CE 4200 or concurrent enrollment. (Normally offered spring semester)

4350 [4810]. Design of Hydraulic Engineering Systems. 3. For seniors and graduate students in civil engineering who desire to learn design of municipal water distribution and wastewater collection (storm and sanitary) systems by combining principles from hydraulics, hydrology and environmental engineering course work into an integrated design approach. *Prerequisite:* CE 3300.

4400. Design of Water Treatment Facilities. 3. A theoretical and practical design course for municipal potable water treatment systems. Major emphasis includes health criteria, operational control procedures, primary and secondary drinking water regulations, as well as the latest treatment design standards for production of drinking water. *Prerequisite:* CE 3400.

4410. Design of Wastewater Treatment Facilities. 3. A theoretical and practical design course for treatment of municipal wastewaters. Major areas of emphasis include waste characterization and physical, chemical and biological unit processes. *Prerequisite:* CE 3400.

4430 [3420, 2420]. Environmental Engineering Chemistry. 3. Focus includes inorganic, organic, physical, equilibrium, biochemistry, colloidal, and nuclear chemistry with an emphasis on the problems/solutions encountered by environmental and civil engineers. *Prerequisite:* CE 3400.

4440. Solid Waste Engineering. 3. Municipal solid waste characteristics and quantities, collection, landfills, processing of municipal solid

waste, materials separation, combustion and energy recovery, and biochemical processes with an emphasis on materials flow. Integrated solid waste management principles are also discussed. *Prerequisite:* CE 3400.

4510 [5510]. Pavement Design for Airports and Highways. 3. Designing flexible and rigid pavements for highways and airports. Topics include pavement materials and common uses, soil stabilization, quality control of materials, pavement design procedures. Dual listed with CE 5510. *Prerequisite:* CE 3500 or 3600.

4530. Traffic Engineering: Operations. 3. Basic characteristics of traffic, such as drivers, vehicles, volumes, speeds, delay, origins and destinations, intersection performance, capacity, termination and accidents; techniques for making traffic engineering investigations; traffic laws and ordinances, regulations, design and application of signal systems; curb parking control; enforcement and traffic administration; and public relations. Dual listed with CE 5530. Prerequisite: CE 3500.

4555 [4520]. Geometric Design of Highways. 3. Criteria controlling geometric design of highways including design speed, design volume, vehicle requirements and capacity design standards for different highway types; design of sight distance, alignment, grade; cross-section design; access control, frontage roads; intersection design elements, and design of intersections and interchanges. Students may not receive credit for both CE 4555 and CE 5555. Dual listed with CE 5555. *Prerequisite:* CE 3500.

4610 [5610]. Foundation Engineering. 3. Site characterization and soil properties. Includes bearing capacity, stress distribution, settlement. Design of shallow and deep foundations. *Prerequisite:* CE 3600.

4620. Soil and Rock Slope Engineering. 3. Covers the topic of engineered slopes for civil infrastructure. Topics include engineering and geologic classification of landslides; field investigations; soil and rock strength properties for stability analysis; analytical and numerical methods for analysis of slope stability; design of engineered stabilization systems. *Prerequisites:* CE 3600.

4630. Geotechnical Engineering. 3. Covers topics in design and analysis of soil site investigation and construction, such as instrumentation, soil improvement, water control and remedial measures. *Prerequisite:* CE 3600.

4700. Coastal Water Boundaries. 3. The physical and legal issues involved with property rights of lands abutting tidal waters, a review of the Public Land Survey System, the Submerged Lands Act and the Swamp and Overflowed Lands Act. Includes case law research. P*rerequisites:* CE 3740, CE 3750.

4730. Inland Water Boundaries. 3. Introduces the physical and legal issues involved in locating property rights associated with lands that abut non-tidal, navigable and non-navigable rivers and lakes. The property rights which attach to, as well as the limitations placed on these riparian parcels will be examined and discussed with respect to statutory, administrative and case law. *Prerequisite:* CE 4700.

4740 [2086]. Advanced Public Land Surveys. 4. Advanced topics in situations and problems in the Public Land Survey system, with discussion of major court cases involving everyday applications to surveyors. 1975 BLM casebook and other sources of survey reference. *Prerequisite:* CE 2085 and 3740.

4750. Remote Sensing/Photogametry for Surveyors. 3. Procedures and methods used for deriving metric information from photographs, analog processes for using aerial photographs in production of topographic maps, flight planning, and cost estimation in aerial mapping work. Introduction to photocoordinate measurement devices and their calibration. Mathematics of modern photogrammetry. *Prerequisite:* CE 3760.

4800. Hydrology. 3. Analysis of elements of the hydrologic cycle and design with emphasis on precipitation, evapotranspiration, infiltration, runoff and groundwater. Precipitation/Runoff relationships, routing methods, flood prediction, groundwater yield and drawdown in unconfined and confined aquifers, unsteady well behavior, and method of images are also introduced. *Prerequisite:* CE 3300.

4820 [AGRE 4200]. Groundwater and Drainage Engineering. 3. Principles and basic equations associated with saturated and unsaturated flow in soils describing groundwater and drainage flow will be developed. Design and analysis of surface and subsurface drainage systems will occur for steady and transient flow. *Prerequisite:* ES 2330.

4900. Comprehensive Design Experience in:_____. 1-4 (Max. 4). Concentrated, comprehensive design course focusing on one or more subdisciplines within civil engineering. See your departmental adviser for further information and requirements. *Prerequisites:* senior standing in civil engineering; concurrent enrollment in the designated companion course.

4920. Senior Civil Engineering Problems. 1-3 (Max. 6). A study of current engineering problems that are applicable to civil engineering either on an individual basis or for small seminar type groups. *Prerequisite:* senior standing or approval of department head.

4959. Enrichment Studies. 1-4 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may NOT be included in an undergraduate or graduate program of study for a degree or for credit towards a certificate program. *Prerequisite*: consent of instructor.

4970. Wyoming D.O.T. Design Squad Cooperative Experience. 3. Experience with Wyoming Department of Transportation design procedures and fundamentals. Participation in development of design documents used to construct actual projects. Offered S/U Only. *Prerequisites:* selection for Laramie Design Squad employment and consent of department head.

4975. Civil and Architectural Engineering Internship. 1-3 (Max. 3). Students who receive progressive engineering during an extended work period (>30 weeks) may present a proposal for internship work one month prior to the end of the semester before the experience. Application may be approved by CE/ARE curriculum committee prior to start. Completion report will determine hours of pass/fail approved. *Prerequisite:* junior standing.

5000. Solid Mechanics I. 3. The first in a sequence of two introductory courses in solids mechanics. It includes elements of continuum mechanics, in addition to the introduction of elasticity theory (limited to plane problems), as well as elements of viscoelasticity and plasticity. Cross listed with ME 5000. *Prerequisites:* CE 3200 or ME 3010 and MATH 2310.

5010. Advanced Mechanics of Materials. 3. Elements of elasticity, unified approach to strength of structural members design and failure criteria; basic concepts of fracture mechanics; stress concentration factors; treatment of torsion, bending, axial and shear in structural members including plastic effects; bending of flat plates. *Prerequisite:* ME 3010 or CE 3200, MATH 2310.

5040 [5020]. Introduction to Finite Element Analysis. 3. An introduction to the theory and application of finite elements to the solution of various problems with emphasis on structural mechanics. Includes development of the underlying matrix equations, the treatment of element generation and properties, and implementation of boundary conditions. Cross listed with ME 5040. *Prerequisite:* MATH 2310 and (CE 4200 or ARE 4200 or ME 3010).

5045. Advanced Finite Element Analysis. 3. Advanced topics in finite element analysis with emphasis on mathematical foundations of the method, numerical algorithms for software

implementation, and analysis of problems with material and geometric nonlinear behavior. Cross listed with ME 5045. *Prerequisite:* ME 4040 or ME 5040 or CE 5040.

5140. Computational Methods in Applied Sciences I. 3. First semester of a three-semester computational methods series. Review of iterative solutions of linear and nonlinear systems of equations, polynomial interpolation/approximation, numerical integration and differentiation, and basic ideas of Monte Carlo methods. Comparison of numerical techniques for programming time and space requirements, as well as convergence and stability. Identical to ME 5140, PETE 5140, CHE 5140, COSC 5310 and Math 5310. *Prerequisite:* Math 3310, COSC 1010.

5200. Advanced Structural Analysis. 3. Analysis of framed structures with stiffness-based matrix methods including plane trusses, frames, and grid systems and space trusses and frames. Column, beam, beam-column and frame stability. Geometric and material nonlinearities of framed structures. Plastic analysis and moment-curvature relationships. Computer applications are emphasized. *Prerequisite:* CE 4200 or equivalent.

5220. Structural Dynamics. 3. Introduction to general structural dynamics, general dynamic loading, generalized coordinated and nonlinear structural response, linear and nonlinear response spectra, multiple degree of freedom systems, continuous systems, and discretization of continuous systems. Introduction to seismic load specifications. *Prerequisite: CE 4200 or equivalent and MATH 2310.*

5230. Advanced Materials. 3. The objective of this course is to introduce the graduate student to the behavior of various materials found in typical structural engineering applications and to the mechanics of obtaining materials properties and structural response. *Prerequisite:* CE 4260.

5240. Structural Systems Design. 1-5 (Max. 6). A comprehensive design course for steel and reinforced concrete building structures. Topics include preliminary design, selection of framing systems, braced and unbraced frames, stability effects and nonlinear behavior. Students use case studies to develop design alternatives. *Prerequisite:* CE 4200, 4250, 4260.

5255. Advanced Steel Design 3. A comprehensive design course for steel building structures. Topics include preliminary design, selection of framing systems, braced and unbraced frames, stability effects and nonlinear behavior. Includes building design project for seismic regions. *Prerequisites*: grade of C or better in CE or ARE 4250.

5260. Prestressed Concrete Design. 3. This is a classical course on prestressed and precast concrete. The subject focuses on the principles, behavior and performance of prestressed and precast concrete. Topics include flexure, shear, and axial load, construction and fabrication issues, and applications. The course complements CE 4260. *Prerequisite:* CE 4260.

5270. Highway Bridge Engineering. 3. A study of the analysis, design and rating of highway bridges, including consideration of dead and vehicular loads, analysis of typical systems, service, fatigue and ultimate strength behavior, rating of existing bridge design, and bridge operations. Composite and non-composite steel and concrete bridges are considered. Includes investigations that require field trips outside the schedule class times. Contemporary issues are routinely discussed. Prerequisites: CE 4250 and 4260.

5280. Behavior of Reinforced Concrete. 3. Broad-based coverage of the behavior of concrete, both at the member and structure level. The course will have no assigned text, although students will be expected to have an undergraduate concrete design textbook and a current ACI Code. Readings will include a number of technical papers in each area covered. Emphasis will be on the background of the code, code development, and investigative techniques. *Prerequisite:* CE 4200 and 4260.

5290. Earthquake Engineering. 3. Second course in a series to design earthquake resistant structures. Topics include interpreting code requirements, calculating design forces on structures, evaluating inelastic behavior of structures, understanding how materials behave and advances in earthquake engineering. *Prerequisite:* CE 5220.

5300. Open-Channel Hydraulics. 3. Analysis and design of steady, uniform, gradually varied and spatially varied flow in open channels. Emphasis on basic fluid flow equations associated with natural and man-made open channels. *Prerequisite:* CE 3300.

5310. Hydraulics of Closed Conduits. 3. Pipe transmission and distribution systems design including flow control, flow measurement, energy dissipation, pump selection, transients, and cavitation. *Prerequisite:* CE 3300.

5330. Design of Hydraulic Structures. 3. Basic hydraulic principles and design of man-made channels. Analysis and design of control and regulating devices and measurement devices used in water resources systems. *Prerequisite:* CE 3300.

5400. Water Treatment. 3. Advanced theory and practice of collection, purification, and distribution of potable water; special emphasis on purification techniques, and plant requirements and design. *Prerequisite:* CE 4400.

5410. Advanced Biological Wastewater Treatment. 3. Theory and practice of advanced biological treatment processes for municipal and industrial wastewaters, sludges, groundwater bioremediation and solid waste. Emphasis is on fundamental principles applied to the design and control of existing processes and the development of innovative systems. Cross listed with CHE/ENVE 5410. *Prerequisites:* consent of instructor.

5425. Environmental Engineering Microbiology. 3. Development of microbiology for environmental engineering applications. Introduction to bacteria, fungi, protozoa and viruses with particular focus on pathogenicity and practical metabolic capabilities for waste treatment and remediation. Also examines the basis and pathways of important biochemical reactions including nitrification, hydrogen fermentation, dehalogenation and methanogenesis. *Prerequisite:* consent of instructor.

5435. Environmental Transport Processes. 3. Designed for graduate students and engineering seniors interested in the principles of mass transport and their application to environmental systems. Deals with the hydrodynamics of mixing and transport, as well as the interaction of mixing and various reaction rate processes. Applications include water and wastewater treatment, groundwater pollution, and transport and mixing in rivers, lakes and reservoirs. *Prerequisite:* MATH 2310 and ES 2330.

5445. Hazardous Waste Site Remediation. 3. The contamination of soil, air, and groundwater by improper disposal of hazardous wastes is covered. Control and cleanup of contaminated groundwater plumes, treatment of polluted soils and soil gases is emphasized. Case studies are extensively used. Prerequisite: CE 3400 and consent of instructor.

5450. Advanced Physical-Chemical Treatment. 3. A study of physical and chemical processes for treatment of water and waste water. Cross listed with ENVE 5450. *Prerequisite:* CE 4400.

5455. Project Management for Environmental Engineering. 3. Covers the fundamentals of project management as applied to the environmental remediation field. Emphasis will be placed on project organization, work breakdown structures, life cycle management project implementation and control, and the

integration of individual projects into the overall project management framework. *Prerequisite:* CE 3400.

5460. Industrial Waste Treatment. 3. A critical study of the sources and treatment of various industrial wastewaters is covered, including the regulatory framework establishing treatment goals. Case studies of various industries are used to illustrate methods of volume and strength reduction. Design of unit operations and processes peculiar to industrial waste treatment is emphasized. *Prerequisite:* CE 5410.

5510. Pavement Design for Airports and Highways. 3. Designing flexible and rigid pavements for highways and airports. Topics include pavement materials and common uses, soil stabilization, quality control of materials and pavement design procedures. Dual listed with CE 4510. *Prerequisite:* CE 3500 or 3600.

5530 [5520]. Traffic Engineering: Operations. 3. Basic characteristics of traffic, such as drivers, vehicles, volumes, speeds, delay, origins and destinations, intersection performance, capacity, termination and accidents; techniques for making traffic engineering investigations; traffic laws and ordinances, regulations, design and application of signal systems; curb parking control; enforcement and traffic administration; and public relations. Dual listed with CE 4530. *Prerequisite:* CE 3500.

5535. Engineering Decision Making. 3. A study of engineering decision-making techniques based on monetary and non-monetary criteria. Includes benefit-cost analysis, sufficiency ratings and sensitivity and risk analysis; mathematical programming and optimization models; multi-attribute and multi-objective decision-making methods; and management systems. *Prerequisite:* CE 3900.

5540. Traffic Control. 3. Planning, designing, and operating transportation facilities to optimum efficiency using traffic control devices. Topics included are traffic flow theory; pavement markings, signing, and signal design; computer design of signal systems using linear and network models; traffic control in construction areas. *Prerequisite:* CE 3500 and ES 2110.

5545. Transport Network Analysis. 3. Traffic assignment and network modeling techniques; deterministic and stochastic user equilibrium assignment; mathematical programming formulations and solution algorithms; extensions to basic models; and applications to roadway pricing and other planning scenarios. *Prerequisite:* graduate standing in civil engineering.

5555. Geometric Design of Highways. 3. Criteria controlling geometric design of highways including design speed, design volume, vehicle requirements and capacity design standards for different highway types; design of sight distance, alignment, grade; cross-section design; access control, frontage roads; intersection design elements; and design of intersections and interchanges. CE 5555 students are required to do an additional integrated design term project using design software. Students may not receive credit for both CE 4555 and CE 5555. Dual listed with CE 4555. *Prerequisites:* CE 3500.

5560. Traffic Safety. 3. Safety design and operational practices for streets and highways including safety improvement programs, design of barrier systems, bicycle and pedestrian consideration; access control; safety evaluation; and measures of effectiveness. *Prerequisite:* CE 3500 and STAT 4220.

5570. Transportation Planning. 3. Short and long-range transportation planning; land-use planning, travel behavior and transportation studies including demand forecasting; parking and transit studies; highway and street planning; and freight transportation and multimodel planning. *Prerequisite:* CE 3500.

5575. Intelligent Transportation Systems. 3. The use of Intelligent Transportation Systems (ITS) to improve the safety, efficiency, reliability, and/or security of transportation systems. Covers ITS applications, technologies, deployment issues, and system performance in both urban and rural environments. *Prerequisites:* CE 3500.

5585. Pavement Management Systems. 3. A study of the systems that a transportation agency may utilize to manage the pavement in their road network. History and purpose of pavement management are studied as well as hot to make objective pavement management decisions. The distinction between project-level and network-level management concerns is explored and the implementation of a pavement management system is studied. Finally, methods for utilizing the information from the management system is studied. *Prerequisite:* CE 3500.

5590. Pavement Materials. 3. Selecting materials for highway construction, testing aggregates and bituminous materials, designing and testing asphalt mixtures; and recommending maintenance and rehabilitation strategies for deteriorated pavements. *Prerequisite:* CE 3500.

5620. Earth Retaining Structures and Slope Stability. 3. Earth pressure theories. Design of rigid and flexible earth retaining walls and braced excavations. Analysis, design, and control of natural and man-made slopes. *Prerequisite:* CE 3600.

5700. Civil Engineering Problems I. 1-3 (Max. 6). A special course, designed to make possible the study and investigation of problems or phases of civil engineering selected to fit the needs of the students. *Prerequisite:* consent of instructor.

5710. Civil Engineering Seminar I. 1-3 (Max. 6). A seminar type class furnishing motivation for advanced study of current problems in broad field of civil engineering by means of library research, study of current literature, and carefully guided class discussion. *Prerequisite:* consent of instructor.

5720. Civil Engineering Problems II. 1-3 (Max. 6). A special course designed to make possible the study and investigation of problems or phases of civil engineering selected to fit the needs of the student. *Prerequisite:* consent of instructor.

5730. Civil Engineering Seminar II. 1-3 (Max. 6). A seminar-type class furnishing motivation for advanced study of current problems in the broad field of engineering by means of library research, study of current literature, and carefully guided class discussions. *Prerequisite:* consent of instructor.

5785. H.T. Person Seminar. 3. Special topics in engineering as presented by the H.T. Person distinguished professor. *Prerequisite:* graduate standing.

5810. Groundwater Hydrology. 3. Laws governing the movement, recharge, and production of underground water with special emphasis on techniques and methods for analysis and modeling for development of groundwater resources. *Prerequisite:* CE 4800.

5820. Design of Small Earth Dams. 3. Develop understanding, analysis, design and construction techniques for all components considered in small earth dam design. integration of hydrology, hydraulics and soil mechanics into a sound dam design. Dam design will be emphasized from foundation through embankment. *Prerequisite:* CE 3300, 3600 and 4800 or concurrent enrollment.

5830. Flow in Porous Media. 3. Examines fluid (liquid, gas, vapor) and heat flow in porous media and its effects specifically in soil. Near surface effects (impibation, infiltration and evaporation) is emphasized. Analytic and numerical solution techniques will be developed. *Prerequisite:* CE 5810 or consent of instructor.

5860. Soil Erosion and Conservation. 3. Physical principles of soil erosion by wind and water, computer simulations of erosion, selection and design of erosion control practices and structures. *Prerequisite:* CE 4300, CE 4800.

5865. Deterministic Hydrology. 3. Philosophy of modeling, hydrologic model formulation and design; lumped, semi-distributed, and physics-based hydrologic models for watershed- and landscape-scale predictions; process-level mathematical and numerical descriptions and coupling; model calibration, testing, and validation; parameterization, numerical approximations of flow equations; scale effects, modeling ethics. *Prerequisite:* CE 4800.

5870. Water Resources Engineering. 3. Study in water resource planning and design and problem solving applying engineering principles and procedures. Western United States water problems are emphasized, including user completion, reallocation, consumptive use, water development, conservation, conveyance losses, and return flows. *Prerequisite:* CE 3300.

5875. Probalistic Hydrology. 3. Introduction to the language, methods and tools in systems analysis in stochastic hydrologic modeling; parameter estimation; sensitivity analysis; optimization schemes; uncertainty analysis; probabilistic forecasting; state-space modeling with Kalman filtering, and data assimilation. *Prerequisite:* CE 4800.

5880. Advanced Hydrology. 3. Advanced hydrologic analysis of floods, sediment, water utilization, flow routing, and the application of special hydrologic problems. *Prerequisite:* CE 3300 and CE 4800.

5885. Hydrometeorology. 3. Global radiation budget, global hydrologic cycle, precipitation formation, occurrence and remote sensing, snow melt, evapotranspiration, interception, infiltration and runoff generation mechanisms, overland flow, land surface modeling, stream routing. *Prerequisite:* CE 3300.

5900. Practicum in College Teaching. 1-3 (Max. 3). Work in classroom with a major professor. Expected to give some lectures and gain classroom experience. *Prerequisite:* graduate status.

5920. Continuing Registration: On Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5940. Continuing Registration: Off Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5959. Enrichment Studies. 1-3 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

5960. Thesis Research. 1-12 (Max. 24). Graduate level course designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. *Prerequisites:* Enrolled in a graduate degree program.

5980. Dissertation Research. 1-12 (Max. 48). Designed for students who are involved in research for their dissertation project. Also used for students whose coursework is complete and are writing their dissertation. *Prerequisite:* enrolled in a graduate level degree program.

5990. Internship. 1-12 (Max. 24). *Prerequisite:* graduate standing.

Architectural Engineering

Architectural Engineering is a rapidly expanding profession that deals with the myriad aspects of buildings and their design, construction and operation. Architectural engineers are typically specialists, responsible for the design and integration of such building elements as the structural, plumbing, fire protection, heating and air conditioning, or lighting and electrical systems. The curriculum in architectural engineering is designed to acquaint students with the various aspects of building design and construction and exposes them to a variety of courses dealing with different building materials and systems. The curriculum also includes course work in the humanities and social sciences, both to enrich the student's academic experience and assist in dealing with and contributing to society. The program leads to a Bachelor of Science in Architectural Engineering, preparing graduates to engage in practice as Professional Engineers upon completion of post-graduate registration requirements. Graduate work with emphasis in Architectural Engineering leading to a Master of Science and Doctor of Philosophy degree is offered through the Civil and Mechanical Engineering Programs. Additionally, advanced study can also be pursued in allied areas such as architecture, business or other engineering fields.

Students choose an area of emphasis in either structural or mechanical systems and select courses from approved electives, usually beginning their elective sequence in the second semester of their junior year. Consult with the Civil and Architectural Engineering Department for current elective lists.

Architectural engineering degree candidates must meet the academic requirements of the college and in addition must have an average GPA of 2.0 (C) in civil and architectural engineering courses attempted at this university.

Architectural Engineering Objectives

Three to six years after graduation, graduates of the University of Wyoming Civil Engineering Program will:

ARE-OB1 Be able to successfully practice the profession of Architectural Engineering.

ARE-OB2 Be prepared and motivated to accept challenging assignments and responsibilities.

ARE-OB3 Demonstrate successful career growth.

ARE Outcomes

University of Wyoming Architectural Engineering graduates shall:

ARE-OT01 Solve problems in mathematics (through differential equations), in probability and statistics, in calculus-based physics and general chemistry, and in engineering science.

ARE-OT02 Design or select an engineering laboratory test to meet a need; conduct the test, and analyze and interpret the results.

ARE-OT03 Design a complex system or process to meet desired needs within constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.

ARE-OT04 Function effectively as a member of a multi-disciplinary team.

ARE-OT05 Solve well-defined engineering problems in two technical areas in Architectural Engineering.

ARE-OT06 Analyze a complex situation involving conflicting professional and ethical interests, to determine an appropriate course of action.

ARE-OT07 Develop and deliver effective verbal, written, and graphical communications.

ARE-OT08 Based on a broad education, determine the global, economic, environmental and societal impacts of a specific, relatively constrained engineering solution.

ARE-OT09 Demonstrate the ability to learn independently, without the aid of formal instruction.

ARE-OT10 Incorporate contemporary issues into the identification, formulation, and solution of engineering problems.

ARE-OT11 Apply relevant techniques, skills, and engineering tools to solve problems.

ARE-OT12 Apply fundamental principles of architectural design to open-ended problems.

ARE-OT13 Demonstrate an understanding of key concepts in architectural history.

ARE-OT14 Be able to communicate and interact with design professionals in the building industry.

Architectural Engineering Curriculum[1]

Suggested Course Sequence

Freshman and Sophomore years are the same for both the Structural and Mechanical options.

FRESHMAN YEAR: Fall		Hrs.
ES	1000	1
MATH	2200	4
CHEM	1020	4
ES	1060	3
ENGL	1010	3
PEAC	1001	1
	Total Hrs.	**16**

FRESHMAN YEAR: Spring		Hrs.
US and WY Constitutions[2]		3
MATH	2205	4
PHYS	1210	4
ES	2110	3
University Studies[3]		3
	Total Hrs.	**17**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2210	4
ARE	2100	3
ARE	2200	3
ES	2410	3
ES	2120	3
	Total Hrs.	**16**

SOPHOMORE YEAR: Spring		Hrs.
MATH	2310	3
GEOL	1100 or 1500	4
ES	2310	3
ES	2330	3
ARE	2410	3
	Total Hrs.	**16**

Structural Option

JUNIOR YEAR: Fall		Hrs.
ARE	3030	3
ARE	3200	3
ARE	3400 or Math/Sci. Elective[4]	3
ARE	3600	3
ES	2210	3
ARE Elective[5]		3
	Total Hrs.	**18**

JUNIOR YEAR: Spring		Hrs.
ARE	3210	3
ARE	3300 or Math/Sci. Elective[4]	3
ARE	4200	3
ARE	4260	3
CE	3600	3
CE	3900	3
	Total Hrs.	**18**

SENIOR YEAR: Fall		Hrs.
ARE	3100	3
ARE	4250	3
ARE	4600	3
ARE Elective[5]		3
STAT	4220	3
	Total Hrs.	**15**

SENIOR YEAR: Spring		Hrs.
ARE	4720	4
ARE Electives[5]		6
ENGL	4010	3
University Studies[3]		3
	Total Hrs.	**16**

Mechanical Option

JUNIOR YEAR: Fall		Hrs.
ARE	3030	3
ARE	3200	3
ARE	3400	3
ARE	3600	3
ES	2210	3
ARE	3360	3
	Total Hrs.	**18**

JUNIOR YEAR: Spring		Hrs.
ARE	3100	3
ARE	3210	3
ARE	3300	3
ARE 4430 or ARE 4490		3
CE	3900	3
Math/Science Elective		3
	Total Hrs.	**18**

SENIOR YEAR: Fall		Hrs.
ARE	4260	3
ARE	4600	3
ARE 4330 or ARE 4390		3
ARE Elective[5]		3
STAT	4220	3
	Total Hrs.	**15**

SENIOR YEAR: Spring		Hrs.
ARE	4740	4
ARE 4490 or ARE 4430		3
ARE Elective[5]		3
ENGL	4010	3
University Studies[3]		3
	Total Hrs.	**16**

[1]All civil and architectural engineering classes require a grade of C or better in prerequisites.

[2]Must meet 2003 University Studies Program requirements for V courses.

[3]Must meet 2003 University Studies Program requirements for CS, CA, C courses.

[4]Structural option students must complete either ARE 3400 (typically offered in the fall) or ARE 3300 (typically offered in the spring). They should complete their Math/Science elective requirement in the alternate semester.

[5]To be selected from Departmentally approved lists for specific structural or mechanical option electives.

Architectural Engineering (ARE)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

2100. Architectural Engineering Graphics. 3. Introduction to architectural drafting basics, including computer-aided drafting, architectural presentation drawings, freehand sketching, essentials of architectural design and building code compliance. *Prerequisite:* ES 2110; or FCSC 2188 or concurrent enrollment (in FCSC 2188).

2200. Building Materials and Construction Methods. 3. The study of nomenclature of construction as applied to dwelling and commercial buildings, including selection of appropriate building methods and materials. *Prerequisite:* ES 2110; or FCSC 2188 or concurrent enrollment (in FCSC 2188).

2410. Fundamentals of Building Performance. 3. Introduction to building performance measures that embrace a global notion of environmental stewardship. Emphasis on passive heating and cooling systems and daylighting strategies to manage the thermal and luminous environments over the facility life cycle. *Prerequisite:* PHYS 1210.

3030. History of Architecture. 3. [(none)◆▶CH, G] A survey of the history of architecture and its allied fields, focusing on the formal, aesthetic, cultural and sociopolitical dimensions, from prehistory to the present. *Prerequisites:* WA.

3100. Civil and Architectural Engineering Practice. 3. Civil and architectural engineering practice from project inception through construction documentation. Topics include: codes, marketing, specifications, budgeting, contracts, subcontracting, registration, construction planning, scheduling bidding, liability, insurance, and boding. Cross listed with CE 3100. *Prerequisites:* CE 2100 or ARE 2100.

3200. Structural Analysis I. 3. Introductory design and analysis topics in stress and displacement analysis of structures, including beams, trusses and frames, classical flexibility and stiffness methods. Cross listed with CE 3200. *Prerequisite:* ES 2410.

3210. Civil Engineering Materials. 3. [(none)◆▶WB] Laboratory investigation and design of materials used in civil engineering: metals, masonry, concrete and timber. Nondestructive evaluation of materials. Analysis and presentation of data, including various types of written reports and oral presentations. Cross listed with CE 3210. *Prerequisites:* WA and ES 2410.

3300. Building Electrical and Plumbing Systems. 3. Introduction to National Electrical Code. The topics include basic circuits, AC and DC single phase, three phase power, transients, capacitance and inductance, branch circuits. Study of plumbing systems and fixtures including wastewater, water supply, storm water, and venting systems. Study of International Plumbing Code. *Prerequisites:* ES 2210, ES 2330, and ARE 2410.

3360 [3430, 4420]. Fundamentals of Transport Phenomena. 3. Basic concepts of heat and mass transfer and their applications to problems involving engineering analysis and design. Topics include steady-state and transient conduction, free and forced convection (heat and mass), radiation and heat exchangers. Cross listed with ESE/ME 3360. *Prerequisites:* MATH 2310, ES 2310 and ES 2330. (Offered both semesters)

3400 [3800]. Heating, Ventilating and Air Conditioning of Buildings. 3. Qualitative and quantitative study in concepts of basic air-conditioning with focus on buildings including building envelope, moist air thermodynamics, human comfort, thermal load calculations, thermal behavior of buildings, HVAC systems/equipment, and design of space air-conditioning and its relationship to architectural design. Cross listed with ME 3400. *Prerequisites:* ES 2310, ES 2330, and either ARE 2410 or ME 3360.

3600. Architectural Design I. 3. Introduction to the process of architectural design through the completion of several projects, including residential, commercial and institutional architecture. *Prerequisite:* ARE 2100, 2200, 2410.

4030. History of Green Building. 3. Examines Green Building themes as practiced in the past and present. Areas of emphasis are: methods of heating, cooling and lighting in pre-modern buildings; the history of mechanical heating, cooling and lighting as related to architecture; and connections between exemplary contemporary buildings and historical examples. *Prerequisites:* ARE 2410 and 3030.

4040. Historic Preservation and Sustainability. 3. Explores the historic preservation and sustainability movements and contemporary practices in these inter-related fields. Through reading, lectures, discussions and site visits, students will study how the historic preservation and the building industry professions can address advanced issues in sustainability related to the environment, culture and economics. Cross listed with AMST 4040. *Prerequisites*: 6 hours in AMST or ARE.

4200. Structural Analysis II. 3. Stress and displacement of indeterminate structures. Determination of loads on buildings. Matrix stiffness methods. Cross listed with CE 4200 *Prerequisite:* ARE/CE 3200.

4250. Structural Steel Design. 3. Design of structural components and applications utilizing steel. Cross listed with CE 4250. *Prerequisite:* ARE/CE 4200 or concurrent enrollment.

4260. Structural Concrete Design. 3. Design of structural components and systems using reinforced concrete. Cross listed with CE 4260. *Prerequisite:* ARE/CE 3200.

4280. Reinforced Masonry Design. 3. Design of structural components in reinforced masonry buildings, including walls, columns, beams and connections. Particular attention is paid to current codes, specifications and analysis. Cross listed with CE 4280. *Prerequisite:* ARE/CE 4260 and concurrent enrollment in ARE/CE 4200. (Normally offered fall semester)

4290. Structural Timber Design. 3. Design of structural components and systems utilizing timber. Particular attention is paid to current codes, specifications and analysis. Cross listed with CE 4290. *Prerequisite:* CE 4200 or concurrent enrollment. (Normally offered spring semester)

4330. Building Electrical Systems. 3. Analysis and design of electrical systems in buildings using the National Electrical Code. The topics include panel boards, motors, system sizing, electrical distribution in buildings, methodology of reducing the available short circuit current, transformers, capacitors in buildings, and power systems harmonics. Students will perform an electrical building design project. *Prerequisites:* ARE 3300.

4390. Building Safety and Fire Protection. 3. Fundamentals of building design for fire and life safety. Emphasis is on a systematic design approach. Basic considerations of building codes, fire loading, fire resistance, means of egress design, introduction to protective systems including fire protection systems, and fundamentals of fire and smoke control. *Prerequisites:* ARE 3300.

4430 [3420, 4810]. HVAC Systems Analysis and Design. 3. Engineering design and performance analysis procedures for commercial building mechanical systems including energy conservation techniques. Relationship to aesthetic, architectural and structural elements are considered. Cross listed with ME 4430. *Prerequisites:* ARE/ME 3400. (Normally offered alternate spring semesters)

4440 [3500]. Building Acoustics. 3. A study of the acoustical environment of buildings, including basic theory with an emphasis on room acoustics and mechanical system noise and vibration. *Prerequisite:* ARE 3400. (Normally offered alternate fall semesters)

4470. Alternative Energy Sources and Applications. 3. An introduction to energy conversion systems likely to become significant sources of energy in the coming decades is presented. Some specific areas that will be discussed include existing energy demands and policy, origin of energy, wind, solar, biomass, and nuclear energy, and energy storage. This course is typically offered every 3rd semester. Cross listed with ME 4470. *Prerequisite:* ME 3360/ARE 3360.

4480. Building Air and Hydronic Systems. 3. Design and analysis of building air and hydronic systems with focus on the application, design and analysis of thermal energy distribution systems (air and hydronic systems) for building space air conditioning. Requires enrollment in associated laboratory session. Cross listed with ME 4480. *Prerequisite:* ARE/ME 4430.

4490. Modeling and Optimization of Energy Systems. 3. Application of principles of thermodynamics, fluids, and heat and mass transfer in the component and system-level design of energy/thermal systems, including modeling, simulation and optimization techniques. Examples are drawn from building environmental control, energy conversion and thermal industrial processes. Students work on projects for integration of these components in the design of energy/thermal systems. Requires enrollment in associated laboratory session. Cross listed with ME 4490. *Prerequisites:* ARE/ME 3400.

4600. Architectural Design II. 3. Continuation of concepts introduced in ARE 3600 with more emphasis on larger and more complex building types and systems. *Prerequisite:* ARE 3600 and senior standing in Architectural Engineering.

4720. Structural Systems Design Project. 4. Final course in the building structural systems sequence incorporating elements of previous design courses by executing design of a hypothetical building with a concentration on a detailed design of the project's structural systems. *Prerequisites:* ARE 4200, 4250, 4260, and 4600.

4740. Mechanical Systems Design Project. 4. Final course in the building mechanical systems sequence incorporating elements of previous design courses by executing design of a hypothetical building with a concentration on a detailed design of the project's mechanical systems. *Prerequisites:* ARE 3300, ARE 3400, ARE 4600, and one of ARE 4330, ARE 4390, ARE 4430, or ARE 4490.

4920. Senior Architectural Engineering Problems 1-3 (Max. 6). A study of current engineering design problems that are applicable to architectural engineering either on an individual basis or for small seminar type groups. Not for graduate credit. *Prerequisite:* senior standing or consent of department head.

5400. Building Energy Management. 3. A rigorous treatment of issues related to the judicious use of energy in the design and use of buildings is provided. Energy-efficient HVAC systems and system control, energy-conscious building design, building energy analysis, auditing, building envelope, energy-efficient lighting design, energy management programs, energy sources and conservation, rate schedules, waste-heat recovery, passive solar heating/cooling and daylighting. *Prerequisites:* ARE 3430, 4460.

5700. Architectural Engineering Problems I. 1-3 (Max. 6). A special course, designed to make possible the study and investigation of problems or phases of architectural engineering selected to fit the needs of the students. *Prerequisite:* consent of instructor.

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Over the past 50 years computers have developed from a novelty with a few technical numerical applications to a ubiquitous tool, essential to science and technology, to business and finance, to government, to communications, and even to entertainment. Computer Science has grown from a specialization in mathematics or business or electrical engineering to an independent, broadly based area of study covering all aspects of the use and understanding of computers and the computation process.

Computer Science education concentrates on the creation and understanding of computer software. The curriculum focuses first on programming and then on the central processes that support programming: operating systems, programming languages, and computational theory. The program of study culminates with a senior design project that produces a working program for a real world problem.

Computers and Business Concentration

An understanding of business fundamentals is essential for students planning a career in applied computer science in a business environment. This program of study provides a foundation in computer science, business and information management. It includes courses in accounting, management, marketing, database fundamentals, and design and implementation of software systems. The curriculum leads to the Bachelor of Science in Computer Science degree. It is highly recommended that students declare a Business minor, since they will meet all the requirements without any additional courses.

International Engineering Concentration

Computer Science is a global profession, and today's computer scientists must be able to work and interact in a variety of diverse cultural and technical environments. The international engineering concentration gives computer science students an opportunity to study culture and foreign language at the same time as they pursue their computer science degrees.

The concentration includes at least one semester of study abroad with courses taken in a foreign language. In addition, students may participate in a four-to-five month international internship. Foreign language skills can be earned through a variety of means, including formal university coursework, intensive summer language programs, and previous education.

Foreign language education and the study-abroad experience satisfy the cultural context requirements of the University Studies Program. The curriculum leads to the Bachelor of Science in Computer Science degree.

Program Objectives

The following are the measurable objectives for graduated computer science students (Standard I-1):

OB1: Have successfully applied the fundamentals of computer science to solve software-oriented computing problems.

OB2: Have effectively communicated within and outside the discipline and work effectively with others.

OB3: Have extended their knowledge by independent learning and continuing education.

OB4: Appreciate the role of computer science in the societal context and appreciate the importance of ethics in the practice of the profession.

Program Learning Outcomes

The program of study in Computer Science enables students to achieve, by the time of graduation:

(a) An ability to apply knowledge of computing and mathematics appropriate to the discipline;

(b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution;

(c) An ability to design, implement and evaluate a computer-based system, process, component, or program to meet desired needs;

(d) An ability to function effectively on teams to accomplish a common goal;

(e) An understanding of professional, ethical, legal, security, and social issues and responsibilities;

(f) An ability to communicate effectively with a range of audiences;

(g) An ability to analyze the local and global impact of computing on individuals, organizations and society;

(h) Recognition of the need for, and an ability to engage in, continuing professional development;

(i) An ability to use current techniques, skills, and tools necessary for computing practices.

(j) An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices;

(k) An ability to apply design and development principles in the construction of software systems of varying complexity.

Computer Science Undergraduate Major

The computer science requirements are subject to minor program changes. The published curricula are general guides. Students should consult the department Web pages (www.cs.uwyo.edu) for current information.

Students must complete ENGL 1010, 4010; COSC 1010, 1030, 2030, 2150, 2300, 3011, 3015, 3020, 3050, 4950, 4955, theory course: 4100 or 4200, operating systems course: 4740, programming language course: 4780 or 4785, system course: 4820 or 4760; and 12 semester hours of COSC courses at the 3000+ level that are not fulfilling another requirement. Three hours can be from the Computer Engineering [CPEN] electives.

The science requirement consists first of two tightly related lab sciences chosen from the following pairs: PHYS 1210 and 1220, or 1310 and 1320, or LIFE 1010 and 2022 or 2023, or CHEM 1020 and 1030 or CHEM 1050 and CHEM 1060; two additional courses from among ASTR 2310, EE 2390, and any four-credit lab science, for the science major, which meets the USP S, SB, SP, or SE requirement excluding LIFE 1002 and CHEM 1000.

The mathematics requirement is MATH 2200, 2205, Stat Course: STAT 4220 or MATH/STAT 4255 or MATH/STAT 4265, and six semester hours selected from among MATH 2210, or higher numbered courses, COSC 4340 or STAT 3000- or 4000-level courses, except for MATH 2350, 2355, 4000 and variable-credit courses.

The foreign language requirement is two semesters of a single foreign language (or one semester at the 2nd or 3rd-semester level), or satisfactory score on one of the following; Departmental Examination, College Level Examination Program, Advanced Placement Examination. Refer to the languages department sections in this bulletin for detailed information.

In addition to the required courses listed above, students must choose courses that complete satisfaction of the following University Studies Program requirements: Writing 1 (WA), Writing 2 (WB), Writing 3 (WC), three cultural context courses (CH, CS, CA), oral communications (O), U.S. and Wyoming Constitutions requirement (V), Global Awareness (G), Information Literacy (L), U.S. Diversity (D), Intellectual Community (I) and Physical Activity (P).

Additional requirements: 6 upper-division hours in non COSC courses (UDNC). All COSC, MATH, and STAT courses must have a grade of C or better. The student's program must fulfill the university requirement of 48 semester credit hours in upper division (junior/senior or graduate-level) courses.

Suggested B.S. Program in Computer Science

Course Sequence of Major requirements

Students are free to satisfy program requirements in any order that complies with course prerequisites.

FRESHMAN YEAR: Fall		**Hrs.**
ES	1000	1
COSC	1010	4
MATH	2200	4
ENGL	1010	3
Science I		4

FRESHMAN YEAR: Spring		**Hrs.**
COSC	1030	4
MATH	2205	4
Science II		4
COJO	1010	3
PEAC	1001	1

SOPHOMORE YEAR: Fall		**Hrs.**
COSC	2030	4
COSC	2150	3
COSC	2300	3
Foreign Language I		4
USP Cultural Context		3

SOPHOMORE YEAR: Spring		**Hrs.**
COSC	3011	3
COSC	3020	4
Math Elective		3
Foreign Language II		4
USP Cultural Context		3

JUNIOR YEAR: Fall		**Hrs.**
COSC	3015	3
Operating Systems Course		4
COSC Elective		3
Science Elective		4
USP V Course		3

JUNIOR YEAR: Spring		**Hrs.**
COSC Elective		3
COSC	3050	1
Science Elective		4
Math Elective		3
USP Cultural Context		3

SENIOR YEAR: Fall		**Hrs.**
COSC	4950	1
System Course		3
STAT course		3
Theory Course		3
ENGL	4010	3
UDNC		3

SENIOR YEAR: Spring	Hrs.
COSC 4955	2
COSC Electives	6
Programming Language Course	3
UDNC	3

Computer Science Computers and Business Concentration Undergraduate Major

The computers and business concentration requirements are subject to minor program changes. The published curricula are general guides. Students should consult the department Web pages (www.cs.uwyo.edu) for current information.

Students must complete ENGL 1010, 4010; COSC 1010, 1030, 2030, 2150, 2300, 3011, 3020, 3050, 4210, 4220, 4820, 4950, 4955, one operating systems course: 3750, 4740 or 4750; and 6 semester hours of COSC courses at 3000+ level that are not fulfilling another requirement.

The science requirement consists first of two tightly related lab sciences chosen from the following pairs: PHYS 1210 and 1220, or 1310 and 1320, or LIFE 1010 and 2022 or 2023, or CHEM 1020 and 1030 or CHEM 1050 and 1060; two additional courses from among ASTR 2310, EE 2390, and any four-credit lab science, for the science major, which meets the USP S, SB, SP, or SE requirement excluding LIFE 1002 and CHEM 1000.

The mathematics requirement is MATH 2200 or 2350 and 2205 or 2355, STAT 2010, 2050, or 2070.

The business requirement is ACCT 1010, ACCT 1020, MGT 1040, MGT 3110, MGT 3210, MKT 3210, FIN 3250 and three semester hours of business courses at the 3000+ level that are not fulfilling another requirement.

In addition to the required courses listed above, students must choose courses that complete satisfaction of the following University Studies Program requirements: Writing 1 (WA), Writing 2 (WB), Writing 3 (WC), three cultural context courses (CH, CS, CA), oral communications (O), U.S. and Wyoming Constitutions requirement (V), Global Awareness (G), Information Literacy (L), U.S. Diversity (D), Intellectual Community (I) and Physical Activity (P).

Additional requirements: 3 upper-division semester hours in a non COSC course (UDNC). All COSC, MATH, Business and STAT courses must have a grade of C or better. The student's program must fulfill the university requirement of 48 semester credit hours in upper division (junior/senior) or graduate-level courses.

It is highly recommended that students declare a Business minor, since they will meet all the requirements without any additional courses. If you are planning on attending graduate school, then you should take COSC 4740 for the operating systems course and COSC 4100 and COSC 4780 for the two computer science electives.

Suggested B.S. Program in Computer Science Computers and Business Concentration

Course Sequence of Major requirements

Students are free to satisfy program requirements in any order that complies with course prerequisites.

FRESHMAN YEAR: Fall	Hrs.
ES 1000	1
COSC 1010	4
MATH 2200	4
ENGL 1010	3
Science I	4

FRESHMAN YEAR: Spring	Hrs.
COSC 1030	4
MATH 2205	4
Science II	4
COJO 1010	3
PEAC 1001	1

SOPHOMORE YEAR: Fall	Hrs.
COSC 2030	4
COSC 2150	3
ACCT 1010	3
COSC 2300	3
USP Cultural Context	3

SOPHOMORE YEAR: Spring	Hrs.
COSC 3011	3
MGT 1040	3
USP Cultural Context	3
ACCT 1020	3
COSC 3020	4

JUNIOR YEAR: Fall	Hrs.
MGT 3110	3
STAT 2050	4
Science Elective	4
USP V Course	3
COSC Operating Systems Course	3-4

JUNIOR YEAR: Spring	Hrs.
FIN 3250	3
Science Elective	4
COSC 4820	3
COSC 3050	1
MGT 3210	3

SENIOR YEAR: Fall	Hrs.
COSC 4950	1
COSC 4210	3
COSC Elective	3
Business Elective	3
ENGL 4010	3
MKT 3210	3

SENIOR YEAR: Spring	
COSC 4955	2
COSC 4220	3
USP Cultural Context	3
COSC Elective	3
UDNC	3

Computer Science International Engineering Concentration

Computer science international engineering concentration requirements are subject to minor program changes. The published curricula are general guides. Students should consult the department office Web pages (www.cs.uwyo.edu) for current information.

Students must complete ENGL 1010, 4010; COSC 1010, 1030, 2030, 2150, 2300, 3011, 3015, 3020, 3050, 4950, 4955, theory course: 4100 or 4200, operating system course: 4740, programming language course: 4780 or 4785, system course: 4820 or 4760; and 12 semester hours of COSC courses at 3000+ level and not fulfilling another requirement. Three hours can be from the Computer Engineering [CPEN] electives.

The science requirement consists first of two tightly related lab sciences, chosen from the following pairs: PHYS 1210 and 1220, or 1310 and 1320, or LIFE 1010 and 2022 or 2023, or CHEM 1020 and 1030 or CHEM 1050 and 1060; two additional courses from among ASTR 2310, EE 2390, and any four-credit lab science, for the science major, which meets the USP S, SB, SP, or SE requirement excluding LIFE 1002 and CHEM 1000.

The mathematics requirement is MATH 2200, 2205, Stat Course: STAT 4220 or MATH/STAT 4255 or MATH/STAT 4265, and six semester hours selected from among MATH 2210, or higher numbered courses, COSC 4340 or STAT 3000- or 4000-level courses, except for MATH 2350, 2355, 4000 and variable-credit courses.

The foreign language requirement is four semesters of a single foreign language and one semester of study abroad. Foreign language skills can be earned through a variety of means, including formal university coursework, intensive summer language programs, and previous education.

In addition to the courses listed above, students must choose courses that complete satisfaction of the following University Studies Program requirements: Writing 1 (WA), Writing 2 (WB), Writing 3 (WC), oral communications (O), U.S. and Wyoming Constitutions requirement (V), Information Literacy (L), Intellectual Community (I) and Physical Activity (P).

Additional requirements: six upper-division hours in non COSC courses (UDNC). All COSC, MATH, and STAT courses must have a grade of C or better. The student's program must fulfill the university requirement of 48 semester credit hours in upper division (junior/senior) or graduate-level courses.

Suggested B.S. Program in Computer Science International Engineering Concentration

Course Sequence of Major requirements

Students are free to satisfy program requirements in any order that complies with course prerequisites.

FRESHMAN YEAR: Fall		**Hrs.**
ES	1000	1
COSC	1010	4
MATH	2200	4
Foreign Language I		4
ENGL	1010	3

FRESHMAN YEAR: Spring		**Hrs.**
COSC	1030	4
MATH	2205	4
Foreign Language II		4
COJO	1010	3
PEAC	1001	1

SOPHOMORE YEAR: Fall		**Hrs.**
COSC	2150	3
COSC	2030	4
COSC	2300	3
Foreign Language III		4
Science I		3

SOPHOMORE YEAR: Spring		**Hrs.**
COSC	3011	3
COSC	3020	4
MATH Elective		3
Foreign Language IV		4
Science II		4

JUNIOR YEAR: Fall		**Hrs.**
COSC	3015	3
Operating Systems Course		4
COSC Elective		3
Science Elective		4
USP V Course		3

JUNIOR YEAR: Spring		**Hrs.**
Study Abroad		
COSC Elective		3
Science Elective		4
MATH Elective		3
UDNC		3

SENIOR YEAR: Fall		**Hrs.**
COSC	4950	1
System Course		3
STAT Course		3
Theory Course		3
ENGL	4010	3
UDNC		3

SENIOR YEAR: Spring		**Hrs.**
COSC	4955	2
COSC	3050	1
COSC Elective		3
COSC Elective		3
Programming Language Course		3

Computer Science Minor Requirements

Requirements for a minor in Computer Science are as follows:

- A total of 18 credits of computer science courses of which 9 credits must be upper-division.
- All 18 credits must have a grade of C or better.
- At least 12 of the credits must not be counted simultaneously for a major.

Graduate Study

The Department of Computer Science offers graduate work leading to the master of science degree in computer science and the doctor of philosophy in computer science.

Program Specific Admission Requirement

Applicants must meet the minimum standards of the university.

Acceptance will be based on the student's academic records.

High performing undergraduates in computer science can elect for Quick Start admission to the graduate program, allowing the sharing of up to six credit hours of 5000-level coursework toward the completion of both the B.S. and the graduate degree programs.

For the master's degree and the Ph.D. program, the following courses or their equivalent are considered preparatory for graduate work in computer science: COSC 3020, COSC 4100 or 4200, COSC 4740, and COSC 4780 or 4785. Students admitted to the program must show proficiency in these courses.

An applicant whose previous studies are in a field significantly removed from computer science may be admitted to the regular master's degree or the Ph.D. program on the condition that he or she take additional courses to remove deficiencies in his or her computer science background.

Admission to the master's degree program or the conferring of a master's degree will not constitute a de facto admission to the Ph.D. program.

The curriculum is divided into four areas of study. These areas represent current areas of interest and expertise on the part of the faculty and are subject to change.

Computer Theory includes the theoretical and structural study of algorithms, automata, computability, computational complexity, information, formal languages, models, mathematical logic, recursive functions and sequential machines.

Parallel Computing and Systems includes the design, development and evaluation of computing machines, computing languages, language processors, operating systems and special purpose systems. It is further concerned with the analysis of complex problems into subparts that can be handled by multiple processors located at one or more sites and coordinated so as to produce a complete solution.

Mathematical Computation and Modeling includes numerical solution of algebraic equations and systems of equations, numerical differentiation and integration, interpolation, optimization and linear programming, matrix computation, eigenvalues and eigenvectors, numerical solution of differential equations and approximation theory.

Machine Intelligence is concerned with endowing machines with such manifestations of human intelligence as vision, spoken language recognition, knowledge representation, task planning, the application of search procedures to problem solving, question answering, inference, and the dispensing of expert knowledge and advice.

Program Specific Degree Requirements

All students must complete COSC 5050 (Research Writing for Computer Science).

At least 15 hours applied to the degree program must be in courses offered by the computer science department, not including the 14 hours of courses considered preparatory and not including seminars, individual projects, COSC 5050 or reading courses. Courses

cross listed with computer science department courses will be considered computer science department courses.

No more than 6 hours from the 4000 level preparatory coursework may be counted toward the total credit requirement. At most 2 hours from the 4000 level preparatory coursework may be counted toward an area requirement. All required preparatory coursework will be listed on the program of study with the corresponding increase in total hours required.

The student must complete at least one 5000-level computer science course, not including seminars, individual projects or reading courses, offered by the computer science department in the following areas: a) Computer Theory and b) Parallel Computing and Systems.

The student must complete at least 6 hours of courses in each of two areas of study. These two areas will be called major areas. The 6 credit hours in each of two areas of study must be completed from the current list of courses designated to satisfy the area of study requirements. "Current list" is defined to mean the list in effect when the student enters the graduate program or any succeeding list.

Master's Program

Each Master's student will have a supervising committee of at least three members appointed. The committee will consist of at least two members of the computer science faculty and at least one non-COSC faculty member. In reviewing the student's program of study, the committee should ensure that at least 15 hours are applied at the 5000-level, not including seminars, COSC 5050 and Independent Study or Research.

Both Plan A and Plan B students are required to formally defend their papers before their graduate committees.

Plan A (thesis)

The student must complete a minimum of 29 hours of courses, including at least two COSC 5000 seminars.

The student must complete a minimum of 4 hours of 5960, Thesis Research.

At least two-thirds of the coursework (20 hours) must consist of computer science department courses.

The students must give a public colloquium on their research prior to their formal defense. All defenses must be open and announced three weeks in advance.

Plan B (non-thesis)

The student must complete a minimum of 33 hours of courses, including at least two COSC 5000 seminars, and present a paper as described in the general requirements for Plan B.

At least two-thirds of the coursework (22 hours) must consist of Computer Science Department courses.

The graduate examination, which serves as the Ph.D. qualifying examination, will also be administered to Plan B master's students, who will be required to pass two areas in order to receive their degrees. Passing criteria will be determined by the student's graduate committee.

Doctoral Program

Each doctoral student will have a supervising committee of at least five members appointed. The primary functions of this committee are to suggest coursework, to administer the preliminary and final examinations, and to oversee and evaluate the research of the candidate. The committee will consist of at least three members of the computer science department faculty and at least one non-COSC faculty member. The standards that this committee should consider when recommending programs of study are outlined in the following sections.

A total of at least 72 credit hours must be completed. A minimum of 42 of these credit hours must be taken as coursework. At least 21 hours must be taken at the 5000 level (COSC 5050 and seminars may not be applied to this requirement). Each doctoral student must participate in at least four graduate seminars. A minimum of 12 hours of dissertation research must be taken.

A program of original and innovative research will be undertaken by the candidate. At the end of` this program, the candidate will document this research in a dissertation. The dissertation will present the details and results of the candidate's research in addition to providing a critical comparison with related published works.

Each successful doctoral student must pass three examinations. These include a qualifying examination, a preliminary examination, and a final (dissertation) defense.

The departmental graduate examination will serve as the Ph.D. qualifying examination. This examination will be given once each year during the spring semester, and should be taken no later than the fifth semester of graduate study. The graduate examination will test knowledge and reasoning skills based on the upper-division preparatory courses as well as on graduate courses in the core areas. Ph.D. students will be required to answer questions from the undergraduate core courses but will be given greater flexibility to select questions from the graduate courses.

A preliminary examination will consist of a presentation and defense of the proposed dissertation research. This examination is intended to motivate the candidate to review relevant literature extensively prior to pursuing the original and innovative portions of the research. If the nature of the proposed research and methodology are deemed to be both appropriate and significant by the supervisory committee, then the committee will approve the research direction after having administered this examination.

The final examination (dissertation defense) will consist of an oral presentation by the candidate of his/her research and the results that were derived. At this examination, the candidate is expected to defend the research as being original and contributory to the discipline of computer science.

All Ph.D. candidates must satisfactorily complete COSC 5050 (Research Writing for Computer Science).

Information concerning timeline and deadlines for meeting doctoral degree requirements is available from the department office.

Academic Dishonesty

For cases in which a graduate student has admitted to an act of academic dishonesty or has been found culpable through university procedures according to University Regulation 6-802, the graduate committee will meet with the student and faculty member(s) involved to assess the severity of the act. Both the faculty member(s) and the student will be afforded the opportunity to present views and information relevant to the act. The graduate committee may then take action by recommending that the student be terminated from graduate study in the department (for flagrant violations) or that a letter of reprimand be sent to the student with a copy sent to the Office of the Registrar.

Computer Science (COSC)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

1010. Introduction to Computer Science I. 4. [M2◆▶(none)] Introduces the fundamental concepts of programming from an object-oriented perspective. Topics include simple data types, control structures, array and string data structures, algorithm development, and debugging techniques. Emphasizes good software engineering principles and developing fundamental programming skills in the context of a language that supports the object-oriented paradigm. *Prerequisite:* grade of C or better in MATH 1400 or Level 4 or higher on the Math Placement Exam within one year prior to the start of the course.

1030. Computer Science I. 4. [M3◆▶(none)] Continues the introduction from COSC 1010 to the methodology of programming from an object-oriented perspective. Through the study of object design, introduces the basics of human-computer interfaces, the social implications of computing, with an emphasis on software engineering. *Prerequisite:* COSC 1010 or equivalent experience and concurrent registration in MATH 1405 or MATH 1450.

1100. Computer Science Principles and Practice. 3. [M3◆▶(none)] Introduces use of computers for algorithmic problem solving. Studies scope, major contributions, tools and current status of computer science. Presentation of computer science principles; use of software packages and evaluation of their effectiveness; and elementary programming. *Prerequisite:* C or better in MATH 1400 or in any University Studies QB or Level 4 or higher on Mathematics Placement Exam. (Offered based on sufficient demand and resources)

1200. Computer Information Systems. 3. Introduces computers and information processing, computer systems and hardware, computer software, information processing systems, information systems and information resource management. Uses word processing, data base language and electronic spreadsheet program in hands-on exercises. *Prerequisite:* passing of Mathematics Placement Examination at Level 2 or equivalent.

2000. Undergraduate Topics: Computer Science. 1-3 (Max. 6). Elementary topics current in computer science. *Prerequisite:* consent of instructor. (Offered based on sufficient demand and resources)

2030. Computer Science II. 4. Builds on the introduction to object-oriented programming begun in COSC 1010 and 1030 with an emphasis on algorithms, data structures, and software engineering. *Prerequisite:* COSC 1030.

2150. Computer Organization. 3. Introduces students to the organization and architecture of computer systems, beginning with the standard von Neumann model and then moving forward to more recent architectural concepts. *Prerequisite:* COSC 1030.

2300. Discrete Structures. 3. Introduces the mathematical concepts that serve as foundations of computer science: logic, set theory, relations and functions, graphs (directed and undirected), inductively defined structures (lists and trees), and applications of mathematical induction. Provides an introduction to abstract and rigorous thinking in advanced mathematics and computer science. Cross listed with MATH 2300. *Prerequisite:* COSC 1030, MATH 2200 or 2350.

2409. _____ Programming. 1-3 (Max. 6). Describes various computer languages focusing on their differences from prerequisite languages and uses of these new features. *Prerequisite:* consent of instructor. (Offered based on sufficient demand and resources)

3011. Introduction to Software Design. 3. Introduces the principles and practice of software design, including UML and design patterns. Uses case studies to illustrate design in action. *Prerequisites:* COSC 2030.

3015. Functional Programming. 3. Studies programming in the context of a functional language that emphasizes algorithmic strategies over syntactic detail. *Prerequisites:* COSC 2030 and 2300.

3020. Algorithms and Data Structures. 4. Introduces formal techniques to support the design and analysis of algorithms, focusing on both the underlying mathematical theory and practical considerations of efficiency. Topics include asymptotic complexity bounds, techniques of analysis, algorithmic strategies, and an introduction to automata theory and its application to language translation. *Prerequisites:* COSC 2030, 2150 and 2300.

3050. Ethics for the Computer Professional. 1. The proliferation of computers has had a profound effect on our society. Computing professionals must be aware of the social and ethical implications of our activities. Examines the codes of behavior related to computer science through readings, discussions and case studies. *Prerequisites:* COSC 2030.

3340. Introduction to Scientific Computing. 3. Introduces basic numerical methods to solve scientific and engineering problems. Topics include: code structure and algorithms, basic numerical methods for linear systems, eigenvalue problems, interpolation and data fitting, nonlinear systems, numerical differentiation and integration. Cross listed with MATH 3340. *Prerequisites:* COSC 1010 and MATH 2210.

3750. Linux Programming for System Applications. 3. Provide the necessary tools and skills to begin programming effectively on UNIX and Linux operating systems. Topics will include, shells and basic shell scripting, Linux utilities, editors, compilation, I/O and the file system, sockets and interprocess communication, and time permitting, threads. *Prerequisites:* COSC 3020.

3900. Upper Division Topics in Computer Science. 1-3 (Max. 9). Individual or small group pursuit of interdisciplinary problems in the use of computers or study of topics of interest within industry. *Prerequisite:* consent of instructor. (Offered based on sufficient demand and resources)

3970. Internship in Computing. 1-3 (Max. 3). Allows students to gain practical experience in computing. A signed contract with a supervisor and departmental adviser must be completed before enrolling for the internship. *Prerequisite:* COSC 3020.

4000. Topics in Computer Science for Educators. 1-6 (Max. 12). Current computer science topics appropriate for K-12 teachers. Credit may not be applied to major requirements in computer science or management information systems. *Prerequisite:* graduate standing. (Offered based on sufficient demand and resources)

4010. Special Topics in Computer Science. 1-3 (Max. 9). Individual or small group pursuit of interdisciplinary problems in the use of computers or study of advanced topics. (Maximum of 12 hours from 4010 and 5010 may be applied to graduate study.) *Prerequisites:* COSC 3020 concurrently and consent of instructor. (Offered based on sufficient demand and resources)

4100. Foundations of Computing. 3. Introduces several theoretical areas which are the basis of computer science. Languages and automata, computability, complexity, analysis of algorithms, logic, and the specification and correctness of programs. *Prerequisite:* COSC 3020.

4200. Computability and Complexity. 3. Introduction to theoretical study of computability and efficient computation. Finite-state and pushdown automata; turing machines and the Church-Turing thesis; undecidability, computational complexity; NP-completeness. *Prerequisite*: COSC 3020.

4210. Analysis and Design of Information Systems. 3. Students with information technology skills learn to analyze and design information systems. Practice of software engineering techniques during team-oriented analysis and design of a departmental system. *Prerequisite:* COSC 3020 or concurrent enrollment.

4220. Design and Implementation in Emerging Environments. 3. Students who have completed the analysis and design course extend their knowledge by implementing an information system in an emerging systems environment. Teams use project management principles to implement the system. *Prerequisite:* COSC 4210.

4340. Numerical Methods for Ordinary and Partial Differential Equations. 3. Further develops the skills needed for computational problem solving and numerical analysis. Topics addressed include: one-step and linear multistep methods for solving initial value problems; truncation errors, stability analysis, and convergence of the numerical methods; finite difference approximation for elliptic equations and initial boundary value problems; iterative methods for sparse linear systems. Students typically complete a final project in this course. Cross listed with MATH 4340. *Prerequisites:* MATH 3340.

4350. System Simulation. 3. Introduces simulation and comparison with other techniques. Studies discrete simulation models, and introduction to, or review of, queuing theory and stochastic processes. Compares discrete change simulation languages. Examines simulation methodology including generation of random numbers and variates, design of simulation experiments for optimization, analysis of data generated by simulation experiments, and validation of simulation models and results. Selected applications of simulation. Dual listed with COSC 5350. *Prerequisites:* COSC 3020; MATH 4250 or STAT 2010.

4420. Advanced Logic. 3. Studies advanced topics in mathematical logic. Takes up such topics as: uninterpreted calculi and the distinctive contributions of syntax and semantics; metatheory, including completeness and consistency proofs; modal logic and semantics; logic as a philosophical tool. Dual listed with COSC 5420; cross listed with MATH/PHIL 4420. *Prerequisite:* PHIL 3420 or equivalent.

4450. Computer Graphics. 3. Introduction to computer graphics, an increasingly important area of computer science. Computer graphics, together with multimedia and the World Wide Web, offers exciting new possibilities for the design of human-computer interfaces. Presents the principles, techniques, and tools that enable these advances. Dual listed with COSC 5450. *Prerequisites:* COSC 3020 and MATH 2250.

4530. Digital Image Processing. 3. Methodologies and algorithms for processing digital images by computer. Includes color spaces, pixel mappings, filtering, image segmentation, geometric operations and pattern classification. Cross listed with EE 4530. *Prerequisites:* MATH 2205 and 2250; COSC 1030 or 3070.

4550. Introduction to Artificial Intelligence. 3. A computational study of intelligent behavior. Focus is on intelligent agents, which could be software agents or robots. Covers how agents sense, reason, and act within their environment. Includes problem-solving, search, knowledge representation, planning, game playing, learning, and neural and belief networks. Dual listed with COSC 5550. *Prerequisites:* COSC 3020.

4555. Machine Learning. 3. Goal is to program machines to learn and improve their performance on their own, based on experience and/or data. First half covers machine learning techniques; second half covers applications. Dual listed with COSC 5555. *Prerequisite:* COSC 3020.

4560. Modern Robots and Softbots. 3. Popular agent designs: logic-based, biomimetic, and physicommimetic. Foundational issues on internal robot and softbot knowledge representations. Planning and control, followed by issues of how agents can reason and plan under real-world conditions of environmental uncertainty. Concludes with discussions about papers on modern robot and softbot applications, as well as invited lectures by graduate students and faculty. Dual listed with COSC 5560.

4570. Data Mining. 3. Examine methods that have emerged from artificial intelligence and statistics and proven to be of value in recognizing patterns and making predictions with large data sets. Will include both theory and practice while developing several projects. *Prerequisite*: COSC 4550.

4730. Mobile Application Programming. 3. Introduces development of applications on mobile devices. Presents the principles, techniques, and tools for developing mobile applications. Differences between desktop applications and mobile applications are discussed. Dual listed with COSC 5730. *Prerequisite*: COSC 3020.

4740. Operating Systems Design. 4. Studies systems programming languages and computer systems design. Includes interacting processes, main storage management, procedure and data sharing, scheduling, deadlock problems and file management in batch processing and multi-programming systems. Operating system implementation. *Prerequisite:* COSC 3020.

4750. Systems Programming and Management. 3. Comparatively studies features found in commercial and experimental operating systems. Discusses issues in system-level programming and administration, including shell programming, file management, resource control, configuration and security. Advanced topics include multiprocessor and real-time operating systems. *Prerequisites:* COSC 2030.

4755. Network Applications. 3. Introduces the structure, implementation, and theoretical underpinnings of computer networking and the applications that have been enabled by that technology. Dual listed with COSC 5755. *Prerequisites:* COSC 3020.

4760. Computer Networks. 3. Examines TCP/IP network protocols and implementation in depth, from the perspective of the link, network, transport, and application layers. Discusses problems and current solutions regarding the efficient use of network resources in the global, multi-media internet. *Prerequisite:* COSC 2030.

4765. Computer Security. 3. Introduces the topics of computer and network security and provides a foundation to allow students to identify, analyze, and solve computer security problems. *Prerequisite:* COSC 3020.

4780. Principles of Programming Languages. 3. Introduces the methods of analysis and design of programming languages. Covers syntax, typing schemes and the semantics (denotational and operations) in the context of functional and imperative programming languages. Students build interpreters to explore the implications of the different constructs on computations. *Prerequisites:* COSC 3015.

4785. Compiler Construction 1. 3. Theory and implementation of interpreters and compilers. Compiler topics include lexical analysis, top-down and bottom-up parsing methods, symbol tables, and code generation from a block-structured language with recursion and parameters. Project uses compiler writing tools. Dual listed with COSC 5785. *Prerequisite:* COSC 3020.

4790. Programming Language Processors. 3. Discusses principles and design aspects of programming language processors, including interpreters and compilers. Emphasizes components of compiled system, such as scanner, parser, symbol table, code generation, optimization, linking and loading. Uses compiler generation tools. *Prerequisite:* COSC 4780.

4820. Database Systems. 3. Provides comprehensive coverage of the problems involved in database design, in-depth coverage of data

models and database languages. Students acquire practical skills of conceptual/logical database design and general familiarity with the problems and issues of database management. *Prerequisite:* COSC 3020.

4840. Software Engineering. 3. Extends the ideas of software design and development from the introductory programming sequence to encompass the problems encountered in large-scale programs. Topics include software engineering techniques from the technical and managerial perspectives, with a strong emphasis on software design. *Prerequisites:* COSC 3020 and 3011.

4950. Senior Design I. 1. Students choose a senior design project, investigate alternate solutions and submit a preliminary project design. Periodic oral and written project progress reports are required. *Prerequisite*: COSC 3011 and COSC 3020.

4955. Senior Design II. 2. Students complete the senior design project partially designed in COSC 4950. Successful communication of the details of the solution through written documents and oral presentations will be required. *Prerequisite*: COSC 4950.

5000. Seminar in Computer Science. 1-3. (Max. 10). One or more current research areas in computer science are investigated. *Prerequisite:* consent of instructor.

5010. Graduate Topics in Computer Science. 1-6 (Max. 12). Individual or small group pursuit of computer science research areas. (Max. of 12 hours from COSC 4010 and COSC 5010 may be applied to graduate study). *Prerequisites:* graduate standing and consent of instructor.

5020. Advanced Topics in Computer Science. 1-6 (Max. 12). Advanced topics in computer science. (A maximum of 12 hours may be applied to graduate study.) *Prerequisites:* graduate standing and consent of instructor.

5050. Research Writing in Computer Science. 3. Instruction in methods for performing and reporting research in the field of computer science. The primary task is preparation of a research paper; to that end, the class covers how to collect and analyze previously published work, generate and develop a research topic, and present research results in acceptable written form. *Prerequisite:* graduate standing, consent of instructor.

5110. Analysis Of Algorithms. 3. Analysis of algorithms to determine their time and space requirements. Beginning with data structures such as lists, stacks, trees, and sets and their implementations. The class then analyzes specific algorithms for internal sorting, hashing, and string search. Offered fall semester of even numbered years. *Prerequisites:* COSC 3020 or equivalent and consent of the department.

5120. Theory Of Computation. 3. Models of computation, the Church-Turing thesis, computable functions, decidable and enumerable sets, unsolvable problems, correctness of programs, and complexity of computation. The theory of computation provides precise answers to the fundamental questions of computer science: Which problems can be solved by machine computation and which can be solved using a reasonable amount of computer resources. *Prerequisite:* COSC 4100.

5200. Computational Complexity. 3. Study of efficient computation and computational intracability. Time and space complexity; P, NP, and the polynomial-time hierarchy; reductions and completeness; randomized complexity; non-uniform complexity; approximation algorithms and inapproximability. *Prerequisite:* COSC 4100 or COSC 4200.

5220. Languages and Automata. 3. The study of regular, context-free, and context-sensitive languages and their relations to finite-state, pushdown and linear-bounded automata. Context-free language recognition. The halting problem and decidability results. *Prerequisite:* COSC 4100.

5310. Computational Methods in Applied Sciences I. 3. First semester of a three-semester computational methods series. Review of iterative solutions of linear and nonlinear systems of equations, polynomial interpolation/approximation, numerical integration and differentiation, and basic ideas of Monte Carlo methods. Comparison of numerical techniques for programming time and space requirements, as well as convergence and stability. Cross listed with MATH 5310. *Prerequisites:* MATH 3310, COSC 1010.

5340. Computational Methods in Applied Sciences II. 3. Second semester of a three-semester computational methods series with emphasis on numerical solution of differential equations. Topics include explicit and implicit methods, methods for stiff ODE problems, finite difference, finite volume and finite element methods for time-independence PDEs, semi/fully discrete methods for time-dependent PDEs. Cross listed with MATH 5340. *Prerequisite:* MATH/COSC 5310.

5345. Computational Methods in Applied Sciences III. 3. Third semester of a three-semester computational methods series with emphasis on numerical solution of problems displaying sharp fronts and interfaces (nonlinear conservation laws, Hamilton-Jacobi equations. Cross listed with MATH 5345. *Prerequisite:* MATH/COSC 5340.

5350. System Simulation. 3. Introduces simulation and comparison with other techniques. Studies discrete simulation models, and introduction to, or review of, queuing theory and stochastic processes. Compares discrete change simulation languages. Examines simulation methodology including generation of random numbers and variates, design of simulation experiments for optimization, analysis of data generated by simulation models and results. Selected applications of simulation. Dual listed with COSC 4350. *Prerequisite:* COSC 3020, MATH 4250 or STAT 2010. Additional work is assigned for those enrolled for graduate credit.

5420. Advanced Logic. 3. Studies advanced topics in mathematical logic. Takes up such topics as: uninterpreted calculi and the distinctive contributions of syntax and semantics; metatheory, including completeness and consistency proofs; modal logic and semantics; logic as a philosophical tool. Dual listed with COSC 4420; cross listed with COSC/MATH 5420. *Prerequisite:* PHIL 3420 or equivalent; graduate standing.

5450. Computer Graphics. 3. Introduction to computer graphics, an increasingly important area of computer science. Computer graphics, together with multimedia and the world-wide web, offers exciting new possibilities for the design of human-computer interfaces. Presents the principles, techniques, and tools that enable these advances. Dual listed with COSC 4450. *Prerequisites:* COSC 3020, MATH 2250.

5540. Computer Vision. 3. Provides students with an understanding of applying computer methodologies to process two-dimensional and three-dimensional images. Primary areas of investigation are image preprocessing, knowledge representation, pattern recognition and motion understanding. Prerequisites: COSC 3020, MATH 2205, MATH 2250.

5550. Introduction to Artificial Intelligence. 3. A computational study of intelligent behavior. The focus is on intelligent agents, which could be software agents or robots. Covers how agents sense, reason, and act within their environment. Includes problem-solving, search, knowledge representation, planning, game playing, learning, and neural and belief networks. Dual listed with COSC 4550. *Prerequisite:* COSC 3020.

5555. Machine Learning. 3. To program machines to learn and improve their performance on their own, based on experience and/or data. The first part covers machine learning techniques. The second part covers applications. Dual listed with COSC 4555. *Prerequisite:* COSC 3020.

5560. Modern Robots and Softbots. 3. Begins with a presentation of popular agent designs: logic-based, biomimetic, and physicomimetc. Presents foundational issues on internal robot and softbot knowledge representations. Planning and control are then covered, followed by issues of how agents can reason and plan under real-world conditions of environmental uncertainty. Concludes with discussions about papers on modern robot and softbot applications, as well as invited lectures by graduate students and faculty in the UW COSC and ECE departments. Dual listed with COSC 4560. *Prerequisites:* none.

5640. Automated Reasoning. 3. Study of programs, such as automated theorem provers, which require the use of "intelligence" to solve problems. Topics include resolution, unification, proof strategies, induction based theorem provers, expert systems, and Prolog. *Prerequisite:* COSC 4100.

5700. Computer Architecture. 3. A study of the interaction between computing and computer architecture. Memory hierarchies: segmentation, paging, and caches. CPU organizations: pipelining, array processors, parallelism. IO: channels, DMA, auxiliary CPU's. Interprocessor communication in multi-CPU systems. *Prerequisites:* COSC 4740 and 4700.

5730. Mobile Application Programming. 3. Introduces development of applications on mobile devices. Presents the principles, techniques, and tools for developing mobile applications. Differences between desktop applications and mobile applications are discussed. Dual listed with COSC 4730. *Prerequisite*: COSC 3020.

5740. Advanced Operating Systems. 3. Advanced course in operating systems design and implementation. Emphasis on multiprocessing and distributed systems and study of mechanisms for their control. Topics include concurrency control, deadlock memory management, security, and reliability. *Prerequisite:* COSC 4740.

5750. Distributed Computing Systems. 3. Provides an in-depth study of distributed computing systems, including both architecture and software issues. Topics include concepts of distributed computing, communication primitives, distributed operating systems, distributed file management, and distributed programming languages. Particular attention is paid to modeling and analysis of distributed systems and algorithms. Programming projects and research papers are assigned. *Prerequisite:* COSC 5740.

5755. Network Applications. 3. Introduces the structure, implementation, and theoretical underpinnings of computer networking and the applications that have been enabled by that technology. Dual listed with COSC 4755. Prerequisite: COSC 3020.

5785. Compiler Construction I. 3. Theory and implementation of interpreters and compilers. Compiler topics include lexical analysis, top-down and bottom-up parsing methods, symbol tables, and code generation for a block-structured language with recursion and parameters. Project uses compiler writing tools. Dual listed with COSC 4785. *Prerequisite:* COSC 3020.

5790. Compiler Construction II. 3. Advanced topics concerning the front end of a programming language compiler, the description and implementation of features found in the back end of a compiler, and the run time environment. Topics include data type checking, global data flow analysis, flow graph reduction, local and global code optimization, and code generation. Reports on recent research papers. *Prerequisite:* COSC 4785 or 5785.

5820. Database Systems. 3. Provides comprehensive coverage of the problems involved in database design, in-depth coverage of data models and database languages. Students acquire practical skills of conceptual/logical database design and general familiarity with the problems and issues of database management. *Prerequisite:* COSC 3020.

5825. Advance Data Systems. 3. Provides comprehensive coverage of the problems involved in database system design and an in-depth examination of contemporary structures and techniques used in modern database management systems and database applications. *Prerequisite:* COSC 4820.

5840. Software Engineering Management. 3. Management issues in the development of software systems. Topics include planning documentation for requirements, design, implementation and testing, cost projection and modeling, documentation standards, code control, tracking of defects, management psychology, group interaction and communication, and the management of reviews and walk through. *Prerequisites:* COSC 4740, 4780 or equivalent and consent of the department.

5850. Software Management Laboratory. 3. Laboratory course designed to illustrate the principles discussed in COSC 5840. Students are team leaders on a project which involves the integration, testing, and maintenance of a large software system. The project is the same as that used for COSC 4850. *Prerequisite:* COSC 5840.

5880. Software Verification and Validation. 3. Concepts and practices for assuring the quality of software systems. Covers test planning, operational testing, formal verification, proofs of correctness, and validation testing. *Prerequisite:* COSC 3020 or COSC 4050.

5900. Practicum in College Teaching. 1-3 (Max. 3). Work in classroom with a major professor. Expected to give some lectures and gain classroom experience. *Prerequisite:* graduate standing.

5920. Continuing Registration: On Campus. 1-2. (Max 16). *Prerequisite:* advanced degree candidacy.

5940. Continuing Registration: Off Campus. 1-16 (Max. 16). *Prerequisite:* advanced degree candidacy.

5959. Enrichment Studies. 1-3 (Max. 3). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

5960. Thesis Research. 1-12 (Max. 24). Designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. *Prerequisites:* enrollment in a graduate degree program.

5980. Dissertation Research. 1-12 (Max. 48). Designed for students who are involved in research for their dissertation project. Also used for students whose coursework is complete and are writing their dissertation. *Prerequisites:* enrollment in a graduate level degree program.

5990. Internship. 1-12 (Max. 24). *Prerequisite:* graduate standing.

Department of Electrical and Computer Engineering

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Department Head: John McInroy

Professors:

MARK J. BALAS, B.S. University of Akron 1965; M.A. University of Maryland 1970; M.S. University of Denver 1974; Ph.D. 1974; Professor of Electrical Engineering 2004.

STEVEN F. BARRETT, B.S. University of Nebraska 1979; M.E. University of Idaho 1986; Ph.D. University of Texas 1993; Professor of Electrical Engineering 2011, 1999.

JERRY C. HAMANN, B.S. University of Wyoming 1984; M.S. 1988; Ph.D. University of Wisconsin-Madison 1993; Professor of Electrical Engineering 2009, 1993.

STANISLAW F. LEGOWSKI, M.Sc. Technical University of Gdansk, Poland 1962; Ph.D. 1971; Professor of Electrical Engineering 1993, 1983.

JOHN E. McINROY, B.S. University of Wyoming 1986; M.S. Rensselaer Polytechnic Institute 1988; Ph.D. 1991; Professor of Electrical Engineering 2002, 1991.

SURESH S. MUKNAHALLIPATNA, B.E. University of Bangalore, India 1988; M.E. 1991; Ph.D. University of Wyoming 1995; Professor of Electrical Engineering 2010, 1997.

JOHN W. PIERRE, B.S. Montana State University 1986; M.S. University of Minnesota 1989; Ph.D. 1991; Professor of Electrical Engineering 2002, 1991.

DAVID L. WHITMAN, B.S. University of Wyoming 1975; Ph.D. 1978; Professor 1991, 1981.

Associate Professors:

EVA S. FERRE-PIKAL, B.S. University of Puerto Rico 1988; M.S. University of Michigan 1989; Ph.D. University of Colorado 1996; Associate Professor of Electrical Engineering 2004, 1998.

ROBERT F. KUBICHEK, B.S.C.S., B.S.E.E. University of Wyoming 1976; M.S. 1977; Ph.D. 1985; Associate Professor of Electrical Engineering 1997, 1991.

JOHN F. O'BRIEN, B.S. California State Polytechnic University, Pomona 1991; M.S. University of Wyoming 1997; Ph.D. Rensselaer Polytechnic Institute 2001; Associate Professor of Electrical Engineering 2009, 2003.

JON M. PIKAL, B.S. Purdue University 1988; M.S. University of Colorado 1993; Ph.D. Colorado State University 1999; Associate Professor of Electrical Engineering 2005, 1999.

MARGARETA STEFANOVIC, Dipl. Ing., University of Nis, Yugoslavia 1996; M.S. University of Southern California 2002; Ph.D. 2005; Associate Professor of Electrical Engineering 2011, 2005.

CAMERON H.G. WRIGHT, B.S. Louisiana Tech University 1983; M.S. Purdue University 1988; Ph.D. University of Texas 1996; Associate Professor of Electrical Engineering 2008, 2003.

Assistant Professor:

DONGLIANG DUAN, B.E. Huazhong University of Science and Technology 2006; M.S. University of Florida 2009; Ph.D. Colorado State University 2012; Assistant Professor of Electrical Engineering 2012.

Academic Professonal:

JEFFREY R. ANDERSON, B.S.E.E. University of Utah 1989; M.S.E.E 1992; Ph.D. University of Wyoming 2004; Associate Academic Professional Lecturer in Electrical and Computer Engineering 2012.

Adjunct Faculty:

Elena Oggero, Guido Pagnacco

Instructor:

Yelena V. O'Brien

Professors Emeriti:

Christos T. Constantinides, Jerry J. Cupal, Clifford D. Ferris, Raymond G. Jacquot, John W. Steadman, A.H.M. Sadrul Ula

Electrical Engineering

The program of study outlined in the curriculum has been planned to provide the depth of understanding necessary to meet challenges of changing technology while being flexible enough to allow students to pursue in-depth study in at least one area of electrical engineering. In order to attain this, students are required to gain an understanding of mathematics and the basic engineering sciences. The fundamental electrical engineering education consists of courses in circuits, networks, electromagnetics, electronics, digital systems, communications, controls and energy conversion. Selection of elective courses, in consultation with the academic adviser, enables students to specialize in the above mentioned areas, as well as in robotics, microcircuits, microprocessors and high frequency electronics.

Laboratory work associated with electrical engineering courses is an important part of the curricula. This work helps students gain experience in applying the theoretical knowledge they acquire to practical engineering problems. Engineering design is an important component of the curriculum that concludes with a significant design experience in the senior year. Additional programs are described below.

F.M. Long Bioengineering Option. Named in honor of UW Professor Francis M. Long, this area offers excellent opportunities for those interested in applying the techniques of the electronic engineer to problems of environmental science, wildlife studies, biology and medicine. Employment opportunities exist in state and federal agencies, industry and medical institutions. Career placement includes such areas as use of telemetry for wildlife management, environmental monitoring, design and development of biological and medical instrumentation and clinical engineering. With minor modifications, the curriculum shown may be used as preparation for entrance to medical or dental school.

Computer Engineering

Very rapid advances in semiconductor technology have made sophisticated digital devices available as an engineering tool. The computer engineering degree program is designed for those students who want a special emphasis in both the hardware and software associated with incorporating digital devices and microprocessors into various products and systems. It includes courses in computer science and electrical engineering for both software and hardware design. Extensive laboratory work gives students experience with wired logic and microprogrammed digital systems, microprocessors, personal computers, hardware descriptive language, and computer networks.

International Engineering Option

Engineering is a global profession and today's engineers must be able to work and interact in a variety of diverse cultural and technical environments. The international engineering option gives electrical and computer engineering students an opportunity to study culture and foreign language at the same time as they pursue their engineering degrees.

The option includes at least one semester of study abroad with courses taken in a foreign language. In addition, students may participate in a four-to-five month international internship. Foreign language skills can be earned through a variety of means, including formal university coursework, intensive summer language programs, and previous education.

Foreign language education and the study-abroad experience satisfy the cultural context requirements of the University Studies Program.

Educational Objectives

Graduates of the University of Wyoming Electrical and Computer Engineering Programs will have breadth of fundamental knowledge in mathematics, basic sciences, and engineering as well as depth of knowledge in electrical engineering or computer engineering; be able to communicate effectively within and outside their discipline and work effectively with others; be able to understand and resolve ill-defined problems; be effective independent learners; have the broad general education needed to appreciate the role of engineering in the societal context and appreciate the importance of ethics in the practice of the profession.

Graduate Program

The department offers programs of study leading to the Master of Science and Doctor of Philosophy degrees in electrical engineering. Study programs are individually planned to students' interests in both course work and research.

Grade Policy

Electrical and computer engineering majors must achieve a grade of C or better on courses that are prerequisites for courses within the student's course of study. Students must also achieve a grade of C or better in all required mathematics courses.

Concurrent Major and Minor

The department offers a concurrent major and minor in both the electrical engineering and computer engineering programs. Consult the department office for a current detailed list of requirements.

Combined BS/MS Degree

The combined BS/MS program in Electrical and Computer Engineering enables especially well-qualified students to be admitted to the MS program during the junior year of their BS program and to work thereafter towards both the BS and MS degrees. These students would earn the BS degree in either Electrical Engineering or Computer Engineering and the MS degree in Electrical Engineering following the current curricula. This program allows for early planning of the MS portion of the student's education, taking graduate courses as part of the BS degree, more flexibility in the order in which courses are taken, and more efficient use of what would otherwise be a final semester with a light credit hour load.

Program Objectives for Electrical and Computer Engineering

Graduates of the University of Wyoming Electrical and Computer Engineering Program will:

- Be able to successfully practice the profession of Electrical or Computer Engineering.
- Be prepared and motivated to accept challenging assignments and responsibilities and be productive members of society.
- Demonstrate successful career growth (e.g., professional registration, graduate school, promotion and advancement).

University of Wyoming, Electrical and Computer Engineering Program, Program Outcomes

All Electrical (Computer) Engineering graduates shall demonstrate:

(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 design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Electrical Engineering Curriculum

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
ES	1000	1
MATH	2200	4
CHEM	1020	4
ENGL	1010	3
COSC	1010 or ES 1060	3-4
PEAC	1001	1
	Total Hrs.	**16-17**

FRESHMAN YEAR: Spring		Hrs.
MATH	2205	4
MATH	2250	3
ES	2110	3
PHYS	1210	4
US and WY Constitutions		3
EE	1010	1
	Total Hrs.	**18**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2310	3
ES	2120	3
ES	2210	3
PHYS	1220	4
Cultural Context/ Tech Elective		3
	Total Hrs.	**16**

SOPHOMORE YEAR: Spring		Hrs.
MATH	2210	4
EE	2390	4
EE	2220	4
Sciences/ES Elective		3
	Total Hrs.	**15**

JUNIOR YEAR: Fall		Hrs.
EE	3150	3
EE	3310	4
EE	3220	3
EE	3510	4
Cultural Context		3
	Total Hrs.	**17**

JUNIOR YEAR: Spring		Hrs.
EE	3330	4
EE	4390	3
EE	4440	3
EE	4620	3
EE	4075	4
	Total Hrs.	**17**

SENIOR YEAR: Fall		Hrs.
EE	4820	2
EE	4220	3
EE Electives		5
Cultural Context		3
ENGL	4010	3
	Total Hrs.	**16**

SENIOR YEAR: Spring		Hrs.
EE	4830	2
EE Electives		8-9
Technical Elective		3
Cultural Context		3
	Total Hrs.	**16-17**

F.M. Long Bioengineering Curriculum

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
ES	1000	1
MATH	2200	4
CHEM	1020	4
ENGL	1010	3
COSC	1010 or ES 1060	3-4
PEAC	1001	1
	Total Hrs.	**16-17**

FRESHMAN YEAR: Spring		Hrs.
MATH	2205	4
ES	2110	3
PHYS	1210	4
CHEM	2300	4
EE	1010	1
	Total Hrs.	**16**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2310	3
ES	2120	3
ES	2210	3
PHYS	1220	4
Cultural Context		3
	Total Hrs.	**16**

SOPHOMORE YEAR: Spring		
MATH	2210	4

MATH	2250	3
EE	2390	4
EE	2220	4
	Total Hrs.	**15**

JUNIOR YEAR: Fall		**Hrs.**
EE	3310	4
EE	3510	4
EE	3220	3
LIFE	1010	4
ENGL	4010	3
	Total Hrs.	**18**

JUNIOR YEAR: Spring		**Hrs.**
EE	3330	4
EE	4390	3
EE	4075	4
LIFE	2022	4
Cultural Context		3
	Total Hrs.	**18**

SENIOR YEAR: Fall		**Hrs.**
BE	4810 **or**	3
EE	4330	4
EE	4820	2
EE	3150	3
EE	4220	3
EE Elective		3-4
Technical/Cultural Context elective		3
	Total Hrs.	**17-18**

SENIOR YEAR: Spring		**Hrs.**
EE	4250 **or**	
EE	4620	3
EE	4830	2
MOLB	3610	4
US and WY Constitutions		3
Cultural Context		3
	Total Hrs.	**15**

Computer Engineering Curriculum

Suggested Course Sequence

FRESHMAN YEAR: Fall		**Hrs.**
ES	1000	1
MATH	2200	4
CHEM	1020	4
ENGL	1010	3
COSC	1010	4
PEAC	1001	1
	Total Hrs.	**17**

FRESHMAN YEAR: Spring		**Hrs.**
MATH	2205	4
ES	2110	3
PHYS	1210	4
COSC	1030	4
EE	1010	1
	Total Hrs.	**16**

SOPHOMORE YEAR: Fall		**Hrs.**
MATH	2310	3
COSC	2030	4
ES	2120	3
ES	2210	3
PHYS	1220	4
	Total Hrs.	**17**

SOPHOMORE YEAR: Spring		**Hrs.**
MATH	2210	4
MATH	2300	3
EE	2220	4
COSC	2150	3
EE	2390	4
	Total Hrs.	**18**

JUNIOR YEAR: Fall		**Hrs.**
EE	3310	4
EE	3220	3
EE	4490	3
Cultural Context/Technical elective		3
Cultural Context		3
	Total Hrs.	**16**

JUNIOR YEAR: Spring		**Hrs.**
EE	3330	4
EE	3150	3
EE	4390	3
Cultural Context		3
Science/ES Elective		3
	Total Hrs.	**16**

SENIOR YEAR: Fall		**Hrs.**
EE	4820	2
EE	4870 **or**	4
COSC	4760	3
EE or COSC Elective		3
ENGL	4010	3
EE	4220	3
US and WY Constitutions		3
	Total Hrs.	**17-18**

SENIOR YEAR: Spring		**Hrs.**
EE	4830	2
CPEN Option Courses		6
EE or COSC Elective		3-4
Cultural Context		3
	Total Hrs.	**14-15**

Graduate Study

The department offers programs of study leading to the degrees of Master of Science and Doctor of Philosophy in electrical engineering. The areas of major concentration at the graduate level are: control systems (including robotics and electrical energy), electronic systems and devices (including material devices and RF circuits), signal processing (including image processing, computer vision, and biomedical instrumentation), and computer networks. The department also offers a combined B.S./M.S. program for exceptional students wishing to obtain both degrees in a shorter period of time (see below).

Program Specific Admission Requirements

Statement of purpose
Official transcripts from all post-secondary institutions attended
GRE verbal percentile minimum of 40 percent
GRE quantitative percentile minimum of 65 percent. ETS only reports GRE scores taken within five years of the date of request
TOEFL total of 550 or 79 iBT

Program Specific Graduate Assistantships

The English Proficiency Assessment (EPA) is mandatory for incoming non-native English speaking international GAs with responsibilities in instruction. The English Proficiency Assessment is recommended for all international graduate students regardless of teaching responsibilities. Students also will need to follow recommendations for English language advancement.

Program Specific Degree Requirements

Master's Programs

Plan A (thesis)

This is a 30 hour program, 26 hours coursework and 4 hours of thesis

16 (minimum) in ECE formal coursework
3 (minimum) in formal coursework outside the department and approved by the student's committee
7 additional credits in or out of the department with committee approval
4 or more credits of M.S. thesis research
Of the above credit hours in formal coursework, no more than 12 can be 4000 level
The candidate must meet the minimum requirements for the Master of Science degree and also complete and defend a master's thesis.

Plan B (non-thesis)

This is a 30 hour program:
16 (minimum) in ECE formal coursework
3 (minimum) in formal coursework outside the department and approved by the student's committee
11 additional credits in or out of the department with committee approval
Of the above credit hours in formal coursework, no more than 12 can be 4000 level.
The candidate must meet the minimum requirements for the master of science

degree and complete a plan B project

Satisfying the "Plan B project" can be completed in one of the following ways:

Complete a project for a 5000-level EE course, including a class presentation

Complete an independent project under EE 5880 (up to three credit hours), including a presentation

Doctoral Program

Ph.D. Degree Requirements:

Ph.D. Credit Allocation (all at 4000 level minimum)

72 (minimum) of acceptable graduate coursework

42 (minimum) from ECE and closely related formal course work (EE 5980: Dissertation Research not counting toward this minimum)

Of those 42 hours, no more than 12 can be 4000 level

Courses required by the department bachelor of science degree may not be applied for graduate credit

6 (maximum) of EE 4800 (Problems in ...) can be counted for program of study credit

6 (maximum) of EE 5880 (Problems in ...) can be counted for program of study credit

9 (maximum) of EE 5600 (Statistical Signal Processing in ...) can be counted for program of study credit

In addition to the minimum requirements of the university, doctoral students must pass a written and oral comprehensive examination, part of which is a written proposal explaining their planned dissertation research. The student must also present and defend a completed dissertation. Programs of study, including coursework and any research tools, are arranged by consultation between the students and their graduate committee.

Quick Start BS/MS Program

The combined B.S./M.S. program in electrical and computer engineering enables especially well-qualified students to be admitted to the M.S. program during the junior year of their B.S. program, and to work thereafter towards both the B.S. and M.S. degrees. These students would earn the B.S. in either electrical engineering or computer engineering and the M.S. degree in electrical engineering following the current curricula. This program allows for early planning of the M.S. portion of the student's education, taking graduate courses as part of the B.S. degree, more flexibility in the order in which courses are taken, and more efficient use of what would otherwise be a final semester with a light credit hour load.

Up to 6 credit hours from UW, at the 5000-level or above, may be counted toward both the B.S. and M.S. degree programs.

For further information please visit our Web site at wwweng.uwyo.edu/electrical/grad/bsms.html.

Electrical Engineering (EE)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

1010. Introduction to Electrical and Computer Engineering. 1. Introduction to Electrical and Computer Engineering through a laboratory experience. Students perform both hardware and computer laboratory exercises in a wide range of areas of electrical and computer engineering.

2220 [3320]. Circuits and Signals. 4. Review of sinusoidal steady state analysis and ac power. Mutual inductance and linear transformers. Laplace transform. Laplace transform in circuit analysis. Frequency dependent circuits, including RLC circuit resonance. Magnitude and phase response, complex poles and zeros. Bode plots. Filter circuit fundamentals. Fourier series. Laboratory. *Prerequisite:* ES 2210.

2390. Digital Systems Design. 4. Binary logic, digital logic gates, reduction of Boolean expressions, combinational logic design. MSI and LSI combinational logic ICs, flip-flops, synchronous and asynchronous sequential systems design, MSI and LSI sequential system ICs, and algorithmic state machines. *Prerequisite:* MATH 2205. (Offered both semesters)

3150. Electromagnetics. 3. A thorough study of static electric and magnetic fields using vector methods with an introduction to dynamic fields. *Prerequisites:* ES 2210 and MATH 2210.

3220. Signals And Systems. 3. Discrete and continuous-time signals and systems. Topics include linear time-invariant systems; convolution; difference equations; FIR and IIR systems; sampling, aliasing, reconstruction, and quantization. Frequency domain concepts include discrete and continuous Fourier transforms, Z-transforms, system frequency response, Laplace transform properties, and applications of digital filters and DFT analysis. *Prerequisite:* EE 2220.

3310. Electronics I. 4. Physical characteristics and models of semiconductor devices with application to electronic circuit design. Diode circuits, single transistor amplifiers, biasing, and load lines. Laboratory. *Prerequisites:* EE 2220, PHYS 1220 or PHYS 1320. (Offered both semesters)

3330. Electronics II. 4. Current sources, differential and multistage amplifiers; circuits with ideal and non-ideal operational amplifiers; low and high band frequency response, feedback, stability, gain and phase margin of amplifiers; output stages, class A and push-pull; monolithic operational amplifier; oscillators; transistors as switches and introduction to digital electronic circuits. Laboratory. *Prerequisite:* EE 3310.

3510. Electromechanics. 4. Polyphase circuits; ferromagnetic circuits and devices; single phase and polyphase transformers; basic electromechanical energy conversion; steady state characteristics and application of DC machines, AC synchronous and induction machines; fractional-horsepower AC motors. Includes laboratory. *Prerequisite:* EE 2220.

4075 [ES 3075]. C++ with Numerical Methods for Engineers. 4. Introduction to the fundamentals of practical engineering programming, using specific applications of numerical methods to demonstrate these principles. The use of an object oriented approach using C++ in an efficient manner is emphasized. Other solution approaches, including C and Matlab will be discussed as appropriate. Credit will not be allowed in both EE 4075 and ES 3070. *Prerequisites:* MATH 2205 and (COSC 1010 or ES 1060) and (MATH 2250 or MATH 2310).

4220. Probabilistic Signals and Systems. 3. Fundamentals of probability and statistics for engineers; reliability in engineering systems; random processes, statistical estimation, auto/cross correlation and power spectral density functions and linear filtering of random signals. *Prerequisite:* EE 3220.

4245. Digital Signal Processing. 3. Sampling and oversampling A/D's; FIR and IIR digital filter design, effects of quantization, practical realizations; applications of the discrete and fast Fourier Transform (DFT and FFT); correlation, periodograms, window effects, multi-rate techniques, multi-dimensional signal processing, and other topics in digital signal processing. *Prerequisite:* EE 3220.

4250. Network Synthesis. 3. Characterization and design specification of analog filters. First and second order passive and active filters. Butterworth and Chebyshev filter responses. Audio frequency active filter synthesis using operational amplifiers. Introduction to frequency transformations and sensitivity. *Prerequisites:* EE 2220 and 3330 or concurrent enrollment.

4300. Introduction to Microwave and RF Circuits. 3. Analysis and design of microwave and RF circuits with applications to communication and radar systems. Review of transmission line concepts and the Smith Chart, scattering parameters, microstrip lines, and matching networks. Analysis and design of microwave and RF amplifiers, oscillators, and mixers. Dual listed with EE 5300. *Prerequisite:* EE 3150, concurrent enrollment in EE 3330.

4330 [4370]. Electronic Systems Design. 4. Analog integrated circuits such as amplifiers (operational, instrumentation, isolation, video, transconductance, comparator, logarithmic and exponential); voltage regulators; analog multipliers and dividers; AC to DC converters; sample and hold circuits; digital to analog converters; analog to digital converters; function generators; phase locked loops. Includes design procedures for electronic systems implementing analog integrated circuits. Laboratory. *Prerequisites:* EE 2390 and 3330.

4340. Semiconductor Materials and Devices. 3. Physical properties of semiconductor materials and devices, including crystal lattices and energy bands, carrier generation, transport, and recombination. PN, metal-semiconductor, and heterojunction operation. Field Effect Transistors, including Metal Oxide Semiconductor (MOSFET), Junction (JFET), MEtal Semiconductor (MESFET), and High Electron Mobility (HEMT) transistors. Bipolar Junction (BJT) and Heterojunction (HBT) Transistor operation. Cross listed with PHYS 4340. *Prerequisite:* PHYS 1220 or 1320.

4360. VLSI Design. 3. Introduction to CMOS processing, MOS fundamentals including devices models; switching and timing; analog subcircuits and amplifiers; inverters and CMOS gates; concept of standard cells and fully custom design; use of SPICE, digital simulation, and chip layout and verification software. *Prerequisites:* EE/COSC 2390 and EE 3330.

4390. Microprocessors. 3. Design of microcomputers, controllers and instruments which use microprocessors. Semiconductor memory design, CPU architecture, bus structure and timing, input-output interfaces and devices, assembly language programming, assemblers, compilers, editors and simulators. Emphasizes design techniques. Laboratory. *Prerequisite:* EE 2390.

4440. Communication Theory. 3. Amplitude and angle modulation and demodulation; digital baseband and carrier communication systems; performance of communication systems; and current topics in communication systems. *Prerequisite:* EE 3220.

4490. Hardware Descriptive Language (HDL) Digital Design. 3. Hardware Description Language design of digital systems. Industrial CAD tools are used to produce a functional description of hardware that is both simulated and then synthesized into hardware. Methods to describe both combinational logic and synchronous devices are given. Devices such as CPLDs and FPGAs are targeted in this design process. Emphasizes design techniques. *Prerequisite:* EE 2390.

4510. Power Systems. 3. Electric power distribution and transmission. Distribution systems, transmission line calculations, installation and protection; substations, corona, protective relaying and carrier current communication and telemetering. Introduction to system stability studies. *Prerequisites:* ES 2210 and EE 3510.

4530. Digital Image Processing. 3. Methodologies and algorithms for processing digital images by computer. Includes color spaces, pixel mappings, filtering, image segmentation, geometric operations and pattern classification. *Prerequisite:* EE 3220 or equivalent background.

4540. Energy Policies and Impacts. 2. Consequence of energy use; effects of development of coal, oil shale, oil, natural gas, uranium and geothermal energy; environmental impact on air and water pollution; federal, state and local regulations; renewable energy sources such as solar, wind, hydro, ocean thermal and wave. *Prerequisite:* senior standing.

4550. Electrodynamics. 4. Solid state control of AC and DC machines; DC machine dynamics; three-phase AC machine transients and dynamics; single phase motors; two-phase control motors; stepper motors; and synchros and control transformers. *Prerequisite:* EE 3510.

4560. Power Electronics. 3. Thyristors and other semiconductor devices; rectifiers; dual converters and cycloconverters; AC and DC switches and regulators; inverters and frequency changers; protection, control and application of static power converters. *Prerequisites:* EE 3330 and 3510.

4590. Real Time Embedded Systems. 3. Emphasizes a systems approach to real time embedded systems. Students are expected to apply methodical system design practices to designing and implementing a microprocessor-based real time embedded system. Students employ a robot-based educational platform to learn the intricacies of real time embedded systems, distributed processing, and fuzzy logic. Students learn processor input/output interfacing techniques. Students use state-of-the-art design and troubleshooting tools. Dual listed with EE 5590. *Prerequisites:* EE 4390.

4620. Automatic Control Systems. 3. Feedback control systems analysis and design using frequency domain, time response and state-space methods. Routh's criteria, Nyquist criteria and root locus. Dominant pole controller design. Introduction to discreet controllers. Use of MATLAB. *Prerequisite:* EE 2220.

4800. Problems in _____. 1-6 (Max. 6). Section 1 is individual study. Other sections are group study by seminar or class format. Features topics not included in regularly offered courses. *Prerequisite:* consent of instructor.

4820. Senior Design I. 2. Students choose a senior design project and complete the preliminary design. This stage of senior design includes investigation of alternative solutions that meet the project's requirements, cost analysis, and building the prototype circuit. Periodic oral and written project progress reports are required. *Prerequisites:* EE 2390, EE 3330 and corequisite courses in the area of the design project.

4830. Senior Design II. 2. Students complete the senior design project partially designed in EE 4820. The final result of the senior design project includes assembly of a PC board hardware that meets the project's requirements and final report describing the design procedure, designed hardware and software, and results of final testing. Periodic oral and written project progress reports are required. *Prerequisites:* EE 4820 and selected courses in the area of the design project.

4850. Research in _____. 1-3 (Max. 4). Research experience for individual students. Investigations or extensions of topics which are not a part of formal course. May not be substituted for thesis/dissertation research credit and/or undergraduate design requirement. *Prerequisite:* senior standing in EE.

4870. Computer Network Hardware. 4. Study of Computer Network hardware architecture, design and functionality. The course addresses IEEE wired and wireless network architectures, routers, gateways and other network components. System administration of Windows NT and 2000 based networks forms an important component of the course. Laboratory sessions include commercial hardware and performance analysis through simulations. *Prerequisites:* EE 2390.

4970. Graphical Interface. 3. Graphical interface development using a suitable graphics language and foundation classes. The course will address issues like dynamic library links, threads, multitasking, and hardware interface of an application running under an operating system (Windows NT). The majority of the ap-

plications will be in the electrical engineering and computer science areas. *Prerequisites:* EE/COSC 4070 or COSC 2030.

4990. Advanced Microprocessors. 3. Architecture and instruction set of Intel family of microprocessors; Intel System Development Kit and its monitor program; Microsoft Macro Assembler (MASM) and Visual C/C++ Express; modular programming; High level language compilers of object code; Interface design issues of peripheral devices to Personal Computer**.** *Prerequisite:* EE 4390.

5210. Systems Theory. 3. Review of linear time-invariant systems theory. Laplace, Fourier, and Z-transforms. Introduction to complex variable theory and its application to integral transform inversion. State variable formulation of physical systems. Application of linear algebra and matrices to the analysis of finite-state constant differential systems. Controllability and observability. *Prerequisite:* EE 4620.

5300. Introduction to Microwave & RF Circuits. 3. Analysis and design of microwave and RF circuits with applications to communication and radar systems. Review of transmission line concepts and the Smith Chart, scattering parameters, microstrip lines, and matching networks. Analysis and design of microwave and RF amplifiers, oscillators, and mixers. Dual listed with EE 4300. *Prerequisite:* EE 3150 or concurrent enrollment in EE 3330.

5320. Advanced Microwave Circuits. 3. Analysis and design of passive microwave circuits including microwave filters, resonators, power dividers, and directional couplers. Microstrip lines, broadband matching networks and effects of discontinuities in microstrip circuits are also discussed. *Prerequisites:* EE 4300 or EE 5300.

5330. Advanced Electronic Systems Design. 3. Theory of errors. High accuracy: multiplexers; voltage references; sample and hold circuits. Amplifiers: programmable gain; high speed voltage feedback; current feedback. Noise in integrated circuits. Pulse code modulation ADC; sigma delta ADC; oversampling; undersampling. Analog and digital audio systems. CD players. Superheterodyne and digital receivers. Signal transmission and conditioning. Hardware design techniques. *Prerequisite:* EE 4330 and 4210.

5340. Advanced Semiconductor Material and Devices. 3. Advanced semiconductor materials and device concepts including noise in semiconductors, heterostructure and quantum fundamentals, high power materials and devices, high performance transistors including the MESFET, HEMT, and HBT. Also discusses GUNN and IMPATT diodes, Resonant Tunneling devices, and future computing devices based on the quantum properties of semiconductors. *Prerequisite:* EE 4340.

5350. Optoelectronic Semiconductor Materials and Devices. 3. Optoelectronic properties of semiconductor materials and devices. Includes a review of the basic electronic properties of semiconductors materials, epitaxial growth, optical properties including absorption and emission of light, effects of quantum confinement and strain, and Heterostructures. Operation and optimization of basic optoelectronic devices including: photodetectors, LEDs Lasers, and modulators. *Prerequisite:* EE 4340.

5360. Digital VLSI Design. 3. Digital building blocks, stick diagrams, CMOS cells and arrays, CMOS digital subsystems and systems. Chip design software such as layout, simulators and digital synthesis using HDL. Digital design verification and timing issues. *Prerequisite:* EE 4360.

5370. Analog VLSI Design. 3. CMOS amplifiers, comparators, operational transconductance amplifiers, op-amps, D/A and A/D, signal sources, chip design, software and SPICE will be used. *Prerequisite:* EE 4360.

5390. Computer Architecture. 3. Examines the various methodologies used in the design of high-performance computer systems. Topics include CISC and RISC architecture and instruction sets, pipelining, instruction-level parallelism, memory hierarchy (including cache) design and computer networks. *Prerequisite:* EE 4390.

5400. Introduction To Robotics. 3. Representation of pose using Euler angles, quaternions and homogeneous coordinate transformations. Forward and inverse kinematics of rigid body manipulators. Velocity and force transformation in a rigid robot using Jacobians. Trajectory generation using splines. Robotic vision for depth measurement. Analysis of actual robotic systems. *Prerequisite:* MATH 2250.

5410. Neural and Fuzzy Systems. 3. Theory of feed forward and recurrent neural networks. Supervised and unsupervised learning theories. Fuzzy logic and systems. Associative memories. Matching and self-organizing networks. Application of neural and fuzzy systems. *Prerequisite:* EE 3220.

5420. Speech Processing. 3. Introduction to the field of digital speech processing and analysis. Speech production models. Analysis using LPC, spectrum, cepstrum, hidden Markov models. Pitch and formant estimation. Speech coding and compression. Speech and speaker recognition. Speech synthesis and enhancement. *Prerequisite:* EE 3220, EE 4220.

5450. Topics in Robotics. 3. Topics vary between offerings, but include exponential coordinates for describing rigid motion, parallel machines, robotic vision, actuators and sensors, calibration, quaternions, motion planning, multifinger grasp dynamics, singularities, and singularity-free design, and limited-DOF machines. *Prerequisite:* MATH 2250, senior or higher level standing and permission of the instructor.

5470. Optimal Control. 3. Calculus of Variations: Principal of Optimality; Hamilton-Jacobi-Bellman Equation; Linear Quadratic regulator; Linear Quadratic Gaussian; Loop Transfer Recovery; Suboptimal Feedback; LQR with Output Feedback; Optimal Estimation Theory; Pontryagin's minimum principle. *Prerequisites:* EE 4620, MATH 2210, MATH 2310, MATH 2250.

5475. Adaptive Control Systems. 3. Introduction to adaptive identification and control for counteracting uncertainty in a dynamical control system. Stability notions (input/output, Lyapunov, Barbalat's lemma, passivity), online parameter estimation, parameter convergence, persistency of excitation, direct & indirect adaptive control, Model Reference Adaptive Control, certainty equivalence, Adaptive Pole Placement Control, robustness against disturbances and unmodeled dynamics. Supervisory and Switching control. *Prerequisites:* EE 5210.

5490. Convex Optimization. 3. Covers fundamentals of numerical convex optimization. These methods have potential applications in many fields, so the goal of the course is to develop the skills and background needed to recognize, formulate, and solve convex optimization problems. Covers convex sets, convex functions, convex optimization problems and applications. *Prerequisites:* MATH 2250 and senior or higher level standing.

5590. Real Time Embedded Systems. 3. Emphasizes a systems approach to real time embedded systems. Students are expected to apply methodical system design practices to designing and implementing a microprocessor-based real time embedded system. Students employ a robot-based educational platform to learn the intracacies of real time embedded systems, distributed processing, and fuzzy logic. Students learn processor input/output interfacing techniques. Students use state-of-the-art design and troubleshooting tools. Dual listed with EE 4590. *Prerequisites:* EE 4390.

5600. Statistical Signal Processing. 2-4. (Max. 9). Topics vary between offerings but include signal detection, feature extraction and pattern recognition, information theory and

coding, spectral analysis, identification, speech processing, image processing, and seismic processing. *Prerequisite:* EE 4220.

5610. Random Processing Theory I. 3. Introduction to statistical models. Applications of sampling theorems. Correlation functions and spectra. Shot noise and thermal noise. Introduction to measurements and computational techniques. Nonlinear random processes. Term papers on special problems. *Prerequisite:* EE 4220.

5625. Spectral Analysis. 3. Spectral estimation including nonparametric methods such as Welch and Blackman-Tukey; modern parametric methods for AR, MA and ARMA spectra including Yule-Walker and Levinson-Durbin. Parametric line spectral subspace methods including MUSIC and ESPRIT. Filterbank and spatial methods such as beamforming. *Prerequisites:* EE 3220, 4220 or equivalent.

5630. Advanced Image Processing. 3. Introduces students to advanced aspects of image processing (IP), using specific applications to demonstrate these principles. Concepts such as medical imaging; color IP; wavelets and multiresolution IP; image compression; morphological IP; image segmentation, representation, description and understanding are covered. *Prerequisites:* EE 4530.

5640. Adaptive Filters and Signal Processing. 3. Adaptive filtering including eigenanalysis, low-rank modeling, Wiener filters, linear prediction, steepest descent methods, least mean-squares and recursive least squares methods, adaptive beamforming. Performance, convergence, and stability issues. Realization techniques. *Prerequisites:* EE 4220.

5650. Object and Pattern Recognition. 3. Introduces students to both fundamental and advanced aspects of object and pattern recognition, using specific applications to demonstrate these principles. Concepts such as Bayesian, maximum-likelihood, principal components, nonparametric, linear discriminant, multi-layer neural networks, etc., and the trade-offs and appropriateness of classification techniques are covered. *Prerequisite:* EE 4220.

5660. System Identification. 3. Fundamental and advanced topics in identification of system models from measured data. A variety of model structures are studied such as ARX, ARMAX, and State Space. Both non-parametric and parametric identification techniques are investigated with applications to real world systems and data. Experiment design and model validation are also examined. *Prerequisites:* EE 4220.

5700. Power Engineering. 2-6 (Max. 6). Design of transmission lines and distribution systems. Coordination studies. System stability studies, load distribution and dispatching. System interconnections. Correlation of machines and transmission systems. *Prerequisite:* EE 4510.

5740. Digital Control Systems. 3. Mathematical models of digital control system components; Sample-and-Hold Device, A/D and D/A conversion, Pulse transfer function, Modified Z-transform; Jury's and Routh-Hurwitz test, Bilinear Transformations, Nyquist Criterion, Root Locus; Frequency Domain Techniques (Bode Diagrams, Nichols Charts); Digital Control Design, Observers; DT state space representation; Sampling and Quanitization, Aliasing. Design Project. *Prerequisite:* EE 4620.

5770. Non Linear Systems. 3. Time variable parameter systems, approximation methods for small nonlinearites. Phase-plane methods. The second method of Liapunov. Describing function. Optimum switched systems. Adaptive control systems. *Prerequisite:* EE 4620.

5880. Problems In Electrical Engineering. 1-6 (Max. 9). A graduate special topics course in which advanced developments are studied. Section 1 is individual study. Other sections primarily seminar format in which participants present reports on the subject under study. *Prerequisite*: Prior approval of the instructor is required.

5885. Special Topics in Electrical Engineering. 1-6 (Max 30). Features topics not included in regularly offered classes. Normally offered in regular class lecture format; may include a lab component if appropriate. *Prerequisite*: Prior approval of the instructor is required.

5900. Practicum in College Teaching. 1-3. (Max 3). Work in classroom with a major professor. Expected to give some lectures and gain classroom experience. *Prerequisite:* graduate status.

5920. Continuing Registration: On Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5940. Continuing Registration: Off Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5959. Enrichment Studies:. 1-3 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

5960. Thesis Research. 1-12 (Max. 12). Designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. *Prerequisites:* enrolled in a graduate degree program.

5980. Dissertation Research. 1-12 (Max. 48). Designed for students who are involved in research for their dissertation project. Also used for students whose coursework is complete and are writing their dissertation. *Prerequisites:* enrolled in a graduate level degree program.

5990. Internship. 1-12 (Max. 24). *Prerequisite:* graduate standing.

Bioengineering (BE)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

4800. Topics in Bioengineering. 2-6 (Max. 6). Independent or group study of current topics not included in more formal course offerings in bioengineering, biology or engineering. *Prerequisite:* consent of instructor.

4810. Bioinstrumentation. 3. Electronic systems used to monitor physiological systems and function (cardiovascular, pulmonary, nervous); transducer systems, amplifiers and recording systems used in research and clinical applications. Laboratory. *Prerequisites:* EE 3330.

4820. Biodata Systems. 3. Extraction of physiological signals from noise, biomedical signal and image processing and modeling of physiological functions from experimental data. Includes hands-on exercises using both simulated and actual biomedical signals and/or images. Complements BE 4810, and can be taken alone, before, or after BE 4810. *Prerequisites:* EE 3320.

5810. Bioinstrumentation. 3. Discussion of the cardiovascular, pulmonary, and nervous systems with regard to monitoring function and the transducers used to measure system parameters. Transducer systems, amplifiers, and recording systems used in research and clinical applications. Dual listed with BE 4810. *Prerequisite:* basic course or equivalent in electronics, ZOO 4240 or concurrent enrollment.

5820. Bio-Data Systems. 2. Extraction of signals from noise and data analysis. Emphasis on system modeling of physiological functions from experimental data. Dual listed with BE 4820. *Prerequisite:* basic course, or equivalent, in electronics, ZOO 4240 or concurrent enrollment.

5959. Enrichment Studies. 1-3 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

Environmental Engineering

3074 Engineering Building, 766-5255
E-mail: ceinfo.uwyo.edu
Web site: www.eng.uwyo.edu/civil

A master of science in environmental engineering is available in the College of Engineering through a joint effort of the Department of Civil and Architectural Engineering and the Department of Chemical and Petroleum Engineering in cooperation with the School of Environment and Natural Resources. This interdisciplinary degree offers students an engineering perspective for solutions to environmental problems. Emphasis is on minimization, monitoring, control, and processing of waste products as well as treatment and disposal associated with point and non-point pollution sources. Integration of engineering with science, regulatory, and policy aspects of environmental engineering is an important component of this unique program. Further information is available from the environmental engineering graduate studies program office and/or departments involved.

Program Specific Admission Requirements

Any additional requirements as per cooperating department: Civil and Architectural Engineering or Chemical and Petroleum Engineering.

Program Specific Degree Requirements

Master of Science in Environmental Engineering
Plan A (thesis)

Students must meet university minimum requirements.

Early in the program, the student must submit a program of study listing coursework for approval by the departmental graduate studies committee, the department head, and subsequently, the Office of the Registrar.

Plan A is required of all state supported graduate assistants.

Plan B (non-thesis)

Students must meet university minimum requirements

Early in the program, the student must submit a program of study listing coursework and the course number that the Plan B paper covers for approval by the graduate studies committee, the department head, and subsequently, the Office of the Registrar.

Environmental Engineering (ENVE)

5410. Advanced Biological Wastewater Treatment. 3. Theory and practice of advanced biological treatment processes for municipal and industrial wastewaters, sludges, groundwater bioremediation and solid waste. Emphasis is on fundamental principles applied to the design and control of existing processes and the development of innovative systems. Cross listed with CE/CHE 5410. *Prerequisites:* consent of instructor.

5430. Environmental Engineering Chemistry. 3. Focus includes inorganic, organic, physical, equilibrium, biochemistry, colloidal and nuclear chemistry with an emphasis on the problems/solutions encountered by environmental and civil engineers. *Prerequisite*: CHEM 1020.

5450. Advanced Physical Chemical Treatment. 3. A study of physical and chemical processes for treatment of water, and waste water. Cross listed with CE 5450. *Prerequisite:* CE 4400.

5880. Topics. 1-3 (Max. 6). Selected topics in environmental engineering. Offered on an individual or small group basis as appropriate. Intended to accommodate various specialized subjects not offered on a regular course. Students may enroll in more than one section of this course provided topics are different. *Prerequisite:* consent of instructor.

5885. Problems. 1-3 (Max. 6). Special course designed to make possible individual investigation of problems of environmental engineering selected to fit student's educational research needs. *Prerequisite:* consent of instructor.

5895. Environmental Engineering Seminar. 1-3 (Max. 3). Departmental seminar on current research with formal training for professional and scholarly presentation of research/technical papers. *Prerequisites:* consent of instructor, graduate standing.

5960. Thesis Research. 1-12 (Max. 24). Designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. *Prerequisite:* enrollment in a graduate degree program.

Department of Mechanical Engineering

2052 Engineering Building, 766-2122
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Department Head: Paul A. Dellenback

Professors:

DENNIS N. COON, B.S. Alfred University-New York; M.S. 1984; Ph.D. Pennsylvania State University 1986; Professor of Mechanical Engineering 1999, 1988.

DIMITRI J. MAVRIPLIS, B.S. McGill University 1982; M.Eng. 1982; Ph.D. Princeton University 1987; Professor of Mechanical Engineering 2003.

JONATHAN W. NAUGHTON, B.S. Cornell University 1986; Ph.D. Pennsylvania State University 1993; Professor of Mechanical Engineering 2012, 1997.

DAVID E. WALRATH, B.S. University of Wyoming 1974; M.S. 1975; Ph.D. University of Delaware 1986; Professor of Mechanical Engineering 1998, 1986.

Associate Professors:

PAUL A. DELLENBACK, B.S. Texas Tech University 1978; M.S. 1980; Ph.D. Arizona State University 1986; Associate Professor of Mechanical Engineering 1994, 1990; Head of Mechanical Engineering 2009.

MARK R. GARNICH, B.S. Michigan Technological University 1981; M.S. 1983; Ph.D. University of Wyoming 1996; Associate Professor of Mechanical Engineering 2001.

CHUNG-SOUK HAN, Dipl.-Ing. Darmstadt University of Technology, 1994; Dr.-Ing. University of Hannover, 1999; Associate Professor of Mechanical Engineering 2010.

Assistant Professors:

RAY S. FERTIG III, B.S. University of Wyoming 2001; M.S. 2003; Ph.D. Cornell University 2010; Assistant Professor of Mechanical Engineering 2011.

CARL P. FRICK, B.S. University of Colorado at Boulder 1999; M.S. 2003; Ph.D. 2005; Assistant Professor of Mechanical Engineering 2008.

JAYANARAYANAN SITARAMAN, B.Tech., Indian Institute of Technology India 1998; M.S. University of Maryland 2000; Ph.D. 2003; Assistant Professor of Mechanical Engineering 2009.

MICHAEL STOELLINGER, M.S. Technical University Munich 2005; Ph.D. University of Wyoming 2010; Assistant Professor of Mechanical Engineering 2012.

YUAN ZHENG, B.S. Shanghai Jiaotong University, China 1992; M.S. Purdue University 1999; Ph.D. 2003, Assistant Professor of Mechanical Engineering 2009.

Associate Lecturer:
ANN NANCY PECK, B.S. Lehigh University 1984; M.S. Rensselaer Polytechnic Institute 1987; Ph.D. 1992; Associate Lecturer in Mechanical Engineering 2000, 1997.

Senior Research Scientist:
SCOTT A. MORTON, B.S. University of Wyoming 1972; M.S. 1978; Senior Research Scientist in Mechanical Engineering 2006, 1999.

Professors Emeriti:
Donald F. Adams
Bruce R. Dewey
William R. Lindberg
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Mark J. Balas
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Rowland Linford
Dan Stanescu

Mechanical Engineering is the broadest area of study in engineering. In contrast to other engineering disciplines, mechanical engineers are employed in significant percentages in almost all industrial and governmental organizations that employ engineers.

The spectrum of activities in which mechanical engineers are engaged continues to expand. The curriculum has in turn become flexible to allow for the education of mechanical engineering students in many diverse and allied areas, or for graduate school preparation.

The educational objectives of the Department of Mechanical Engineering are as follows:

- Demonstrate career success through professional accomplishments
- Demonstrate continued development of problem solving skills through independent learning
- Demonstrate effective communication and design skills with recognition of appropriate constraints
- Demonstrate ethical considerations, safety, and sustainability in engineering practice

The undergraduate program includes a foundation in mathematics, science, and engineering sciences. The three key elements of the mechanical engineering undergraduate program are laboratory experience, design experience, and development of communication skills.

The mechanical engineering curriculum affords the student the flexibility to pursue specific professional goals within the discipline. Such an opportunity needs to be carefully considered by each student, so that elective courses are chosen with these goals in mind. During the junior and senior years, the student selects 15 credit hours of technical electives.

Mechanical and Energy Systems engineering degree candidates must meet the academic requirements of the college and in addition must have an average GPA of 2.0 (C) in Mechanical and/or Energy Systems engineering courses completed at this university. A grade of (C) or better must be earned in all engineering science and required mathematics courses.

International Engineering Option

An International Option is available for the mechanical engineering program. The program requires two years of college-level foreign language and a study abroad experience, which together satisfy most cultural context requirements of the University Studies Program. This program requires 134 credit hours. A detailed curriculum is available from the Mechanical Engineering Department office.

Mechanical Engineering Curriculum*

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
MATH	2200	4
ES	1000	1
ES	1060	3
CHEM	1020	4
ENGL	1010	3
Physical education[8]		1
	Total Hrs.	**16**

FRESHMAN YEAR: Spring		Hrs.
MATH	2205	4
ES	2110	3
COJO	1010	3
US & Wyoming Consitutions		3
Math/Science elective[1]		3
	Total Hrs.	**16**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2210	4
ES	2120	3
ES	2210	3
ES	2410	3
PHYS	1220	4
	Total Hrs.	**17**

SOPHOMORE YEAR: Spring		Hrs.
MATH	2310	3
ES	2310	3
ES	2330	3
ME	2020	2
ENGL	2005	3
CHEM 1030 or PHYS 2310 or 2320		3-4
	Total Hrs.	**17-18**

JUNIOR YEAR: Fall		Hrs.
ME	2160	2
ME	3010	3
ME	3020	3
ME	3040	3
Business Elective[2]		3
	Total Hrs.	**14**

JUNIOR YEAR: Spring		Hrs.
ME	3170	3
ME	3360	3
ME	3450	3
ME	4020	3
Technical Elective[3]		3
Cultural Context Elective[7]		3
	Total Hrs.	**18**

SENIOR YEAR: Fall		Hrs.
ME	4010 or EE 4620	3
ME	4060	3
ME Elective[4]		3
Math/Science Elective[1]		3
Cultural Context Elective[7]		3
	Total Hrs.	**15**

SENIOR YEAR: Spring		Hrs.
ME	4070	3
ME Elective[4]		3
ME Solids Elective[5]		3
ME Fluids Elective[6]		3
Cultural Context Elective[7]		3
	Total Hrs.	**15**

*A minimum of 128 credit hours graded (A-F) course hours are necessary to satisfy degree requirements. Students selecting the International Studies Option require a minimum of 134 credit hours to satisfy degree requirements. (Credits earned by examination count in these hours).

[1] Math/Science electives: To be selected from the department-approved list.

[2] Business elective: ACCT 1010, BADM 1040, CE 3900, DSCI 3210, DSCI 4260, ES 4910, FIN 3250 or others as approved by adviser.

[3] Technical elective: Must have prior approval of the advisor. May be chosen from any engineering discipline, mathematics, science or business. 2 of the 4 elective courses (from among Math/Science, Business, and or Technical Electives) must be at the 3000+ level.

[4] ME Elective. Any ME course.

[5] ME Solids Electives: ME 4040, 4100, 4210, 4215.

[6] ME Fluids Electives: ME 3400, 4240, 4330, 4340, 4350, 4470.

[7] The Cultural Context Electives must be chosen to earn one each of the following credits: CH (Humanities); CS (Social Sciences); CA (Arts) G (Global Awareness); and D (Cultural Diversity in the US).

[8] Offered S/U only. Need not be taken during freshman year, but must be completed prior to graduation.

Graduate Study

The Department of Mechanical Engineering offers graduate study leading to the Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Mechanical Engineering. Mechanical engineering faculty conduct research in the areas of aerodynamics, computational fluid dynamics, wind energy, heat transfer, gasification, biomaterials, composite materials, continuum mechanics, computational material science, materials reliability, mechanical behavior of materials, and nanomechanics of surfaces and interfaces.

Department Specific Admission Requirements

Applicants should possess a Bachelor of Science (B.S.) degree or equivalent in Mechanical Engineering. Students that do not hold B.S./M.E. degrees may qualify as M.S. candidates by completing, without credit, certain prerequisite courses as specified by the Department. These prerequisites would depend upon the candidate's background and upon the area in which he/she plans to specialize.

In addition to the required application materials (i.e. application form, academic transcript, GRE/TOFEL scores, letters of reference) the applicant must submit a Statement of Purpose indicating their technical area of interest, abilities, and objectives in completing a graduate degree in mechanical engineering.

A minimum composite score of 294 (MS) or 307 (PhD) on the Verbal and Quantitative sections of the GRE is typically required for full admission to the Mechanical Engineering Department. For international students, a minimum score of 577 on the written exam or 90 on the Internet-based test (iBT) is typically required for full admission.

Program Specific Degree Requirements

Master of Science (M.S.) Program

The Mechanical Engineering Department offers both a thesis (Plan A) and a non-thesis (Plan B) M.S. program. For either program, courses should be chosen so that one is a 5000-level course outside the student's area of primary interest, and two courses should be mathematics-oriented. In conjunction with their adviser, students select the remaining courses in their program. No graduate credit is allowed for 4000-level mechanical engineering courses.

Plan A (thesis)

A thesis project is chosen in consultation with an ME faculty member, and constitutes 4 credit hours of the 30-hour Plan A program. A maximum of 9 credits at the 4000-level may be taken.

ME 5478 (Seminar) is to be taken during the final semester when the thesis is presented and defended, and constitutes 2 credit hours of the 30-hour Plan A program.

Plan B (non-thesis)

The Plan B M.S. degree can be completed by earning a minimum of 31 credits beyond the baccalaureate degree.

Classes must meet the following constraints:

Mathematics or Statistics (4000-level or above); minimum of 6 hours

ME courses (5000-level); minimum of 15 hours

Graduate Project (ME 5961); minimum of 1 hour

Technical Electives (4000-level or higher); minimum of 9 hours

Total: minimum of 31 hours

- Technical electives must be chosen with the approval of the academic adviser. They can be in mathematics, statistics, science, or other engineering disciplines. Up to two courses may be from the fields of business, ENR, or public policy.
- A maximum of 12 credits at the 4000 level may be taken. Special topic credits may be earned using ME 5475; a maximum of 6 credits may be earned in this manner.
- Research credits earned through ME 5960 as part of an unfinished M.S. Plan A program may not be counted. Although the Plan B M.S. degree is not research-oriented, the program must contain an "element of discovery," documented by completing ME 5961 (Graduate Project). This could be a special project performed as independent study or as part of a graduate course. The department's graduate committee must approve the project.
- On-campus students enrolled in the Plan B program will be expected to attend at least three Mechanical Engineering Department graduate seminars per semester.

Quick Start BS/MS Program

Through judicious choice of undergraduate electives, this program allows double-counting up to two 5000-level courses from the B.S. program toward M.S. degree requirements, thus reducing the time requirement for completing an M.S. degree. Students can apply for admission to the B.S./M.S. program by achieving junior status and meeting the following requirements for admission:

- completion of the four core ME courses (ME 3010, ME 3020, ME 3040, and ME 3360),
- a minimum overall GPA of 3.25,
- a minimum GPA of 3.25 in ME courses, and
- a minimum of three letters of recommendation (at least two must be from ME faculty at UW).

Students must maintain a GPA of at least 3.25 in their undergraduate and at least 3.0 in their graduate coursework in order to remain in good standing in the program. Not meeting the GPA requirement places a student on probation for one semester. If the GPA requirement is not met after that semester, the student will be dismissed from the Quick Start program.

Transfer students must have taken courses equivalent to the ME core courses. Transfer students must have also completed at least 15 credit hours of courses at UW in order to be eligible for admission.

Doctoral Program

For students of outstanding academic ability and with demonstrated capacity for undertaking independent research on advanced engineering problems, the Ph.D. program in mechanical engineering is offered. The PhD requires a minimum of 72 graduate hours, at least 42 of which must be earned in formal coursework. No graduate credit is allowed for 4000-level mechanical engineering courses. A preliminary exam is required, and in most cases this should be taken before completing the third semester of study. The preliminary exam shall consist of a written component administered by the student's committee and an open presentation of the proposed dissertation research. The dissertation research will be publicly presented and conclusions defended in accordance with university policy.

Mechanical Engineering (ME)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◆▶QB]).

2020 [2010]. Design of Experiments Lab. 2. A laboratory course designed to introduce students to basic experimental concepts in the context of statics and dynamics. The development of skills in report writing, experimental design, utilization of productivity software, interpersonal teamwork and fundamental statistics are emphasized. Cross listed with ESE 2020. *Prerequisites:* ES 1060; ES 2120; companion course ENGL 2005 for WB credit.

2160 [2140]. Fluids Laboratory. 2. A laboratory course to present experimental techniques, develop laboratory and interpersonal teamwork skills, and demonstrate some of the fundamental concepts of thermodynamics and fluid dynamics. Cross listed with ESE 2160. *Prerequisites:* ES 2330 and ME/ESE 2020.

3010. Intermediate Mechanics of Materials. 3. Expansion of the principles of solid mechanics: stress, strain, principal stresses, elastic and plastic behavior, failure theories and the use of energy methods. Analysis and design of thick-walled pressure vessels, noncircular cross sections under torsion, nonsymmetric beams under bending and curved beams. *Prerequisite:* ES 2410.

3020. System Dynamics. 3. Theoretical and experimental study of the dynamics of linear and non-linear lumped parameter models of mechanical, electrical, electronic, fluid, thermal and mixed systems. Cross listed with ESE 3020. *Prerequisites:* ES 2210, ME/ESE 2020, and MATH 2310. (Normally offered fall semester)

3040. Thermodynamics II. 3. Consideration of advanced thermodynamic topics including Maxwell's relations, compressible flow, and combustion. Applications to design of refrigeration cycles, humidification systems, and Rankine cycles. Cross listed with ESE 3040. *Prerequisite:* CHEM 1020 and ES 2310. (Normally offered fall semester)

3170. Machine Design. 3. Application of engineering mechanics and materials science to the analysis and design of mechanical components such as bolted connections, springs, gears, bearings and shafts. Design for dynamic loading conditions. Principles of hydrodynamic lubrication. Introduction to computer-aided design. Case studies with appropriate topics. *Prerequisite:* ES 2410. (Normally offered spring semester)

3360 [ES 3360, ES 4360]. Fundamentals of Transport Phenomena. 3. Basic concepts of heat and mass transfer and their applications to problems involving engineering analysis and design. Topics include steady-state and transient conduction, free and forced convection (heat and mass), radiation and heat exchangers. Cross listed with ARE/ESE 3360. *Prerequisites:* ES 2310, ES 2330 and MATH 2310.

3400. Heating, Ventilating and Air Conditioning of Buildings. 3. Qualitative and quantitative study in concepts of basic air-conditioning with focus on buildings including building envelope, moist air thermodynamics, human comfort, thermal load calculations, thermal behavior of buildings, HVAC systems/equipment, and design of space air-conditioning and its relationship to architectural design. Cross listed with ARE 3400. *Prerequisites:* ES 2310, ES 2330, and either ARE 2410 or ME/ESE 3360.

3450 [ES 3450]. Properties of Materials. 3. Mechanical, electrical, thermal and chemical properties of materials. Theoretical treatment of structure of solids and designs for specified properties. Laboratory. *Prerequisite:* CHEM 1020 and ES 2310. (Normally offered spring semester)

4010. Mechanical Vibrations. 3. The theory of single and multi-degree-of-freedom systems with an introduction to continuous systems. Determination of equations of motion, including natural frequency for free vibration and amplitude of forced vibration. Design of discrete and continuous systems for transient and harmonic excitations. *Prerequisites:* ES 2120, ES 2410, and MATH 2310. (Normally offered fall semester)

4020. Design of Mechanical/Electronic Systems. 3. Theoretical and experimental study of sensors and actuators, interfacing sensors and actuators to a microcomputer, discrete and continuous controller design, analog and digital electronics, and real-time programming for control. *Prerequisites:* ME 3020. (Normally offered spring semester)

4040. Introduction to Finite Elements. 3. An introduction to the theory and application of finite elements to the solution of various problems with emphasis on structural mechanics. The course includes development of the underlying matrix equations, the treatment of element generation and properties, and implementation of boundary conditions. Dual listed with ME 5040. *Prerequisites:* MATH 2310 and (CE/ARE 4200 or ME 3010).

4060 [3070]. Systems Design I. 3. First of a two-course design sequence constituting a capstone design experience. Student multidisciplinary teams prepare a project proposal or SOQ, generate a morphological study of their project and prepare project plans and specifications. Project management methods are also presented. *Prerequisites:* ME 3010, ME 3170, and ME/ESE/ARE 3360. (Normally offered fall semester)

4070. Systems Design II. 3. [W3◆▶WC] Continuation of a two-course design sequence. The design teams refine their designs, fabricate the project, test the project for compliance with the design specifications, write a comprehensive engineering design report including socioeconomic factors, and prepare and deliver a presentation of the project in a public forum. *Prerequisites:* ME 4060 and WB. (Normally offered spring semester)

4100. Manufacturing Processes. 3. Details of manufacturing processes used in production of metal, plastic and ceramic components with an emphasis on science and mechanics of processes. *Prerequisites:* ME 3010 and ME 3450.

4210. Introduction to Composite Materials. 3. Applications, mechanical properties and fabrication of fiber reinforced composite materials; stress analysis of laminated, anisotropic composite structures; study of special problems unique to composites. *Prerequisite:* ME 3010. (Normally offered fall semester)

4215. Composite Materials Design and Manufacturing. 3. Introduction to composite material manufacturing processes. Aspects of constiuent material production, as well as design, fabrication, and testing of composite materials. Laboratory exercises, such as laminating, filament winding, pultrusion and compression molding. *Prerequisite:* ME 4210. (Normally offered spring semester)

4240. Gas Dynamics I. 3. Thermodynamics of a compressible fluid; one-dimensional isentropic flow, normal and oblique shocks, expansion wave, flows with friction and heat transfer. *Prerequisites:* ES 2310 and ES 2330.

4330. Internal Combustion Engines. 3. Thermodynamic analysis and design of Otto and Diesel cycles for vehicle applications and stationary power generation. A substantial laboratory component will examine design and manufacturing issues, as well as engine performance in a variety of scenarios. Cross listed with ESE 4330. *Prerequisites:* ME/ESE 3040 and ME/ARE/ESE 3360.

4340. Gas Turbine Engines. 3. Thermodynamic analysis and design of ground-based and aero-propulsion gas turbine engines. *Prerequisites:* ES 2310 and ES 2330. (Normally offered spring semester)

4350. Airplane Aerodynamics and Flight. 3. Introduces students to the fundamentals of airfoil and wing design, airplane aerodynamics, and airplane stability. Links these fundamental

ideas to the design and performance of real aircraft. *Prerequisites:* ES 2330. (Normally offered spring semester)

4360. Introduction to Nuclear Energy. 3. Introduction to the fundamentals of nuclear engineering, including power plant design and the fuel cycle. Topics include the fuel cycle and fuel design, reactor physics, reactor theory and design, reactor thermo-hydraulics, radiation protection and safety, and fuel reprocessing and recycling. Cross listed with ESE 4360. *Prerequisites:* MATH 2310, ME/ESE 3040, and ME/ARE/ESE 3360.

4380. Steam Plant Engineering I. 3. Consideration of detailed component design for major subsytems in steam plants, including various boiler types, steam turbines, coal pulverizers, coal gasifiers, heat exchangers, air heaters, sulfur scrubbers, and ash removal systems. Applications to solar, geothermal, biomass, nuclear, natural gas, and coal-fired plants will be presented. Integration of steam plants in combined cycles and coal gasification cycles will be discussed. Cross listed with ESE 4380. *Prerequisites:* ME/ESE 3040 and ME/ESE/ARE 3360.

4430. HVAC Systems Analysis and Design. 3. Engineering design and performance analysis procedures for commercial building mechanical systems including energy conservation techniques. Relationship to aesthetic, architectural and structural elements are considered. Cross listed with ARE 4430. *Prerequisites:* ME/ARE 3400. (Normally offered alternate spring semesters)

4450 [3110]. Principles of Materials Selection. 3. A review of the economic and engineering aspects of materials selection. A detailed study of the properties, applications and limitations of engineering materials systems. Emphasis is on metal alloy systems, but non-metallics are included. Forming and joining processes are outlined. *Prerequisite:* ME 3450. (Normally offered spring semester)

4460. Solar and Geothermal Engineering. 3. An introduction to the engineering of solar-powered energy systems, including evaluation of the energy resource, passive design considerations, economics of active solar systems, design of flat plate collectors and water heating systems, and design of concentrating collectors for larger building or electrical generation applications. Design considerations for geothermal energy systems for both small-scale and commercial-scale applications. Cross listed with ESE 4460. *Prerequisite:* ESE/ME/ARE 3360.

4470. Wind and Ocean Energy Engineering. 3. Introduction to the harvesting of wind and ocean energy, including discussions of the wind resource, wind turbine aerodynamics, blade materials, turbine dynamics, electrical systems, control systems, and energy storage. An overview of ocean energy capture systems is also presented. Cross listed with ESE 4470. *Prerequisites:* ES 2210, ES 2310, ES 2330, and ES 2410.

4474. Topics in Mechanical Engineering I. 1-3 (Max. 6). Directed research in mechanical engineering. *Prerequisite:* junior standing in engineering.(Offered both semesters)

4480. Building Air and Hydronic Systems. 3. Design and analysis of building air and hydronic systems with focus on the application, design and analysis of thermal energy distribution systems (air and hydronic systems) for building space air conditioning. Requires enrollment in associated laboratory session. Cross listed with ARE 4480. *Prerequisite:* ME/ARE 4430.

4490. Modeling and Optimization of Energy Systems. 3. Application of principles of thermodynamics, fluids, and heat and mass transfer in the component and system-level design of energy/thermal systems, including modeling, simulation and optimization techniques. Examples are drawn from building environmental control, energy conversion and thermal industrial processes. Students work on projects for integration of these components in the design of energy/thermal systems. Requires enrollment in associated laboratory session. Cross listed with ARE 4490. *Prerequisites:* ME/ESE/ARE 3360 and ME/ARE 3400.

5040. Introduction to Finite Element Analysis. 3. An introduction to the theory and application of finite elements to the solution of various problems with emphasis on structural mechanics. Includes development of the underlying matrix equations, the treatment of element generation and properties, and implementation of boundary conditions. Dual listed with ME 4040. *Prerequisites:* MATH 2310 and (CE 4200 or ARE 4200 or ME 3010).

5045. Advanced Finite Element Analysis. 3. Advanced topics in finite element analysis with emphasis on mathematical foundations of the method, numerical algorithms for software implementation, and analysis of problems with material and geometric nonlinear behavior. Cross listed with CE 5045. *Prerequisite:* ME 4040 or ME 5040 or CE 5040.

5140. Computational Methods I. 3. First semester of a three-semester computational methods series. Second and third courses of this series offered in MATH Department. Review of iterative solutions of linear and nonlinear systems of equations, poloynomial interpolation/approximation, numerical integration and differentiation, and basic ideas of Monte Carlo methods. Comparison of numerical techniques for programming time and space requirements, as well as convergence and stability. Identical to: PETE 5140, CE 5140, CHE 5140 and COSC 5310 and MATH 5310. *Prerequisite:* MATH 3310, COSC 1010.

5422. Advanced Vibrations. 3. Advanced principles of dynamics: Hamilton's principle, Lagrange's equations, modal analysis of discrete systems. Analysis of continuous systems; natural modes, approximate methods, forced vibration. Introduction to random vibration. *Prerequisite:* ME 4010.

5431. Analysis of Composite Materials. 3. An introduction to the methods of analysis applied to heterogeneious material systems. Emphasis of this course is on stress based formulations and failure analysis of fiber reinforced materials including laminates. *Prerequisite:* graduate standing.

5432. Advanced Materials Science. 3. An analysis of the relationships between the structures of materials and their mechanical and physical properties, leading to the application of these relationships to the design of materials for advanced engineering systems. Topics include crystallography, lattice defects, transport phenomena, phase transformations, fracture, environmental effects, and control of microstructure by processing. *Prerequisites:* ME 3450.

5434. Computational Materials Science. 3. Fundamentals of quantum and statistical physics with application to modeling and simulation of engineering materials at the atomic scale. Course includes simulation of structural and mechanical properties of nanostructured materials. *Prerequisite:* ME 5000 or equivalent.

5435. Failure of Engineering Materials. 3. Introduction to failure of common engineering materials. Considers both experimental and analytical techniques for failure analysis and prevention. Topics include overload, fracture mechanics, fatigue, environmentally assisted fatigue, and creep. *Prerequisite:* ME 3450 or equivalent.

5438. Plasticity and Viscoelasticity. 3. Analysis of stress and deformation of idealized plastic and viscoelastic solids. Limit theorems in plasticity. Time-dependent behavior of viscoelastic materials. *Prerequisite:* ME 5000.

5440. Fluid Mechanics. 3. Lagrangian and Eulerian descriptions, conservation laws, stress and rate-of-stress tensors, Navier-Stokes equations, energy equations, vorticity and circulation inviscid and potential flows, laminar flows, turbulent flows, boundary-layer theory. Cross listed with CHE 5440. *Prerequisites:* none.

5442. Advanced Fluid Mechanics. 3. Introduction to inviscid and viscous hydrodynamic stability; closure in turbulent flows; vorticity and vortex dynamics, theoretical aerodynamics, numerical simulations of viscous flows, experimental methods in fluid flows. *Prerequisite:* ME 5440.

5444. Optical Diagnostics in the Thermal and Fluid Sciences. 3. An introduction to optical measurement schemes used in gas and liquid flows. Topics include a review of relevant optical principles and lasers, and in-depth coverage of laser velocimetry, droplet and particle sizing, and temperature measurement. *Prerequisite:* graduate standing.

5446. Turbulence. 3. Basic notions, properties and scales in turbulent flows. Transport equations; Reynold's stresses, mixing and phenomenological theories. Turbulence dynamics; mean and fluctuating kinetic energy balances, vorticity and temperature fluctuations. Statistical description of turbulence; correlations and spectra, transport, isotropy and homogeneity. Shear flows; plane jets, wakes and boundary layers (including planetary). Turbulent diffusion. Cross listed with CHE 5446. *Prerequisite:* ME 5440.

5448. Experimental Fluid Dynamics. 3. Provides an introduction to the design of fluid dynamics experiments. Specific instrumentation will be discussed and methods of analyzing and assessing data will be presented. *Prerequisites:* graduate standing.

5450. Conduction and Radiation. 3. Applications of principles of heat transfer and thermodynamics to solution of steady-state and transient problems. Classical heat conduction theory. Radiation heat transfer theory. *Prerequisite:* MATH 4440 or concurrent registration.

5452. Convection Heat Transfer. 3. Convection, including heat and momentum transfer. Boundary layer theory. Laminar and turbulent flows, steady and unsteady formulations including differential and integral descriptions. High velocity, compressible systems. Cross listed with CHE 5452. *Prerequisite:* ES 3360 or consent of instructor.

5455. Introduction to Combustion Engineering. 3. An introduction to the basic physics and chemistry of combustion engineering and its applications, including chemical thermodynamics, chemical kinetics and fuel oxidation mechanism, multicomponent conservation equations, laminar nonpremixed flames, droplet combustion, carbon particle combustion, and applications to modern IC engines, biomass and clean coal systems. *Prerequisites* graduate standing.

5461. Computational Fluid Dynamics I. 3. An introduction to the fundamental techniques and theory of computational fluid dynamics. Topics include discretization methods (finite difference, finite volume, and finite element methods), numerical stability, consistency and convergence, and solution techniques such as explicit, implicit and multigrid methods. The emphasis will be on modern techniques for compressible flows. *Prerequisite:* MATH 5310.

5462. Computational Fluid Dynamics II. 3. A study of advanced techniques in modern-day scientific computing as applied to Computational Fluid Dynamics. These include unstructured mesh generation using Delaunay triangulation, searching and sorting techniques, and efficient data structures. Other topics cover efficient hardware implementation including cache-effects and parallel computing and sensitivity analysis for design optimization. Prerequisite: ME 5461.

5472. Continuum Mechanics. 3. The basic laws of the physical behavior of continuous media. Stress and deformation at a point; fundamental equations of balance of mass, momentum, and energy; second law of thermodynamics; curvilinear coordinate analysis. Applications to linear elasticity and fluid mechanics. *Prerequisite:* MATH 3310.

5474. Energy Methods. 3. Introduction to variational calculus with applications in solid mechanics. The basic theorems of virtual work, minimum potential energy, and complementary energy are developed. Direct methods such as Castigliano's theorem as well as the approximate methods of Ritz and Galerkin are developed and used to obtain solutions for a variety of problems in solid mechanics. *Prerequisite:* ME 3010.

5475. Topics in Mechanical Engineering II. 1-6 (Max 6). Directed research in mechanical engineering. *Prerequisite:* senior or graduate standing in engineering.

5476. Topics in Mechanical Engineering III. 1-6 (Max. 6). Directed research in mechanical engineering. *Prerequisite:* graduate standing in engineering.

5478. Seminar in Mechanical Engineer. 2. Prerequisite: graduate standing in engineering.

5900. Practicum in College Teaching. 1-3 (Max. 3). Work in classroom with a major professor. Students are expected to give some lectures and gain classroom experience. *Prerequisite:* graduate standing.

5920. Continuing Registration: On Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5940. Continuing Registration: Off Campus. 1-2 (Max. 16). *Prerequisite:* advanced degree candidacy.

5959. Enrichment Studies. 1-3 (Max. 99). Designed to provide an enrichment experience in a variety of topics. Note: credit in this course may not be included in a graduate program of study for degree purposes.

5960. Thesis Research. 1-12 (Max. 24). Designed for students who are involved in research for their thesis project. Also used for students whose coursework is complete and are writing their thesis. *Prerequisite:* enrollment in a graduate degree program.

5961. Graduate Projects. 1-4 (Max. 4). Limited to those students enrolled in a Plan B graduate program. Students should be involved in non-course scholarly activities in support of their Plan B project. Prerequisites: enrollment in Plan B program and have departmental approval.

5980. Dissertation Research. 1-12 (Max. 48). Designed for students who are involved in research for their dissertation project. Also used for students whose coursework is complete and are writing their dissertation. *Prerequisite:* enrollment in a graduate level degree program.

Energy Systems Engineering

Energy Systems Engineering is a new undergraduate degree offering by the Dept. of Mechanical Engineering. The ESE program was designed to train engineers to address one of this country's foremost challenges: to achieve energy independence and yet meet the growing demand for energy, while at the same time addressing critical environmental concerns. The program is intended to help meet these challenges by preparing students to be:

- technology leaders in energy conversion and environmental protection systems
- capable managers in the energy industry
- versatile overseers of energy development by the governmental sector
- technically-trained and environmentally-sensitive liaisons between the energy industry and the public.

ESE students will be trained in alternative and environmentally-friendly energy conversion systems, as well as more traditional technologies that will continue to play an important role for the foreseeable future.

Although the discipline of mechanical engineering has historically been responsible for the design of energy conversion cycles and equipment, issues outside the conventional realms of engineering are increasingly important to address as new and improved

energy conversion systems are implemented. The engineer trained in Energy Systems will be better equipped than traditional mechanical engineers to deal with the environmental, legal, political, economic, and ethical aspects of new energy projects.

The ESE degree has many course work requirements in common with the Mechanical Engineering degree, particularly in the thermal, fluids, and energy conversion sciences. However, the ESE program emphasizes energy conversion aspects of Mechanical Engineering and requires course work from UW's School of Environment and Natural Resources (SENR), course work in environmental ethics and environmental law, and two electives picked from a list of classes that focus attention on energy and the environment. The SENR courses will expose students to issues related to permitting such as preparation of environmental impact studies, and regulations such as the Endangered Species Act. In addition, there are five technical electives that allow the student to choose more detailed study in personal areas of interest, including for example, courses in environmental engineering, wind engineering, solar engineering, nuclear engineering, and petroleum engineering.

It should be emphasized that ESE is a rigorous engineering program that requires dedicated preparation in high school, including four years of math, science, and language arts. In fact, technical writing skills are emphasized throughout the ESE curriculum so that the program has more extensive writing requirements (including two "WC" courses) than most other programs at UW.

The Energy System Engineering degree program obtained it initial accreditation with ABET in 2012 with retroactive application to past graduates.

The educational objectives of the ESE program are the same as those listed for the ME program. Energy Systems Engineering degree candidates must meet the academic requirements of the college, obtain a grade of (C) or better in all Engineering Science and required mathematics courses, and must have an average GPA of 2.0 (C) in ESE and ME course work. An International Engineering Option similar to that in ME is also available. No graduate degree program in ESE is anticipated at this time.

Energy Systems Engineering Option Curriculum*

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
MATH	2200	4
ES	1000	1
ES	1060	3
CHEM	1020	4
ENGL	1010	3
	Total Hrs.	**15**

FRESHMAN YEAR: Spring		Hrs.
MATH	2205	4
ES	2110	3
COJO	1010	3
LIFE	1010	4
US & Wyo Constitutions		3
	Total Hrs.	**17**

SOPHOMORE YEAR: Fall		Hrs.
MATH	2210	4
ES	2120	3
ES	2210	3
ES	2410	3
PHYS	1220	4
	Total Hrs.	**17**

SOPHOMORE YEAR: Spring		Hrs.
MATH	2310	3
ES	2310	3
ES	2330	3
ESE	2020	2
ATSC	2100	3
Cultural Context Elective[1]		3
	Total Hrs.	**17**

JUNIOR YEAR: Fall		Hrs.
ESE	3020	3
ESE	3040	3
Math/Science Elective[2]		3
ESE Electives[3]		6
Physical Education[8]		1
	Total Hrs.	**16**

JUNIOR YEAR: Spring		Hrs.
ESE	2160	2
ESE	3360	3
ESE Technical Elective[4]		3
PHIL	2330 or 2345	3
Law Elective[5]		3
Cultural Context Elective[1]		3
	Total Hrs.	**17**

SENIOR YEAR: Fall		Hrs.
ESE	4060	3
Technical Elective[4]		3
Technical Elective[4]		3
ENR	4000	3
Business Elective[6]		3
	Total Hrs.	**15**

SENIOR YEAR: Spring		Hrs.
ESE	4070	3
Technical Elective[5]		3
Technical Elective[7]		3
ENR	4900	3
Cultural Context Elective[1]		3
	Total Hrs.	**15**

* A minimum of 129 credit hours graded (A-F) course hours are necessary to satisfy degree requirements.Degree candidates must meet academic requirements of the college and have an average grade point average of 2.0 in all ESE and ME courses completed at UW.

[1] The Cultural Context Electives must be chosen to earn one each of the following credits: CA (Arts); G (Global Awareness); and D (Cultural Diversity in the US)

[2] Math/Science Elective must be chosen from a Department approved list.

[3] Two ESE Electives to be chosen from: ENR 4890 Applied GIS, POLS 4051 Environmental Politics, POLS 4350 Sustainable Development and Global Policy, GEOL 3500 Global Change - A Geologic Perspective, GEOL 3650 Energy - A Geologic Perspective, PETE 4000 Environment, Tech, and Society, and ECON 1300: Oil: Business, Culture, and Power

[4] Four Technical Electives to be chosen from: PETE 2050 Intro to Petroleum Engineering, GEOL 4190 Petroleum Geology, CE 3400 Intro to Environmental Engineering, CE 4430 Environmental Engineering Chemistry, ME 3450 Properties of Materials, ME 4020 Mechatronics, ME 4340 Gas Turbine Engines, ME 4470 Wind and Tidal Energy Engineering, ME 4460 Solar and Geothermal Engineering, ESE 4330 Gasoline and Diesel Engines, ESE 4360 Nuclear Engineering, and ESE 4380 Steam Plant Engineering

[5] Law Elective to be chosen from: ENR 4890 Environmental Law, ENR 4890 ENR Law and Policy, or ENR 4890 Wildlife Law and Energy Development

[6] Business Elective to be chosen from: CE 3900, DSCI 3210, DSCI 4260, FIN 3250, ES 4910 or others as approved by advisor.

[7] Technical Elective at 3000 level or higher. Must be approved by advisor. May be chosen from any engineering discipline, mathematics, science, business, or from ESE Technical Elective list.

Energy Systems Engineering (ESE)

USP Codes are listed in brackets by the 1991 USP code followed by the 2003 USP code (e.g. [M2◗QB]).

2020 [2010]. Design of Experiments Lab. 2. A Laboratory course designed to introduce students to basic experimental concepts in context of statics and dynamics. Development of skills in report writing, experimental design, utilization of productivity software, interpersonal teamwork and fundamental statistics are emphasized. Cross listed with ME 2020. *Prerequisites:* ES 1060; ES 2120; companion course ENGL 2005 for WB credit.

2160. Fluids Laboratory I. 2. A laboratory course to present experimental techniques, develop laboratory and interpersonal teamwork skills, and demonstrate some of the fundamental concepts of thermodynamics and fluid dynamics. Cross listed with ME 2160. *Prerequisites:* ES 2330 and ESE/ME 2020.

3020. System Dynamics. 3. Theoretical and experimental study of the dynamics of linear and non-linear lumped parameter models of mechanical, electrical, electronic, fluid, thermal and mixed systems. Cross listed with ME 3020. *Prerequisites:* ESE/ME 2020, ES 2210, and MATH 2310. (Normally offered fall semester)

3040. Thermodynamics II. 3. Consideration of advanced thermodynamic topics including Maxwell's relations, compressible flow, and combustion. Applications to design of refrigeration cycles, humidification systems, and Rankine cycles. Cross listed with ME 3040. *Prerequisite:* CHEM 1020 and ES 2310. (Normally offered fall semester)

3360. Fundamentals of Transport Phenomena. 3. Basic concepts of heat and mass transfer and their applications to problems involving engineering analysis and design. Topics include steady-state and transient conduction, free and forced convection (heat and mass), radiation and heat exchangers. Cross listed with ME/ARE 3360. *Prerequisites:* ES 2310, ES 2330 and MATH 2310.

4060. Energy Systems Design I. 3. First of a two-course design sequence constituting a capstone design experience on an energy-related project. Multidisciplinary teams prepare a project proposal or Statement of Qualifications, generate a morphilogical study of their project, develop mathematical models of their design, and prepare project plans and specifications. Project management and methods are also presented. *Prerequisites:* ESE/ME 3040 and ESE/ME/ARE 3360 (Normally offered fall semester)

4070. Energy Systems Design II. 3. [W3◂▸WC] Continuation of a two-course design sequence. The design teams refine their designs, fabricate the project, test the project for compliance with the design specifications, write a comprehensive engineering design report including socioeconomic factors, and prepare and deliver a presentation of the project in a public forum. *Prerequisites:* ESE/ME 4060 and WB. (Normally offered spring semester)

4330. Internal Combustion Engines. 3. Thermodynamic analysis and design of Otto and Diesel cycles for vehicle applications and stationary power generation. A substantial laboratory component with examine design and manufacturing issues, as well as engine performance in a variety of scenarios. Cross listed with ME 4330. *Prerequisites:* ESE/ME 3040 and ESE/ME/ARE 3360.

4360. Introduction to Nuclear Energy. 3. Introduction to the fundamentals of nuclear engineering including power plant design and the fuel cycle. Topics include the fuel cycle and fuel design, reactor physics, reactor theory and design, reactor thermo-hydraulics, radiation protection and safety, and fuel reprcocessing and recycling. Cross listed with ME 4360. *Prerequisites:* MATH 2310, ESE/ME 3040, and ESE/ME/ARE 3360.

4380. Steam Plant Engineering I. 3. Consideration of detailed component design for major subsytems in steam plants, including various boiler types, steam turbines, coal pulverizers, coal gasifiers, heat exchangers, air heaters, sulfur scrubbers, and ash removal systems. Applications to solar, geothermal, biomass, nuclear, natural gas, and coal-fired plants will be presented. Integration of steam plants in combined cycles and coal gasification cycles will be discussed. Cross listed with ME 4380. *Prerequisites:* ESE/ME 3040 and ESE/ME/ARE 3360.

4460. Solar and Geothermal Engineering. 3. An introduction to the engineering of solar-powered energy systems, including evaluation of the energy resource, passive design considerations, economics of active solar systems, design of flat plate collectors and water heating systems, and design of concentrating collectors for larger building or electrical generation applications. Design considerations for geothermal energy systems for both small-scale and commercial-scale applications. Cross listed with ME 4460. *Prerequisite:* ESE/ME/ARE 3360.

4470. Wind and Ocean Energy Engineering. 3. Introduction to the harvesting of wind and ocean energy, including discussions of the wind resource, wind turbine aerodynamics, blade materials, turbine dynamics, electrical systems, control systems, and energy storage. An overview of ocean energy capture systems is also presented. Cross listed with ME 4470. *Prerequisites:* ES 2210, ES 2310, ES 2330, and ES 2410.

4474. Topics in Energy Systems Engineering. 1-3 (Max. 4). Directed research in mechanical engineering. *Prerequisite:* ME/ESE 2020.