College of Engineering and Applied Science

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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 Construction Management
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
- Architectural engineering
- 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 120 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 2.000 (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.

The College of Engineering and Applied Science adheres to prerequisite coursework being completed before moving forward to advanced coursework. If a student is found to be enrolled in a course without meeting the prerequisites, the student will be administratively dropped from the course.

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.

International Engineering Minor

Students in the College of Engineering and Applied Science may earn a Minor in International Engineering. The Minor requires:

a) a study abroad experience;
b) 9 credits of lower-division coursework; and
c) 9 credits of upper-division coursework.

More detailed requirements are available at: www.uwyo.edu/ceas/academics/intleng.html.

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.
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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 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

1000. Orientation to Engineering Study. 1. [I,L◀▶(none)] 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.

1002. Introduction to Engineering Information Literacy. 0.5. [L◀▶(none)] 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.

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 representation, dimensioning, and drawing annotation. *Prerequisite:* MATH 1400 or MATH 1450 or ACT Math Score of 25 or Math Placement Exam score of 4.

1101. First-Year Seminar. 3. [(none)◀▶FYS]

2110. Statics. 3. 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.

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.

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 or concurrent enrollment.

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:* MATH 2210 and either ES 2120 or PHYS 1210.

2330. Fluid Dynamics. 3. Incompressible flow of ideal and real fluids. Potential and stream functions; similitude and dimensional analysis. *Prerequisites:* MATH 2210 and either ES 2120 or PHYS 1210.

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

3001. International Systems Engineering. 3. This 4-week service learning course will offer students hands-on experience in fabricating, assembling and installing a system as part of a team. Students will learn about materials, welding, electrical systems, and aerodynamics, all the while experiencing international life and cultures. *Prerequisite:* MATH 2310.

3010. Culture and Engineering in Latin America. 3. [(none)◀▶H] Engineering and Culture of Latin America - A study of ancient engineering problems in Latin America that are applicable to civil engineering. Students will be exposed to cultural aspects that influenced Mayan infrastructure. *Prerequisite:* ES 2110 or PHYS 1210.

3020. Comparison of Entrepreneurial Ecosystems. 3. The goal of this course is to expose students to different entrepreneurial ecosystems and let them think about how the environment, legal, technical, cultural, and economic, could impact their entrepreneurial endeavors. The class will accomplish this by visiting a developed country (e.g. Spain) and a developing country (e.g. Morocco) to learn about the ecosystems and talk with entrepreneurs to see how the forces impacted their startups. Cross listed with ENTR 3020.

3100. Internship Prepared. 1. The purpose of this Internship Preparation course is to prepare students for applying to internships in all applicable facets. Students will learn how to build their resume, write job specific cover letters, search for positions, and communicate with employers effectively. This course is a self-study with assignments given weekly. Students will be required to complete assignments and schedule individual appointments with an instructor in order to follow up on assignments. *Prerequisite:* 6 credits within your discipline.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ARE/ATSC/CE/CHE/COSC/EE/PETE 3890. *Prerequisite:* sophomore standing.

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing research mentor, obtaining approval by said mentor, and communicating the student/faculty partnership tot he appropriate staff in their home department. Must be in the Engineering Honors Program. Cross listed with ATSC/BE/CE/CHE/COSC/ESE/PETE 4580. *Prerequisite:* junior or senior standing.

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.

4920. Entrepreneurship for Engineers. 3. Traditional engineering education does not prepare graduates for work in entrepreneurial ventures. The goal of this course is to have students demonstrate skills in developing business ideas, performing preliminary market research, estimating cash flow, and launching a business. *Prerequisites:* 9 hours within an engineering discipline and junior standing.

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.

5600. Research Data Management. 3. A general approach to research data management for graduate students and researchers. Topics include: the case for data management, data management planning, meeting grant requirements, formatting and organizing, storing and transferring, legal and ethical issues, strategies for research teams, sharing data, and publishing, citing, and rights to research data. Cross listed with GRAD/LBRY 5600. *Prerequisite:* graduate standing.

Department of Atmospheric Science

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

Professors:

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.

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 Professor:

SHANE MURPHY, B.S. University of Colorado 2000; Ph.D. California Institute of Technology 2009; Associate Professor of Atmospheric Science 2019, 2011.

Assistant Professors:

DANA CAULTON, B.S. Indiana University 2010; Ph.D. Purdue University 2014; Assistant Professor of Atmospheric Science 2018.

JEFFREY R. FRENCH, B.S. South Dakota School of Mines 1992; M.S. 1994; Ph.D. University of Wyoming 1998; Assistant Professor of Atmospheric Science 2015.

ZACHARY J. LEBO, B.S. Pennsylvania State University 2007; M.S. 2009; Ph.D. California Institute of Technology 2012; Assistant Professor of Atmospheric Science 2015.

Adjunct Professors:
Xiaohong Liu
Zhien Wang

Professors Emeritus:
Terry L. Deshler, Robert D. Kelly, John D. Marwitz, Derek C. Montague, Thomas R. Parish, Alfred R. Rodi, 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 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 ice 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. The Department of Atmospheric Science is the lead user of the Wyoming allocation of the NCAR Wyoming Supercomputer Center.

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 and doctor of philosophy degrees.

The department has strong research programs in the following areas: cloud physics and dynamics; tropospheric aerosols and clouds; greehouse gases; air pollution and wildfires; boundary layer processes; remote sensing; and airborne instrumentation. The department's observational facilities are: 1) the King Air research aircraft (UWKA); 2) the Wyoming Balloon Launch Facility; 3) the Air Quality Mobile Lab and the Wyoming Air Quality Monitoring Lab; 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 Plan A

Approval of research plan by the graduate committee
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

Master's Program Plan B (non-thesis)

30 hours of acceptable graduate coursework and a Plan B Paper that summarizes internship/research experience

Doctoral Program

Qualifying assessment exam
Approval of research plan by the graduate committee
At least one colloquium presentation per year
Preliminary exam
Oral defense of Ph.D. dissertation
Approval of Ph.D. dissertation by the graduate committee
Ph.D. requires a minimum of 72 graduate hours, with at least 42 hours in formal coursework. This includes 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 the master's program.

ATSC 5010: Physical Meteorology. 4.
ATSC 5011: Physical Meteorology II. 4.
ATSC 5014: Dynamic Meteorology. 4.
ATSC 5016: Synoptic and Mesoscale Meteorology. 4.
ATSC 5018: Ethics & Research Methods. 1.
UW Elective(s) to be determined by committee. 9 minimum

Atmospheric Science (ATSC)

USP Codes are listed in brackets by the 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

1101. First-Year Seminar. 3. [(none)◀▶FYS]

2000. Introduction to Meteorology. 4. [SE◀▶PN] 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. Global Warming: The Science of Humankinds' Energy Consumption Impacting Climate. 3. [(none)◀▶PN] Introduces non-specialists to the fundamental scientific principles governing climate change. The underlying physics of both human and natural contributions to global warming is presented along with uncertainties in predicting climate. Potential strategies to mitigate global warming (alternative energy, carbon capture, and geoengineering) are also discussed.

2200. Severe and Unusual Weather. 3. [(none)◀▶PN] A nontechnical course on severe and unusual weather events that occur around the globe. The focus of the course is on a wide range of weather events that have profound impacts on societies, economics, and cultures, and the material is presented in a qualitative manner such that is highly accessible by students coming from all backgrounds.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ARE/CE/CHE/COSC/EE/ES/PETE 3890. *Prerequisite:* sophomore standing.

4010. Atmospheric Processes I. 3. Tools for understanding of physical processes occurring in the atmosphere are presented and integrated. Emphasis on ideal gas equation (for mixture), parcel concept, hydrostatics, mass conservation modeling, first law thermodynamics and radiation in the cloud-free atmosphere. Rudiments needed for problem solving are emphasized - integral and differential forms and dimensional analysis. *Prerequisites:* PHYS 1320 and either MATH 2210 or MATH 2310.

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.

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing research mentor, obtaining approval by said mentor, and communicating the student/faculty partnership tot he appropriate staff in their home department. Must be in the Engineering Honors Program. Cross listed with BE/CE/CHE/COSC/ES/ESE/PETE 4580. *Prerequisite:* junior or senior standing.

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 advising 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.

5008. Mesoscale Meteorology. 3. Fundamental dynamics of mesoscale motions including departures from hydrostatic balance. Mesoscale energy sources. Boundary layer circulations. Convective initiation. Structure and dynamics of deep convection and mesoscale organized convection. Atmospheric waves. Thermally and dynamically forced flow over mountains. *Prerequisite:* permission of the instructor.

5010. Physical Meteorology I. 4. First and second law of thermodynamics applied to energy transformations in the atmosphere, including dry, moist, and saturated processes and atmospheric stability. Fundamentals of radiation including blackbody, planetary budget, and propagation and how these drive the thermodynamics of the earth's atmosphere. *Prerequisites:* MATH 2210, PHYS 1310 and PHYS 1320 or equivalent.

5011. Physical Meteorology II. 4. Quantitative description of cloud particle nucleation, growth by condensation, and growth by deposition and collection. Ties to other atmospheric processes, e.g., radiation budgets and cloud dynamics, are also emphasized. Course material is presented in lecture and computer-based laboratory settings. A numerical cloud model is developed and analyzed in the laboratory. *Prerequisite:* ATSC 5010.

5014. Dynamic Meteorology. 4. Development and interpretation of the atmospheric equations of motion, scales of motion, horizontal atmospheric winds, thermal wind equation, circulation and vorticity, mesoscale motions. Introduction to planetary boundary layer flows. Data visualization software is also introduced and used to develop understanding of dynamical processes. *Prerequisites:* MATH 2210, PHYS 1310 and PHYS 1320 or equivalent.

5016. Synoptic Meteorology. 4. Large-scale vertical motion as viewed from quasigeostrophic and isentropic potential vorticity perspectives. Baroclinic instability, and the structure and evolution of extratropical cyclones. Identification and development of fronts, jet streams and associated weather features. Role of topography on large-scale circulations. *Prerequisites:* MATH 2210, PHYS 1310 and PHYS 1320 or equivalent.

5018. Ethics and Research Methods. 1. Ethics and ethical dilemmas in research and academia and how to address them are discussed. This course also covers general research methodology and describes processes

for research funding and disseminating research findings and the peer-review process. *Prerequisite:* graduate standing.

5040. Climate Science and Climate Change. 3. Global climate system components, and their interactions. Radiative, dynamic, thermodynamic, chemical, and feedback processes affecting the climate system. Natural and anthropogenic drivers of climate change. Past and present climate variability and sensitivity, and its simulation. Structure of climate models, their components, parameterizations, and attributes. Current climate modeling results and predictions of future climate. *Prerequisites:* ATSC 5001, ATSC 5016.

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 5011 and ATSC 5014.

5310. Atmospheric Dynamics II. 3. Introduction to the dynamic energetics of the atmosphere, wave motions, atmospheric instabilities. Introduction to numerical modeling, applications. *Prerequisite:* ATSC 5014.

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 5010, ATSC 5014.

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 5010, ATSC 5011.

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.

5360. Aircraft Instrumentation. 3. An introduction to instrumentation used on research aircraft to measure properties of the atmosphere. Topics include measuring atmospheric state, atmospheric particles, and other constituents (i.e. trace gases) from aircraft. Principles of measurement techniques are described, complexities due to clouds are presented, and resulting uncertainties and limitations are explored. *Prerequisite:* Graduate student in Atmospheric Science or consent of instructor.

5370. Satellite Remote Sensing. 3. Physical principles of atmospheric remote sensing, with a breadth of applications in passive and active remote sensing of the atmosphere. Offers a solid understanding of remote sensing instrumentation and retrieval approaches for a variety of atmospheric parameters. *Prerequisite:* graduate student in Atmospheric Science or consent of instructor.

5600. Advanced Cloud Microphysics. 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 5010 and ATSC 5011.

5700. Numerical Modeling of Atmosphere. 3. Governing equations and assumptions, finite differencing, subgrid-scale processes, cloud processes, aerosol and atmospheric chemistry, boundary layer processes, radiative transfer, cumulus parameterizations, parcel models, kinematic models, large-eddy simulating (LES) models, cloud-resolving models (CRMs), large-scale regional and global climate models (GCMs). *Prerequisite:* ATSC 5010 or ATSC 5011 or ATSC 5014 or consent of instructor.

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. 1-12 (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 Engineering

4055 Engineering Building,
(307) 766-2500
Web site: www.uwyo.edu/chemical
Department Head: Vladimir Alvarado

Professors:

VLADIMIR ALVARADO, B.Sc. Universidad Central de Venezuela 1987; M.S. Institut Francais du Pétrole 2002; Ph.D. University of Minnesota 1996; Professor of Chemical Engineering 2017, 2006.

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

DAVID A. BELL, B.S. University of Washington 1976; M.S. Rice University 1979; Ph.D. Colorado State University 1992; Professor of Chemical Engineering 2019, 1993.

JOSEPH HOLLES, B.S. Iowa State University 1990; M.E. University of Virginia 1998; Ph.D. 2000; Associate Professor of Chemical Engineering 2010.

JOHN OAKEY, B.S. The Pennsylvania State University 1997; M.S. Colorado School of Mines 1999; Ph.D. 2003; Professor of Chemical Engineering 2019, 2010.
MICHAEL V. PISHKO, B.S. University of Missouri-Columbia 1986; M.S. 1987; Ph.D. University of Texas at Austin 1992; Professor of Chemical Engineering 2015.

Associate Professors:
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KATIE DONGMEI LI-OAKEY, B.S. Shandong University of Technology 1994; M.S. Tianjin University 1997; M.S. University of Colorado at Boulder 1999; Ph.D. 2003; Associate Professor of Chemical Engineering 2018, 2011.
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.

Assistant Professors:
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Adjunct Professors:
John Ackerman
Morris Argyle
Youqing Shen
John Schabron

Professors Emeriti:
Chang Yul Cha
H. Gordon Harris
Henry W. Haynes

Chemical Engineering is one of the most versatile of the engineering programs. It prepares students for employment in many diverse fields, such as production of pharmaceuticals, polymers and plastics, semiconductors, heavy industrial chemicals, synthetic fuels, petrochemicals and petroleum refining. Chemical engineers also work in biological engineering, environmental engineering, enhanced oil recovery, corrosion control, metallurgy and microelectronics. 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 pre-medical and pre-dental students.

The department offers an 18-credit-hour block of approved technical electives. Students select an emphasis in Biological Engineering, Environmental Engineering, Materials Science and Engineering, Chemical Process Industry, Petroleum Engineering, Graduate School Preparation, and Pre-Medicine. Students can also pursue a concurrent major in Chemistry, minors in Physics, Chemistry, Math, Computer Science, Molecular Biology and Business. See department for details. Students are required to take a minimum of 3 credits of Chemical Engineering Technical electives. The Chemical Engineering Program requires that the number of credits of upper division courses be satisfied (ie.,. 10 credits of Technical electives must be 3000+). The Chemical Engineering program requires 48 hours of 3000 and 4000-level coursework. This is fulfilled by required courses and approved technical electives.

Chemical Engineering degree candidates must meet the academic requirements of the college and, in addition, must have a GPA of 2.000 in Chemical Engineering courses attempted at UW that are applied toward graduation for the B.S. degree from the department. Students must achieve a C- or better in all chemical engineering courses serving as a prerequisite for another chemical engineering course.

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 demonstrate:

- 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

For students entering UW Fall 2018 or later.

CHE	1005	1
CHEM	1060	3
CHE	2005	3
CHE	2060	3
CHE	2070	3
CHE	2080	3
CHE	3015	3
CHE	3026	3
CHE	3028	3

CHE	3040	3
CHE	3070	3
CHE	4050	3
CHE	4060	3
CHE	4070	4
CHE	4080	4
CHE	4090	3
CHEM	1050	4
CHEM	2420	4
CHEM	2440	4
CHEM	4507	3
LIFE	1010	4
MATH	2200	4
MATH	2205	4
MATH	2210	4
MATH	2310	3
PHYS	1210	4
PHYS	1220	4

Approved Electives

See CEAS Advising Center for a current list of approved technical electives

Transfer Coursework: All Wyoming Community College equivalent courses will be evaluated for acceptance into the CHE program. For upper-division coursework, no more than two CHE 3000+ courses can be transferred and applied to the CHE degree, however, CHE 4070 Process Design I and CHE 4080 Process Design II cannot be transferred to UW.

In addition, all CHE transfer courses must be completed with a grade of C- or better.

The upper-division rules may be waived for classes taken during Study Abroad and National Student Exchange Programs with pre-approval.

Minor in Process Control and Instrumentation

The goal of the Process Control and Instrumentation Minor is to provide students obtaining Bachelor of Science majors in the College of Engineering and Applied Science at the University of Wyoming with enhanced education to better meet industry's needs. This minor will be particularly useful for students majoring in Chemical Engineering, Electrical Engineering, Mechanical Engineering, and Petroleum Engineering.

Minor Requirements

The Minor in Process Control and Instrumentation will require a minimum of 18 hours of coursework. No more than 6 hours of coursework taken for the minor may also count as required (non-elective) coursework toward a student's major.

Required Courses		**Hrs.**
CHE	2005	3
CHE	2090	2
CHE	3090	1
CHE	4092	3
One of CHE 4090, EE 4620, or EE 4621		3
Approved Elective Courses: At least 6 hours of the following: EE 2210, EE 3220, ME 4020, COSC 4450, COSC 4765, or CHE 4972		6
	Minor Total Hours	**18**

BS/MS CHE Quick Start Program

The BS/MS Quick Start program in Chemical Engineering (CHE) 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 Chemical 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 Chemical Engineering (M.S. CHE) 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 Chemical 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 6 credit hours of 5000-level courses toward both the B.S. and M.S. degree programs. By completing successfully up to 6 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 Chemical Engineering graduate program.

For additional information and an application form, please contact the CHE graduate program coordinator at (307) 766-2500 or stop by 4055 Engineering Building.

Graduate Study

The Department of Chemical Engineering offers graduate programs leading to the M.S. and Ph.D. degrees in chemical 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 Engineering, the Department of 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 3.000 (A = 4.000), 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 6.5.

Unofficial transcripts of all prior college-level coursework, test scores and recommendations from three references must be uploaded as parts of the application.

If admission is granted, then official transcripts, GRE and TOEFL scores are required.

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

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

B. Graduate Study Guidelines

All incoming Ph.D, M.S. Plan A and 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
CHE 5960 Thesis Research	4
Electives	14
Total	30

Plan B (non-thesis)

The coursework requirements are the same as the M.S. Plan A requirements except that Thesis Research (CHE 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. A final presenation is then required.

Doctoral Program

	Credit Hours
M.S. Plan A list (except CHE 5960)	26
Graduate Teaching and Research: Theory and Methods (CHE 5090)	3
Dissertation Research (CHE 5980)	30
Electives (no internship CHE 5990)	13
Total	72

M.S. and Ph.D. Seminar Requirements

All chemical engineering graduate students must enroll in CHE 5890, Chemical 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 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 an 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 an announcement of their defense for advertisement by bulletin board, e-mail, or other means. The results of the examination are reported on the Report of Final Examination 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. 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 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

1005. Introduction to Chemical Engineering. 1. Provides an overview of chemical engineering and its role in the current technological importance: energy, biotechnology, production of chemicals, and materials processing. Introduces strategies for solving engineering problems, including ethical considerations and teamwork, discusses process variables, units, mass balance, and data analysis, and incorporates active learning exercises using spreadsheet to solve chemical engineering problems. *Prerequisite:* concurrent enrollment in MATH 2200.

2005 [3000]. Chemical Process Analysis. 3. Introduces analysis of chemical processes using stoichiometry, material and energy balances, thermodynamics and economics. *Prerequisites:* C- or better in either CHEM 1050 or CHEM 1020 and concurrent enrollment in MATH 2205. (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:* C- or better in CHE 1005 or ES 1060; C- or better in CHE 2005; concurrent enrollment in MATH 2310.

2070. Chemical Thermodynamics. 3. Discusses first and second laws of thermodynamics applied to chemical processes, production of power from heat, refrigeration, and liquefaction processes, develops thermodynamic relations for calculating thermodynamic properties of fluids, including the use of equations of state, and introduces heat effects, Gibbs-energy change of reaction, and chemical-reaction equilibria. *Prerequisites:* C- or better in CHE 2005, PHYS 1210; C or better in MATH 2210.

2080. Chemical Engineering Fluid Mechanics. 3. Introduces the fundamental aspects of macroscopic fluid mechanics, including physical properties, fluid statics, mass, energy, and momentum balances, momentum transport, and flow through pumps, pipes, and other chemical engineering equipment for both incompressible and compressible fluids, and of microscopic fluid mechanics, including differential mass and momentum balances. *Prerequisites:* C- or better in CHE 2005, PHYS 1210, and C or better in MATH 2210.

2090. Practical Fundamentals of Process Control. 2. Introduces students to sensors, valves, actuators and the assembly of process control components. Provide hands-on practical experience with level control, flow control, temperature control and pressure control processes. This course consists of one (1) hour of lecture and two (2) hours of laboratory per week. *Prerequisite:* C or better in MATH 2205.

3015 [3010]. Chemical Thermodynamics II. 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. *Prerequisite*: C or better in CHE 2060, and CHE 2070 or ES 2310. (Normally offered fall semester)

3026. Heat Transfer. 3. Introduces the theory and application of energy transport (e.g. conduction, convection, radiation), discusses in depth fundamentals of microscopic energy transport, and applies the knowledge to macroscopic chemical engineering processes and systems. *Prerequisites:* C- or better in CHE 2060, and CHE 2080 or ES 2330.

3028. Mass Transfer. 3. Introduces mass transfer concepts, including molecular diffusion, convective mass transfer, and mass transfer between phases, and the development of mathematical models of these physical phenomena, applicable to the analysis and design of chemical processes. *Prerequisites:* C- or better in CHE 2005, CHE 2060, and CHE 2080 or ES 2330.

3035. Separation Processes. 3. Applies transport and equilibrium concepts and models to the analysis and design of separation processes, such as distillation, absorption, extraction, leaching, adsorption, crystallization, and membrane separation processes. *Prerequisites:* C or better in CHE 2060, and CHE 2070 or ES 2310.

3040. Unit Operations Laboratory I. 3. [WB◀▶(none)] 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. *Prerequisites:* C- or better in CHE 3026 and CHE 3028 and CHE 4060. (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:* C- or better in CHE 2005, CHE 3015, and CHE 3026 and concurrent enrollment in CHE 3028.

3090. Applying Simulation to Dynamic Processes. 1. Introduces students to dynamic simulation software for controlling individual chemical engineering processes. This course consists of two (2) hours of laboratory per week. *Prerequisite:* C or better in CHE 2005.

3100. Fundamentals of Bioengineering. 3. An introduction to select biological concepts with emphasis on their relevancy to bioengineering. Topics include model organisms, cells and organelles, bioenergetics and metabolism, macromolecules, DNA replication and modern molecular biology methods, and control mechanisms. *Prerequisite:* C- or better in LIFE 1010.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ATSC/ARE/CE/COSC/EE/ES/PETE 3890. *Prerequisite:* sophomore standing.

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. 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 lab sciences.

4050. Unit Operations Laboratory II. 3. 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:* C- or better in CHE 3040. (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 nonisothermal operation. *Prerequisites:* C- or better in CHE 3015 and CHE 3026 and concurrent enrollment in CHE 3028. (Normally offered spring semester)

4070. Process Design I. 4. Encompasses engineering design of chemical processes. Introduces engineering economics, process safety management and environmental management. *Prerequisites:* C- or better in CHE 3028 and CHE 3070 and CHE 4060. (Normally offered fall semester)

4080. Process Design II. 4. [WC◀▶COM3] Intended for the last semester of the senior year. Applies all previous courses to the design of safe, economical and environmentally benign chemical processes. *Prerequisites:* C- or better in CHE 4070, and COM-2.

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:* C- or better in CHE 3028 and CHE 4060.

4092. Controlling Process Systems. 3. Capstone process control course. Students will design process control for systems of linked processes including sensing and transmission, final control elements, and controller. This

course consists of two (2) hours of lecture and three (3) hours of laboratory per week. *Prerequisites:* C or better in CHE 3090 and concurrent enrollment in either CHE 4090, EE 4620, or EE 4621.

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. *Prerequisite:* Completion with a C- or better or concurrent enrollment in CHE 3100 or MOLB 2021.

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.

4165. Biomaterials. 3. Material science and engineering of the various materials used for biomedical applications, in-depth discussion of the molecular and cellular interactions to implanted materials, as well as a survey of practical applications. Materials covered will include polymers, ceramics, metals, composites, silicones, and natural materials, such as collagen, elastic, and silk. Dual listed with CHE 5165. *Prerequisites:* LIFE 1010 and CHEM 1020 or CHEM 1050, or permission of instructor.

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.

4220. Metabolic and Protein Engineering. 3. An introduction to the design of biological systems for conversion of a feedstock to product, with emphasis on synthetic biology and directed evolution design principles, evolutionary mechanisms and tradeoffs. Metabolic pathways and molecules of industrial importance will be discussed, as well as ethics as applied to synthetic biology and bioengineering. Dual listed with CHE 5220. *Prerequisite:* MOLB 2021 or concurrent enrollment in CHE 3100.

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.

4430. Green Chemistry and Global Environmental Problems. 3. Focus includes study of the chemistry of air, water, and soil as well as the effects of anthropogenic activities on natural processes. Emphasis is also placed on sustainability and green chemistry practices and technologies. Cross listed with CE/ENR 4430. *Prerequisite:* CHEM 1020.

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing research mentor, obtaining approval by said mentor, and communicating the student/faculty partnership tot he appropriate staff in their home department. Must be in the Engineering Honors Program. Cross listed with ATSC/BE/CE/COSC/ES/ESE/PETE 4580. *Prerequisite:* junior or senior standing.

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.

4972. Internship in Process Control Engineering. 1-6 (Max. 6). Enables credit for students serving as interns with an approved organization that provides process control and instrumentation experience. *Prerequisite:* Be enrolled in the Process Control and Instrumentation minor.

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 concurrent 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. Utilizing the laws of thermodynamics to a wide variety of process applications. Evaluating current methods for predicting thermodynamic properties of pure fluids and mixtures. Modeling multiphase, multicomponent equilibria. Cross listed with PETE 5020. *Prerequisite:* graduate standing.

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

5060. Flow through 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:* graduate standing.

5090. Graduate Teaching and Research: Theory and Methods. 3. A general approach to scientific research and graduate school. Topics include: purpose of graduate school, careers with graduate degrees, communication basics, literature search skills, presentations, research instrumentation, the scientific methods, developing hypotheses, grant proposal, and paper writing, research ethics, copyrights, patents, research notebooks, and classroom teaching techniques. *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:* Completion with a C- or better or concurrent enrollment in CHE 3100 or MOLB 2021.

Department of Civil and Architectural Engineering

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Department Head: Anthony S. Denzer

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Civil Engineering

The mission of the department of Civil and Architectural Engineering and Construction Management at the University of Wyoming is:

To educate and prepare Civil & Architectural Engineering and Construction Management students to lead as designers, builders, project managers and entrepreneurs as it relates to the sustainable built and natural environments.

To develop technical solutions through research, innovation, and improved infrastructure to diversify and grow the economies that serve Wyoming and the world.

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 2.000 (C) in courses required for the major. Students must complete a minimum of 42 upper division (junior/senior) or graduate-level semester credit hours. Students may have a maximum of 6 credits in courses with a grade of D in upper division CE courses that apply towards their degree program.

Computer Requirement

Many courses in Civil Engineering require students to have a laptop or tablet computer to bring to class, and to be able to download various software program (normally free). See www.uwyo.edu/civil/undergrad/laptop.html for more information.

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.

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

The Civil Engineering department regularly evaluates the following student skills. Specifically, every University of Wyoming Civil Engineering graduate shall have:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Civil Engineering Curriculum

CE 1000: Vista Studio I.....1
CE 1010: Civil Engineering Tools.....3
CE 2000: Vista Studio II.....3
CE 2070: Engineering Surveying.....3
CE 3000: Vista Studio III.....3
CE 3200: Structural Analysis I 3
CE 3210: Civil Engineering Materials.....4
CE 3300: Hydraulic Engineering 3
CE 3400: Introduction to Environmental Engineering 3
CE 3500: Transportation Engineering.....4
CE 3600: Soil Mechanics I 4
CE 4010: Civil Engineering Design.....3
CHEM 1020: Gen Chemistry 1 4
ES 2110: Statics 3
ES 2120: Dynamics 3
ES 2310: Thermodynamics.....3
ES 2330: Fluid Dynamics 3
ES 2410: Mechanics of Materials.....3
MATH 2200: Calculus I.....4
MATH 2205: Calculus II 4
MATH 2210: Calculus III.....4
MATH 2310: Applied Differential Equations I 3
MSTP Elective, 3 courses 11
PHYS 1210 or 1220: Eng Physics I or II.....4
Professional Development elective: 18
Science Elective: (Life, Earth, or Space Sciences Elective) 4
STAT 2050: Statistics.....3

The Civil Engineering Science Elective must be from a third area of basic science beyond chemistry and physics. This includes life, earth, and space sciences.

Approved Electives

Math/Science/Technical Electives

To be selected from approved department list.

Science Electives

To be selected from approved department list.

Professional Development Elective (PDE) Guidelines

18 hours of structured Professional Development Electives (PDE) are required. A CDE activity must be included in those 18 hours. One Structural PDE is required. Electives are to be selected from at least three (3) areas of emphasis:

1. Environmental Engineering
2. Geotechnical Engineering
3. Structural Engineering
4. Transportation Engineering
5. Water Resources Engineering

Professional Development Elective (PDE) Courses

Environmental Engineering

CE 4400, CE 4410, CE/CHE/ENR 4430, CE/ENVE 4441, CE/CHE 54XX, CE 5400, CE/CHE 5410, CE 5425, CE/ENVE/CHE 5430, CE/EWE/CHE 5435, CE/EWE/CHE 5445, CE 5450

Geotechnical Engineering

If a Geotechnical course is selected, the first PDE must be one of the following:
CE 4610/5610, CE 4620/5660, CE 4630/5630, CE 5640

Structural Engineering

One of the following is required:
CE 4250, CE 4260

Beyond the requirement, any of the following:
CE 4200, CE 4265/5265, CE 4285/5285, CE 4295/5295, CE 5010, CE 5200, CE 5220, CE 5255, CE 5270, CE 5280, CE 5290

Transportation Engineering

If a Transportation course is selected, the first PDE must be one of the following:
CE 4510/5510, CE 4555/5555, CE 4530/5530

Beyond the requirement, any of the following:
CE 4970, CE 5540, CE 5560, CE 5570, CE 5575, CE 5585, CE 5590, CE 5700 (Traffic Flow, Traffic Simulation, or Public Transportation)

Water Resources Engineering

CE 4800, CE 4810/5810, CE 4870, CE 5300, CE 5321, CE 5700, CE 5830, CE 5850, CE 5865, CE 5880, CE 5885

Comprehensive Design Experience (CDE) Courses

One of the following is required:
CE 4900

A minimum of 42 credit hours must be upper division (3000+) level.

Transfer Coursework: All Wyoming Community College equivalent courses will be evaluated for acceptance into the CE program. For upper-division coursework, no more than two upper division courses may be transferred and applied to the CE degree. However, CE 4010 and CE 4900 cannot be transferred to UW. Exceptional cases will be considered by petition to the Civil & Architectural Engineering department.

Advanced Civil and Architectural Engineering Standing

All undergraduate students in Civil and Architectural Engineering must fulfill the Gateway Requirement prior to enrolling in any upper-division (3000-5000 level) courses taught in the College of Engineering and Applied Science.

To meet the Civil and Architectural Engineering Gateway Requirement, the student must earn a minimum of 57 Quality Points from any combination of the following seven classes or their equivalent. It is not necessary to complete all seven courses to fulfill the Gateway Requirement.

Gateway Courses

CHEM 1020 - General Chemistry I
PHYS 1210 - Engineering Physics I
or PHYS 1220 - Engineering Physics II
MATH 2200 - Calculus I
MATH 2205 - Calculus II
ES 2110 - Statics
ES 2120 - Dynamics
ES 2410 - Mechanics of Materials

See the advising pages on the Civil and Architectural Engineering website for more information.

Graduate Study

Graduate Programs

An advanced degree in civil and architectural 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: environmental engineering, geotechnical engineering, structural engineering, transportation engineering, and water resources engineering. The department also offers a master of science in architectural engineering and 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 3.000 GPA from an accredited engineering curriculum and a GRE combined minimum score of 298.

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 must apply for admission to the Quick Start program no later then the second semester of their junior 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.

Quick Start students are not required to submit GRE.

Students in the program may apply up to six credit hours of 4000 or 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.

Quick Start applicants are not required to submit GRE scores , but are required to submit a complete application form. 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 42 hours of coursework beyond the baccalaureate, 36 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 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

1000. VISTA Studio I. 1. Introduction to civil and architectural engineering professions through exploration of modern engineering challenges. Students work on a design project, starting with problem definition and working towards concept designs using spreadsheet and communication tools. Professional topics introduced include globabilization, diversity, professional ethics, design limitations and constraints, sustainability, environmental stewardship, and engineering economics. Cross listed with ARE 1000. *Prerequisites:* Corequisites of MATH 1450 or MATH 1405.

1010. Civil Engineering Tools. 3. This course is an introduction to computing tools commonly used in civil engineering practice including 3-D Computer Aided Drafting, Spreadsheets and Presentation Software. Tools will be introduced through design work on typical civil engineering design projects. *Prerequisites:* Corequisite of MATH 2200.

2000. VISTA Studio II. 3. Students work on a real-world project throughout the semester. Professional topics introduced include project management, engineering economic analysis methods, project estimating, professional ethics, engineering business practices common to the civil and architectural engineering professions, and professional leadership. Cross listed with ARE 2000. *Prerequisites:* Corequisites: ARE 1600 or CE 1010 and MATH 2205.

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:* Corequisite of MATH 1450 or MATH 1405.

3000. VISTA Studio III. 3. Students will apply professional skills such as project management, engineering economics, professional ethics, and sustainability to an integrated design project. The role of permitting, regulations, and professional codes to design problems will also be explored. Cross listed with ARE 3000. *Prerequisites:* ARE 2000 or CE 2000, and ES 2410.

3200. Structural Analysis I. 3. [WB◀▶(none)] 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. 4. [WB◀▶COM3] Laboratory investigation and design of materials used in civil engineering: metals, masonry, concrete and timber. Non-destructive evaluation of materials. Analysis and presentation of data, including various types of written reports and oral presentations. Cross listed with ARE 3210. *Prerequisites:* COM2 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. 4. 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 1010.

3600 [4600]. Soil Mechanics I. 4. 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.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ATSC/ARE/CHE/COSC/EE/ES/PETE 3890. *Prerequisite:* sophomore standing.

4010 [3010]. Civil Engineering Design. 3. Students will prepare final civil engineering documents including construction plans, specifications, and engineering estimates for a civil engineering project. Concepts of standard specifications and sustainability measures will also be applied to the design. *Prerequisites:* ARE 3000 or CE 3000, and STAT 2050.

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 3200.

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

4265. Prestressed Concrete Design. 3. This is a classical course on designing prestressed and precast concrete systems. Principles and behavior of prestressed concrete build the foundation for topics that included flexure, shear, and axial load, construction and fabrication, and application. The course continues with fundamental concepts taught in ARE/CE 4260. Dual listed with CE 5265. Cross listed with ARE 4265. *Prerequisite:* ARE/CE 4260.

4285 [4280]. 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 4285. Dual listed with ARE 5285 and CE 5285. Offered on a three semester rotation. *Prerequisites:* ARE/CE 4260 and ARE/CE 3200.

4295 [4290]. Structural Timber Design. 3. Design of structural components and applications utilizing timber. Cross listed with ARE 4295. Dual listed with CE 5295. *Prerequisite:* CE 3200 or equivalent.

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]. Green Chemistry and Global Environmental Problems. 3. Focus includes study of the chemistry of air, water, and soil as well as the effects of anthropogenic activities on natural processes. Emphasis is also placed on sustainability and green chemistry practices and technologies. Cross listed with CHE/ENR 4430. *Prerequisite:* CHEM 1020.

4441 [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.

4565. Traffic Simulation. 3. Traffic modeling and simulation study development; definition, construction, calibration, validation of traffic simulation models; traffic flow dynamics in transportation networks; mathematical optimization of transportation networks; traffic simulation software. Dual listed with CE 5565. *Prerequisite:* CE 3500.

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing research mentor, obtaining approval by said mentor, and communicating the student/faculty partnership tot he appropriate staff in their home department. Must be in the Engineering Honors Program. Cross listed with ATSC/BE/CHE/COSC/ES/ESE/PETE 4580. *Prerequisite:* junior or senior standing.

4610. Foundation Engineering. 3. Site characterization, laboratory shear tests and determination of soil properties. Analyses include bearing capacity, stress distribution and settlement. Design of shallow and control of deep foundations using static and dynamic methods. Dual listed with CE 5610. *Prerequisite:* CE 3600.

4620. Soil and Rock Slope Engineering. 3. Advanced engineering and geologic classification of landslides; detailed field investigations; solid and rock strength properties for stability analysis; advanced analytical and numerical methods for analysis of slope stability; design of engineered stabilization systems. Dual listed with CE 5660. *Prerequisites:* CE 3600.

4630. Ground Improvement, Reinforcement and Treatment. 3. This course is designed to help students understand a number of available geotechnical ground improvement, reinforcement and treatment techniques currently in use. Dual listed with CE 5630. *Prerequisite:* CE 3600.

4650. Instrumentation in Civil Engineering. 3. This lab based course will provide hands on learning to students to install instruments, collect data, analyze results, and use civil engineering judgment to make decisions. Dual listed with CE 5650. *Prerequisite:* ES 2410.

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.

4810. Groundwater Hydrology. 3. Principles and basic equations associated with saturated and unsaturated flow in soils describing groundwater and drainage flow. Laws governing the movement, recharge, and production of underground water with special emphasis on techniques and modeling methods for development of groundwater resources. Dual listed with CE 5810. *Prerequisite:* ES 2330.

4840. Groundwater Contamination. 3. Develop principles and fundamental parameters that control groundwater flow and solute transport in groundwater systems. Introduce basic geochemical processes and contaminant chemistry and site monitoring techniques relevant to groundwater problems. Dual listed with CE 5840. *Prerequisite:* CE 4810 or equivalent.

4870. Water Resource 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. Dual listed with CE 5870. *Prerequisite:* CE 3300.

4900. Comprehensive Design Experience. 3. Team comprehensive project design experience considering the sub-disciplines of civil engineering. *Prerequisites:* 3 of CE 3200, CE 3300, CE 3400, CE 3500, CE 3600, and two of CE 4250, CE 4260, CE 4610, CE 4555, CE 4510, CE 4400, CE 4410, or CE 4800, or instructor consent.

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.

4965. Undergraduate Research. 1-3 (Max. 3). Research activities on a relevant project of limited scope or as part of a laboratory project of greater scope under the advisement of a faculty member or mentor. The normal workload for 3 credits is considered to be 9 hours per week. Students will present at Undergraduate Research Day. *Prerequisite:* CE/ARE 1000.

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 may apply for credit for extended work experience (>10 weeks; full-time) at a professional engineering or architectural firm, supervised by a licensed professional. Students should apply through their adviser prior to the work experience. Enrollment is by departmental approval only. Offered summer only. Cross listed with ARE 4975. *Prerequisite:* consent of department head.

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.

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.

5265. Prestressed Concrete Design. 3. This is a classical course on designing prestressed and precast concrete systems. Principles and behavior of prestressed concrete build the foundation for topics that included flexure, shear, and axial load, construction and fabrication, and application. The course continues with fundamental concepts taught in ARE/CE 4260. Dual listed with CE 4265. Cross listed with ARE 5265. *Prerequisite:* ARE/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.

5285. 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 5285. Dual listed with ARE 4285 and CE 4285. Offered on a three semester rotation.

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.

5295. Structural Timber Design. 3. Design of structural components and applications utilizing timber. Cross listed with ARE 5295. Dual listed with CE 4295. *Prerequisite:* CE 3200 or equivalent.

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.

5321. Engineering and Environment Geophysics. 3. Theoretical background for electrical, electromagnetic, georadar, and other near-surface geophysical measurements. Practical exercises focused on modeling, inversion, data analysis and experimental design. Discussion of applications to engineering and environmental problems. Basic knowledge of MATLAB programming language is helpful, but not required. Cross listed with GEOL 5321. *Prerequisite:* MATH 2250 or MATH 2200.

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.

5430.

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. Cross listed with ENVE 5435 and CHE 5435. *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. Cross listed with ENVE 5445 and CHE 5445. *Prerequisite:* CE 3400.

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.

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.

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.

5565. Traffic Simulation. 3. Traffic modeling and simulation study development; definition, construction, calibration, validation of traffic simulation models; traffic flow dynamics in transportation networks; mathematical optimization of transportation networks; traffic simulation software. Dual listed with CE 4565. *Prerequisite:* graduate standing.

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.

5610. Foundation Engineering. 3. Site characterization, laboratory shear tests and determination of soil properties. Analyses include bearing capacity, stress distribution and settlement. Design of shallow and control of deep foundations using static and dynamic methods. Dual listed with CE 4610. *Prerequisite:* CE 3600.

5630. Ground Improvement, Reinforcement and Treatment. 3. This course is designed to help students understand a number of available geotechnical ground improvement, reinforcement and treatment techniques currently in use. Dual listed with CE 4630. *Prerequisite:* CE 3600.

5650. Instrumentation in Civil Engineering. 3. This lab based course will provide hands on learning to students to install instruments, collect data, analyze results, and use civil engineering judgment to make decisions. Dual listed with CE 4650. *Prerequisite:* ES 2410.

5640. Geotechnical Earthquake Engineering. 3. The purpose of this course is to familiarize students with the field of geotechnical earthquake engineering and soil dynamics. Lectures will focus on stress wave propagation in soil and rock; characterization of earthquakes and ground motions; influence of soil conditions on seismic ground motion characteristics; and liquefaction of soils. *Prerequisite:* CE 3600 or graduate standing.

5660. Soil and Rock Slope Engineering. 3. Advanced engineering and geologic classification of landslides; detailed field investigations; solid and rock strength properties for stability analysis; advanced analytical and numerical methods for analysis of slope stability; design of engineered stabilization systems. Dual listed with CE 4620. *Prerequisite:* graduate standing.

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. Principles and basic equations associated with saturated and unsaturated flow in soils describing groundwater and drainage flow. Laws governing the movement, recharge, and production of underground water with special emphasis on techniques and modeling methods for development of groundwater resources. Dual listed with CE 4810. *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.

5840. Groundwater Contamination. 3. Develop principles and fundamental parameters that control groundwater flow and solute transport in groundwater systems. Introduce basic geochemical processes and contaminant chemistry and site monitoring techniques relevant to groundwater problems. Dual listed with CE 4840. *Prerequisite:* CE 5810 or equivalent.

5850. Advanced Subsurface Hydrology. 3. This course introduces recent advances in dealing with uncertainty issues in subsurface hydrology. Covered topics include reviewing basic statistics required for the course and subsurface flow and transport, uncertainty analysis using Monte Carlo simulations, sensitivity analysis in flow and contaminant transport, heterogeneity of hydrological processes in subsurface, and Bayesian updating. *Prerequisite:* CE 5810 or 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 Resource 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. Dual listed with CE 4870.

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 for the Mountain States, principles of hydrological system, and numerical models. *Prerequisite:* MATH 2310.

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.

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.

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 dif-

ferent 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 2.000 (C) in courses required for the major. Students must complete a minimum of 42 upper division (junior/senior) or graduate-level semester credit hours.

Students may have a maximum of 6 credits in courses with a grade of D in upper division ARE courses that apply towards their degree program.

Computer Requirement

Many courses in Architectural Engineering require students to have a laptop or tablet computer to bring to class, and to be able to download various software programs (normally free). See www.uwyo.edu/civil/undergrad/laptop.html for more information.

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

The Architectural Engineering department regularly evaluates the following student skills. Specifically, every University of Wyoming Architectural Engineering graduate shall have:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Architectural Engineering Curriculum

ARE 1000: VISTA Studio I 1
ARE 2000: Vista Studio II 3
ARE 3000: Vista Studio III 3
ARE 1600: Architectural Design Studio I....3
ARE 2410: Fundamentals of Building Performance 3
ARE 2600: Architectural Design Studio II..3
ARE 3200: Structural Analysis I.....3
ARE 3210: Civil Engineering Materials.....4
ARE 3300: Building Electrical and Plumbing Systems.....3
ARE 3400: Heating, Ventilating and Air Conditioning of Buildings.....3
ARE 3600: Architectural Design Studio III 3
ARE 4600: Architectural Design Studio IV 3
ARE 4740 or ARE 4720: Capstone Design..3
ARE Major Elective: 2 courses.....6
ART 3030: History of Architecture.....3
CHEM 1020: Chemistry 4
ES 2110: Statics 3
ES 2120: Dynamics 3
ES 2310: Thermodynamics.....3
ES 2330: Fluid Dynamics 3
ES 2410: Mechanics of Materials.....3
GEOL 1100, 1500, or 1600.....4
MATH 2200: Calculus I.....4
MATH 2205: Calculus II 4
MATH 2210: Calculus III.....4
MATH 2310: Applied Differential Equations I 3
Math/Science Elective.....3
PHYS 1210 or 1220: Eng Physics I or II.....4
STAT 2050: Statistics.....4

Minimum credit hours required: 126.

Approved Electives

Option Electives: must take six

Third Junior Elective (3)

Structural Courses

ARE 4200, ARE 4250, ARE 4260, ARE 4285/5285, ARE 4295/ARE 5295, CE 3600, CE 4610/5610, CE 4620, CE 4630/5630, CE 4820, CE 5010, CE 5200, CE 5220, CE 5255, CE 5270

Mechanical Courses

ARE 3360, ARE 4330, ARE 4390, ARE 4430, ARE 4490, ME 3040, ME 3170, ME/ESE 4460, ME/ESE 4470

Major Electives: must take two

Any additional Option Elective from the list above, AMST 4900, AMST 5400, ARE 4050, ARE 4400, ARE 4920, ARE 5600, ARE 5700, CE 2070, CE 3300, CE 3400, CE 3500, CE 4965, CE 4970, CE 4975, CM 2000, CM 3100, CM 3120, ENR 4600

Mathematics/Science Electives

Mathematics Electives

MATH 2250, MATH 2300, MATH 3310, MATH 3340, MATH 3500, MATH 4230, MATH 4255, MATH 4300, MATH 4340, MATH 4400, MATH 4440, MATH 4500, MATH 5310, STAT 3050, STAT 4015, STAT 4025, STAT 4115, STAT 4155, STAT 4265

Science Electives

ASTR 2310, ATSC 2000, ATSC 2100, ATSC 4010, ATSC 4320, ATSC 4400, ATSC 4410, LIFE 1010 (Plus all Biology, Botany, and Zoology courses that have LIFE 1010 as a prerequisite), CHEM 1030, CHEM 1060 (Plus all Chemistry courses that have CHEM 1020, 1030, 1050, or 1060 as a prerequisite), ENR 1200, GEOL 1100, GEOL 1110, GEOL

1500, GEOL 1600, GEOL 2000, GEOL 3600, GEOL 4113, GEOL 4444 (Plus all Geology courses that have GEOL 1100 or 1200 as a prerequisite), MOLB 2021 (Plus all Molecular Biology courses that have MOLB 2021 as a prerequisite), PHYS 1210 Engineering Physics I (only if taken before or concurrently with ES 2120), PHYS 1220, PHYS 2310 (Plus all Physics courses that have PHYS 1210 or 1310 as a prerequisite), AECL 2010, AECL 3030, SOIL 2010, SOIL 3130, SOIL 4100, SOIL 4130

A minimum of 42 credit hours must be upper division (3000+) level.

Transfer Coursework: All Wyoming Community College equivalent courses will be evaluated for acceptance into the ARE program. For upper-division coursework, no more than two upper division courses may be transferred and applied to the ARE degree. However, ARE 4720 and ARE 4740 cannot be transferred to UW. Exceptional cases will be considered by petition to the Civil & Architectural Engineering department.

Advanced Civil and Architectural Engineering Standing

All undergraduate students in Civil and Architectural Engineering must fulfill the Gateway Requirement prior to enrolling in any upper-division (3000-5000 level) courses taught in the College of Engineering and Applied Science.

To meet the Civil and Architectural Engineering Gateway Requirement, the student must earn a minimum of 57 Quality Points from any combination of the following seven classes or their equivalent. It is not necessary to complete all seven courses to fulfill the Gateway Requirement.

Gateway Courses

CHEM 1020 - General Chemistry I
PHYS 1210 - Engineering Physics I
or PHYS 1220 - Engineering Physics II
MATH 2200 - Calculus I
MATH 2205 - Calculus II
ES 2110 - Statics
ES 2120 - Dynamics
ES 2410 - Mechanics of Materials

See the advising pages on the Civil and Architectural Engineering website for more information.

Graduate Study

Graduate Programs

An advanced degree in architectural 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 Areas of study in the M.S. programs include: building mechanical systems engineering, environmental engineering, geotechnical engineering, structural engineering, and building energy modeling. Additional information is available from the department or from the Web page.

Students choose an area of emphasis in either, building, 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. Students are required to have a lap top computer.

Architectural engineering degree candidates must meet the academic requirements of the college and in addition must have an average GPA of 2.000 (C) in civil and architectural engineering courses attempted at this university.

MSARE Quick Start Program

The MSARE Quick Start program in Civil and Architectural Engineering (CAE) is de- signed 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 must apply for admission to the Quick Start program no later then the second semester of their junior 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 architectural engineering (MSARE) 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 4000 or 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.

Program Specific Degree Requirements

Master's Program

Areas of study in the master of science program include: building mechanical systems, building energy modeling, structural 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 (AREGS), 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 AREGS and the department head.

Architectural Engineering (ARE)

USP Codes are listed in brackets by the 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

1000. VISTA Studio I. 1. Introduction to civil and architectural engineering professions through exploration of modern engineering challenges. Students work on a design project, starting with problem definition and working towards concept designs using spreadsheet and communication tools. Professional topics introduced include globabiliztion, diversity, professional ethics, design limitations and constraints, sustainability, environmental stewardship, and engineering economics. Cross listed with CE 1000. *Prerequisites:* Corequisites of MATH 1450 or MATH 1405.

1600 [2100]. Architectural Design Studio I. 3. Freshman-level architectural design in a project-based learning environment. Introduction to Building Information Modeling (BIM); architectural presentation drawings; freehand sketching; essentials of architectural design and building code compliance.

2000. VISTA Studio II. 3. Students work on a real-world project throughout the semester. Professional topics introduced include project management, engineering economic analysis methods, project estimating, professional ethics, engineering business practices common to the civil and architectural engineering professions, and professional leadership. Cross listed with CE 2000. *Prerequisites:* Corequisites: ARE 1600 or CE 1010 and MATH 2205.

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.

2600 [2200]. Architectural Design Studio II. 3. Sophomore-level architectural design in a project-based learning environment using Building Information Modeling (BIM). The course builds upon skills learned in ARE 1600, with a new emphasis on building materials and constructions methods. *Prerequisite:* ARE 1600.

3000. VISTA Studio III. 3. Students will apply professional skills such as project management, engineering economics, professional ethics, and sustainability to an integrated design project. The role of permitting, regulations, and professional codes to design problems will also be explored. Cross listed with CE 3000. *Prerequisites:* ARE 2000 or CE 2000, and ES 2410.

3030. History of Architecture. 3. [CH,G◀▶H] A survey of the history of architecture and its allied fields, focusing on the formal, aesthetic, cultural and socio-political dimensions, from prehistory to the present. Cross listed with ART 3030. *Prerequisite:* WA or COM1.

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. 4. [WB◀▶COM3] 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:* COM2 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:* ARE 1600 or CE 1010, and ES 2330 or concurrent enrollment.

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.

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, ARE 2410 or ME 3360, ES 2330 or concurrent enrollment.

3600. Architectural Design Studio III. 3. Junior-level architectural design in a project-based learning environment using Building Information Modeling (BIM). This course builds upon skills learned in ARE 2600, with a new emphasis on the complexities that accompany mid-rise construction, and the integration of structural and mechanical systems. *Prerequisites:* ARE 2410 and ARE 2600.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ATSC/CE/CHE/COSC/EE/ES/PETE 3890. *Prerequisite:* sophomore standing.

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.

4050. Modern Engineering Practice. 3. Study of current professional practices in Architectural Engineering. Students will learn about leading-edge practices through guest speakers, office visits, site visits and research projects focusing on modern building innovation. May be offered as Study Abroad in London, Paris, and Barcelona, or on-campus. *Prerequisite:* ARE 2000.

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 3200.

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

4265. Prestressed Concrete Design. 3. This is a classical course on designing prestressed and precast concrete systems. Principles and behavior of prestressed concrete build the foundation for topics that included flexure, shear, and axial load, construction and fabrication, and application. The course continues with fundamental concepts taught in ARE/CE 4260. Dual listed with ARE 5265. Cross listed with CE 4265. *Prerequisite:* ARE/CE 4260.

4285 [4280]. 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 4285. Dual listed with ARE 5285 and CE 5285. Offered on a three semester rotation. *Prerequisites:* ARE/CE 4260 and ARE/CE 3200.

4295 [4290]. Structural Timber Design. 3. Design of structural components and systems utilizing timber. Cross listed with CE 4295. Dual listed with ARE 5295. *Prerequisite:* CE 3200 or equivalent.

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:* Completion of the ME Success Curriculum, ARE 3400 and ARE/ME 3360 or concurrent. (Normally offered alternate spring semesters)

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. *Prerequisite:* ARE 3400.

4600. Architectural Design Studio IV. 3. Senior-level architectural design in a project-based learning environment using Building Information Modeling (BIM). The course builds upon skills learned in ARE 3600, with a new emphasis on the complexities that accompany high-rise construction, and the integration of structural and mechanical systems. *Prerequisite:* ARE 3600.

4720. Structural Systems Design Project. 3. 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, ARE 4250, and ARE 4260 or concurrent enrollment.

4740. Mechanical Systems Design Project. 3. 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 3400 and concurrent enrollment in 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.

4975. Civil and Architectural Engineering Internship. 1-3 (Max. 3). Students may apply for credit for extended work experience (>10 weeks; full-time) at a professional engineering or architectural firm, supervised by a licensed professional. Students should apply through their adviser prior to the work experience. Enrollment is by departmental approval only. Offered summer only. Cross listed with CE 4975. *Prerequisite:* consent of department head.

5265. Prestressed Concrete Design. 3. This is a classical course on designing prestressed and precast concrete systems. Principles and behavior of prestressed concrete build the foundation for topics that included flexure, shear, and axial load, construction and fabrication, and application. The course continues with fundamental concepts taught in ARE/CE 4260. Dual listed with ARE 4265. Cross listed with CE 5265. *Prerequisite:* ARE/CE 4260.

5285. 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 5285. Dual listed with ARE 4285 and CE 4285.

5295. Structural Timber Design. 3. Design of structural components and applications utilizing timber. Cross listed with CE 5295. Dual listed with ARE 4295. *Prerequisite:* CE 3200 or equivalent.

5600. Collaborative BIM Design. 3. An advanced comprehensive building design course integrating architectural and engineering skills, where design decisions are supported by performance simulation and analysis. Students will sue Building Information Modeling (BIM) software and simulate a professional Integrated Project Delivery (IPD) experience by collaborating with a practicing architect on a real-world project. *Prerequisite:* ARE 3600.

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.

Construction Management

Construction Management is a rapidly-growing discipline, that is focused on the planning and oversight required to deliver construction projects on-time and on-budget. Students learn skills such as project management, decision making, budgeting, scheduling, and site logistics including safety planning, surveying, and building information modeling.

The Construction Management curriculum is designed to prepare students for success in a wide variety of career paths available in the construction sector. The curriculum includes course work in construction, business, humanities and social sciences to enrich the student's academic experiance and to assist them in making a positive contribution to society. The program leads to a four-year Bachelor of Science in Construction Management degree.

Construction Management degree candidates must meet the academic requirements of the college and in addition must have an average GPA of 2.000 in courses required for the major.

A grade of C or better is required in all required courses with a CM prefix.

Construction Management Learning Objectives

Upon graduation students shall be able to:

1. Create written communications appropriate to the construction discipline.
2. Create oral presentations appropriate to the construction discipline.
3. Create a construction project safety plan.
4. Create construction project cost estimates.
5. Create construction project schedules.
6. Analyze professional decisions based on ethical principles.
7. Analyze construction documents for planning and management of construction processes.
8. Analyze methods, materials, and equipment used to construct projects.
9. Apply construction management skills as a member of a multi-disciplinary team.
10. Apply electronic-based technology to manage the construction process.
11. Apply basic surveying techniques for construction layout and control.
12. Understand different methods of project delivery and the roles and responsibilities of all constituencies involved in the design and construction process.
13. Understand construction risk management.
14. Understand construction accounting and cost control.
15. Understand construction quality assurance and control.
16. Understand construction project control processes.
17. Understand the legal implications of contract, common, and regulatory law to manage a construction project.
18. Understand the basic principles of sustainable construction.
19. Understand the basic principles of structural behavior.
20. Understand the basic principles of mechanical, electrical and piping system.

Construction Management Curriculum

ACCT 2010: Accounting 1 3
CE 1000: Vista Studio I 1
CE 2070: Engineering Surveying 3
CM 2000. Introduction to Construction Management 3
CM 2120. Construction Materials and Methods 3
CM 2300: Construction Safety 3
CM 2400: Mechanical, Electrical, and Plumbing 3
CM 2600. Construction Documents 3
CM 3100: Construction Scheduling 3
CM 3XXX: Construction Law & Contract 3
CM 3XXX: Structural Systems 4
CM 3XXX: TBD 3
CM 3120: Cost Estimating 3
CM 3XXX: Soils and Concrete 3
CM 4XXX: Project Management 3
CM 4XXX: Heavy CM Methods 3
CM 4XXX: Building Info. Modeling 3
CM 4XXX: Capstone Project 3
CM Elective: 2 courses 6
COJO 2010: Public Speaking 3
COJO 3010: Business and Prof. Comm 3
ECON 1010: Macroeconomics 3
General Elective: 4 courses 12
GEOL 1100: Physical Geology 4
MATH 1405: Trigonometry 3
MATH 2200: Calculus I 4
MGT 1040: Legal Environment Business 3
MGT 3210: Management & Organization 3
PHYS 1110: General Physics 1 4
STAT 2050: Fundamentals in Statistics 4

Minimum credit hours: 120

Construction Management (CM)

2000. Introduction to Construction Management. 3. Introduction to the practice and principles of construction management as it relates to both vertical and horizontal construction projects.

2120. Construction Materials and Methods. 3. Introduction to building materials and construction practices used in the construction industry to construct both vertical and horizontal construction projects. *Prerequisite:* COM1.

2300. Construction Safety. 3. Introduce students to the various causes of construction accidents and adopted strategies to prevent worksite injuries and illnesses with an emphasis on OSHA standards. *Prerequisite:* CM 2000.

2400 MEP Systems. 3. Introduction to mechanical, electrical and plumbing systems in site infrastructure and vertical construction projects. *Prerequisites:* C in PHYS 1110.

2600. Construction Documents. 3. Introduction to the creation and interpretation of construction documents used in the construction industry to build today's vertical and horizontal construction projects. *Prerequisite:* CM 2000.

3100. Construction Scheduling. 3. Principles of construction scheduling including analytical and quantitative scheduling and management techniques as they apply to both vertical and horizontal construction projects. *Prerequisite:* C in CM 3120.

3160 Construction Law & Contracts. 3. The course covers different contract methods, or arrangements, used by the Construction industry to contract and procure construction work. The course also introduces students to construction law in support of planning and the execution of construction work. *Prerequisites:* CM 2600.

3210. Construction Estimating. 3. The course introduces students to concepts in estimating including but not limited to labor and equipment calculations, the use of price databases, direct and indirect cost, bid preparation and computer applications. *Prerequisites:* C in CM 2600.

4100 Project Management. 3. This course guides students through fundamental Project Management concepts and behavioral skills needed to success-fully launch and lead construction projects in the construction sector. *Prerequisites:* CM 3100.

4140 Heavy CM Methods. 3. The course provides student an overall understanding of construction equipment and selected construction methods used on large scale construction projects. With specific reference to selection, economy, and productivity of common construction equipment and construction procedures for site development and industrial, heavy and civil construction. *Prerequisites:* CM 2120 and CM 3200.

4600 Building Info. Modeling. 3. This course focuses on the skills and information needed to effectively use an existing Building Information Model (BIM) in plan execution for a building construction project. This is a projectbased course where students develop skills on the implementation of BIM concepts throughout the lifecycle of a building, from planning and design, to construction operations. *Prerequisites:* CM 2600.

4900 Capstone Project. 3. This course requires students to participate in a "real" construction situation involving all aspects of managing a project; from initial planning to completion, including budgets, estimating, scheduling, financing and creating contracts and other construction forms as necessary. Case studies will be utilized to develop critical thinking skills. *Prerequisites:* CM 4100.

4970. Construction Management Internship. 3. Students may apply for credit for extended work experience (>10 weeks; full-time) in the construction industry, supervised by a professional. Students should apply through their adviser prior to the work experience. Enrollment is by departmental approval only. Offered summer only.

Land Surveying

A minor in Land Surveying requires 31 hours of specific course work. This minor meets the Wyoming Board of Registration for Professional Engineers and Professional Land Surveyor's surveying education requirements for eligibility as a Land Surveyor in Training. The Land Surveying minor may be paired with any major. With the exception of CE 2070, all classes are offered distance learning through Distance Education Programs.

Land Surveying Minor Curriculum Requirements:

LS	2110	3
CE 2070 or LS 2010 and LS 2015		3
LS	3130	3
LS	3100	2
LS	2400	2
LS	2020	4
ENTK	2500[1]	3
LS	3200	3
LS	3210	4
LS	3120	2
LS	3110	2
	Total Hrs.	**31**

[1]Computer Aided Drafting 1 offered through Sheridan College Outreach Programs.

Land Surveying (LS)

2010 [CE 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.

2015 [CE 2073]. Engineering Surveying Laboratory. 1. Field surveying activities consisting of traversing, differential leveling, construction staking and gathering topographic data. *Prerequisite:* LS 2010 or concurrent.

2020 [CE 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:* LS 2400.

2100 [CE 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.

2110 [CE 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.

2400 [CE 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. *Prerequisite:* CE 2070 or LS 2010.

2410 [CE 2083]. GIS in Surveying. 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:* CE 2070 or LS 2010, and ES 1060 or ES 1061.

2499. Sophomore Land Surveying Topics. 1-6 (Max. 6). A study of current sophomore land surveying problems that are applicable to leand surveying for small group classes. *Prerequisite:* Approval of the Land Surveying Program director.

3100 [CE 2088]. Real Property 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. *Prerequisites:* CE 2070 or LS 2010, and LS 2100 and LS 2110.

3110 [CE 3750]. Boundary Evidence. 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. *Prerequisites:* CE 2070 or LS 2010, and LS 2110.

3120 [CE 3740]. Boundary 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. *Prerequisites:* CE 2070 or LS 2010, and LS 3100 and LS 2110.

3130 [CE 2085]. Public Land Surveys. 3. Basic fundamentals of the Public Land Survey System (PLSS), dependent and independent resurveys, survey plats, "bona fide rights", riparian boundaries, non-rectangular entities, corner evidence and the role of the modern day surveyor. *Prerequisites:* CE 2070 or LS 2010, and LS 2110.

3200 [CE 3710, CE 4710]. Route Surveying. 3. Laying out of super elevation and circular, parabolic, and spiral curves; the difference between highway and railway horizontal curve geometry; offsets to spiral curves as boundaries; area and volumes of earthwork. *Prerequisites:* CE 2070 or LS 2010, and ES 1060 or ES 1061.

3210 [CE 3720, CE 4720]. Advanced Surveying. 4. Advanced topics in surveying computations and procedures, including traverse error analysis, topographic surveying, mapping, astronomical observations, coordinate geometry applications, and state plane coordinates. *Prerequisite:* CE 2070 or LS 2010.

3230 [CE 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 or LS 3210.

3300 [CE 2074]. Ethics for the Professional Surveyor. 1. Introduction to the common ethical and moral issues facing professional surveyors in modern practice. *Prerequisite:* One of LS 3110, LS 3120 or LS 3130.

3400 [CE 4750]. Remote Sensing/Photogammetry 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 2070 or LS 2010.

3500. Junior Surveying Topics. 1-6 (Max. 6). A study of current junior landsurveying problems that are applicable to land surveying for small group classes. *Prerequisite:* Approval of the Land Surveying Program director.

4110 [CE 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:* LS 3110, LS 3120.

4120 [CE 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:* LS 4110.

4130 [CE 2086, CE 4740]. 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. *Prerequisites:* LS 3120 and LS 3130.

4500. Senior Land Surveying Topics. 1-6 (Max. 6). A study of current senior land surveying problems that are applicable to land surveying for small group classes. *Prerequisite:* Approval of the Land Surveying Program director.

Department of Computer Science

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Professors:

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RUBEN GAMBOA, B.S. Angelo State University 1984; M.S. Texas A&M University 1986; Ph.D. The University of Texas 1999; Professor of Computer Science 2015, 2002.

JOHN M. HITCHCOCK, B.S. Iowa State University 1999; M.S. 2001; Ph.D. 2003; Professor of Computer Science 2015, 2003.

Associate Professor:

AMY BANIC, B.S. Duquesne University 2003; M.S. University of North Carolina 2005; Ph.D. 2008; Assistant Professor of Computer Science 2012, 2010.

Assistant Professors:

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Senior Lecturer:

ALLYSON A. ANDERSON, B.S. University of Wyoming 1991; M.S. 1994; Senior Lecturer of Computer Science 2008, 1994.

JAMES S. WARD, B.S. University of Wyoming 1993; M.S. 1997; Senior Lecturer of Computer Science 2011, 2000.

Associate Lecturer:

KIM BUCKNER, B.S. Chapman University 1993; M.S. University of Tennessee, Knoxville 1998; Ph.D. 2003; Associate Lecturer of Computer Science 2014, 2008.

Professor Emeritus:
Thomas A. Bailey, Jr., Henry R. Bauer III, John R. Cowles, John Rowland

Lecturer Emeritus:
Jeri R. Hanly

A Bachelor of Science degree (B.S.) in Computer Science prepares students for careers in virtually any industry or to continue on with graduate study in Computer Science and many other fields. Computer science students learn to approach problems from a computational (algorithmic) point of view, and this approach to problem solving often leads to better and more general solutions. Software systems, information technology, and large scale data applications are core technologies in every area and the applications continue to grow with software and information systems becoming more and more embedded in the fabric of everyday life. These systems are essential tools in science and engineering, for business and finance, government, communications, medicine, and entertainment. Software systems make the world go round and smart devices, such as phones, tablets, glasses, wearable devices, medical implants are ubiquitous. As a result, computer science has grown from a specialized field to an independent, broadly based area that studies all aspects of the use and understanding of software systems, information, and computational processes. Students studying B.S. in Computer Science at the University of Wyoming can study for the B.S. degree in Computer Science and have the option to focus their studies by taking a concentration in Business, Big Data, or the Cybersecurity certificate. The Cybersecurity certificate captures core technical cyber security foundations and principles, from databases and networks to advanced threat detection and mitigation. All of the Computer Science concentrations lead to a Bachelor of Science in Computer Science and all programs are ABET accredited.

Program Objectives

The following are the objectives that the Computer Science program is preparing its graduates to achieve:

Success: Graduates will be employed in a computer science-related field or making progress toward an advanced graduate degree.

Growing: Graduates show continued learning and leading in computing-related professions.

Ethics: Graduates exhibit ethical and responsible behavior in all professional and community endeavors.

Program Learning Outcomes

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

1. Analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions.
2. Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline.
3. Communicate effectively in a variety of professional contexts.
4. Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles.
5. Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline.
6. Apply computer science theory and software development fundamentals to produce computing-based solutions.

Computer Science Undergraduate Major

This major consists of a core set of required and elective courses as seen below. Students may also pursue one of a number of concentrations, which may further constrain the elective courses: Computers and Business, or Big Data. In addition to these courses, Computer Science majors must satisfactorily meet the requirements of the University Studies Program (USP), and they must complete a minimum of 120 credit hours, at least 42 of which must be upper division hours. See the front sections of this catalog for specifics on the USP and university graduation requirements. Note that some of the courses required for the Computer Science core or the concentrations will meet some of the USP requirements. Students do not have to take additional courses to meet those requirements. All courses in Computer Science, Mathematics, and Statistics must be completed with a grade of C or better. A grade of C- is not acceptable.

Computer Science Core

These courses, along with the USP requirements, provide a basic set of skills that all Computer Science majors should master. The courses in this program concentrate 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.

Computer Science Core
(required for all concentrations) Hrs.

Computer Science courses
COSC 1010: Intro to Computer Science 4
COSC 1030: Programming I 4
COSC 2030: Programming II 4
COSC 2150: Computer Organization.....3
COSC 3011: Software Design 3
COSC 3015: Functional Programming 3
COSC 3020: Algorithms & Data Structures 4
COSC 3050: Ethics in Computer Professional 1
COSC 4950: Senior Design I.....1
COSC 4955: Senior Design II 2
Operating Systems Course.....4
Choose one of: COSC 3750: Linux Programming for System Applications (see NOTE below) or COSC 4740: Operating Systems Design
Systems Course 3
Choose one of: COSC 4760: Computer Networks or COSC 4820: Database Systems
Program Language Course 3
Choose one of: COSC 4780: Principles of Programming Languages or COSC 4785: Compiler Construction
Theory Course 3
Choose one of: COSC 4100: Foundations of Computing or COSC 4200: Computability & Complexity
Mathematics and Science courses:
MATH 2200: Calculus I.....4
MATH 2205: Calculus II 4
MATH 2250: Linear Algebra.....3
COSC/MATH 2300: Discrete Structures.....3
Statistics Course: one of STAT 2050 or 2070 4
Science Courses: must take two, 4 hour science courses outside of Computer Science. See NOTE below.....8
Math/Science electives: Elective or electives needed to meet ABET minimum Math/Science requirement of 30 credit hours. See NOTE below for courses meeting the math or science elective.....4

NOTE: If COSC 3750 is taken for the Operating Systems Course. Student must still meet the minimum total coursework requirement for the degree.

NOTE: Math/Stat electives means any MATH courses above Calculus II or STAT courses 3000 and up. Exceptions: cannot count MATH 2350, MATH 2355, MATH 4000, STAT 4220 or any variable credit courses toward this requirement.

NOTE: Courses meeting the Science requirement must have a lab component and be for science or engineering majors. See Department web pages for a current list of other approved courses.

Computer Science Major

Degree Requirement in addition to completion of the core and USP requirement include four COSC Electives and five General Electives.

Computer Science Hrs.
Computer Science courses: (see NOTE below)
COSC Elective #1.....3
COSC Elective #2.....3
COSC Elective #3.....3
COSC Elective #4.....3
General Electives: (see NOTE below)
General Elective #1 3
General Elective #2.....3
General Elective #3 3
General Elective #4.....3
General Elective #5 3

NOTE: COSC electives: include any COSC 3000+ course which is not used to complete any other requirement. Note: a total of 3 credits of COSC 3970 can be used.

NOTE: General electives include any course at or above the 1000 level. They can be used to reach minimum number of upper division hours required for graduation. MATH courses above Calculus II or STAT courses 3000 and up. Exceptions: cannot count MATH 2350, MATH 2355, MATH 4000, or any variable credit courses toward this requirement. Electives need to be selected that will meet the 42 hour requirement for Upper Division credits.

Computers and Business Concentration

An understanding of business fundamentals is essential for students planning a career in applied computer science in a business environment. Students who wish to pursue a Computers and Business concentration are required to complete one of the minors offered by the College of Business. Students should take COSC 4820 to satisfy the system course requirement. In addition, students should take the following courses as part of the Computer and Business Concentration:

Computers and Business Hrs.
Computer Science courses: (see NOTE below)
COSC 4210: Analysis and Design 3
COSC 4220: Design and Implementation 3

COSC Elective #1 3
COSC Elective #2 3
College of Business Minor (see NOTE below)
Business Minor #1 3
Business Minor #2 3
Business Minor #3 3
Business Minor #4 3
Business Minor #5 3

NOTE: COSC electives: include any COSC 3000+ course which is not used to complete any other requirement. Note: a total of 3 credits of COSC 3970 can be used.

NOTE: Minimum Coursework Hours: A minimum of 120 hour is required. However, some Business Minors may require additional coursework in excess of 120 hours, dependent upon the minor selected by the student.

Big Data Concentration

Big data is high volume, high velocity, and/or high variety assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization. The Big Data Concentration directs the students toward data handling (AI, visualization, data mining, and machine learning) courses and data analysis (statistics) courses.

Students who wish to pursue the Big Data concentration should take the following courses to fulfill the Big Data Concentration in addition to the COSC core and USP requirements. In addition, students who wish to pursue a Big Data concentration are required to minor in Statistics.

Big Data **Hrs.**
Computer Science courses
COSC 4450: Graphics 3
COSC 4550: Intro to Artifical Intelligence ..3
COSC 4555: Machine Learning 3
COSC 4570: Data Mining 3
General Elective (see NOTE below) 3
Stat Minor Elective #1 3
Stat Minor Elective #2 3
Stat Minor Elective #3 3

NOTE: General electives include any course at or above the 1000 level. They can be used to reach minimum number of upper division hours required for graduation. MATH courses above Calculus II or STAT courses 3000 and up. Exceptions: cannot count MATH 2350, MATH 2355, MATH 4000, or any variable credit courses toward this requirement. Electives need to be selected that will meet the 42 hour requirement for Upper Division credits.

Cybersecurity Certificate

Cybersecurity is the practice of ensuring the confidentiality, integrity, and availability of information within interconnected systems. Cybersecurity requires extending the typical design and trade-off space to include protection and resiliency to combat malicious actors. Thinking like an adversary becomes a core competency of students in the program, and enables certificate graduates to approach the design and (re)development of systems from a more strategic security-centric mindset. The Cybersecurity Certificate guides students through foundational computer science and statistics concepts necessary for analyzing threat potentials and attack surfaces, building on those with competencies in critical system infrastructure through databases and networks, and further specialized them through two cybersecurity intensive courses.

Cybersecurity Certificate **Hrs.**
COSC 2030: Computer Science II 4
COSC 4010: Cyber Security Topics Course ..3
COSC 4760: Computer Networks 3
COSC 4765: Computer Security 3
COSC 4820: Database Systems 3
STAT 2010, 2050, 2070, or 4220 4
Minimum Required **20**

Note: COSC 4760 can also be replaced by the ECE version ECE 4870 or a second COSC 4010: Cyber Security Topics Course.

Computer Science Minor Requirements

Requirements for a minor in Computer Science are as follows:

A total of 18 credits of computer science courses

All 18 credits must have a grade of C or better. A grade of C- is not acceptable.

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. The Department also offers a graduate minor in computer science.

Program Specific Admission Requirement

Applicants for a graduate degree in computer science are expected to have completed undergraduate courses in Algorithms and Data Structures (COSC 3020 equivalent), Theory of Computing (COSC 4100 or 4200 equivalent), Operating Systems (COSC 4740 equivalent), and Programming languages or Compilers (COSC 4780 or 4785 equivalent). Applicants to the doctoral program must have completed a bachelor's degree in computer science or a closely related discipline at an accredited university or college.

The Graduate Record Examination (GRE) is required of all applicants. GRE scores are required with minimums of 40th percentile for the verbal score and 65th percentile for the quantitative score. Our strongest students tend to have scores substantially above these minimums, with quantitative scores often around the 90th percentile or higher.

Students whose native language is not English must also complete the Test of English as a Foreign Language (TOEFL) with a score of at least 550 on the paper based TOEFL; 213 on the computerized test including a 58 or better in section 1-Reading; 80 for the Internet based TOEFL (iBT) including a score of 23 or better in section 1-Reading or the International English Language Testing System (IELTS) test with a 6.5 score or better.

You must submit to the online application system contact information for three references that can evaluate your potential for graduate study in computer science. If you wish to pursue a Ph.D., the letters should address your ability to pursue quality original research. Letters should also evaluate your oral and written communication skills.

If you meet the minimum criteria and would like to formally apply for admission you will also need to submit the following information during the completion of your application via the application portal:

Copies of transcripts from all colleges and universities (minimum GPA or equivalent 3.000 on a scale of 4.000) for all degrees attained. International applicants must submit copies of individual semester transcripts, consolidated transcripts will not be accepted.

Copy of GRE scores a minimum percentile of 40% on verbal and 65% on quantitative portions of the exam. The majority of admitted students tend to have scores substantially above these minimums.

Contact information for three recommendation letters (applicants should follow-up with recommenders to ensure this requirement is fulfilled; applications will not be processed further until all recommendations have been received).

International students will also need to submit a copy of TOEFL scores, or IELTS scores.

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.

Program Specific Degree Requirements

M.S. Program

Each M.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.

Plan A (thesis)

A total of at least 31 credit hours must be completed. The student must complete a minimum of 27 hours of courses, including the CORE and BREADTH REQUIREMENTS. At least 19 credit hours must be COSC courses. All COSC courses must be at the 5000 level. Courses from other departments, including no more than 6 hours of 4000-level courses, may be included with the approval of the supervising M.S. committee.

Plan A students are required to formally defend their theses before their supervising committees. All defenses must be open and announced at least two weeks in advance. The thesis must be distributed to the committee at least two weeks in advance of the defense. If the student does not pass the defense, the committee will instruct the student as to what needs to be accomplished (and by when) to pass.

Plan B (non-thesis)

The student must complete a minimum of 33 hours of courses, including the CORE and BREADTH REQUIREMENTS. At least 22 credit hours must be COSC courses. All COSC courses must be at the 5000 level. Courses from other departments, including no more than 6 hours of 4000-level courses, may be included with the approval of the supervising M.S. committee.

UW Coursework Requirements for M.S. Transfer Students: M.S. transfer students must complete at least 21 credit hours at the University of Wyoming. At least 12 credits of the CORE & BREADTH REQUIREMENTS must be taken at the University of Wyoming. No more than one class per category of breadth may be counted towards this 12-credit total. The algorithms course credits may be counted toward this 12-credit total.

Summary of Credit Requirements

Plan A

Core: COSC 5110	3
Breadth: theory course, AI course, two systems courses	12
Additional courses	12
Thesis/Dissertation (COSC 5960/5980)	4
Total Hrs.	**31**

Plan B

Core: COSC 5110	3
Breadth: theory course, AI course, two systems courses	12
Additional courses	18
Total Hrs.	**33**

Ph.D.

Core: COSC 5110	3
Breadth: theory course, AI course, two systems courses	12
Additional courses	27
Thesis/Dissertation (COSC 5960/5980)	12
Other credits (may include courses or COSC 5960/5980)	18
Total Hrs.	**72**

Ph.D. 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 qualifying, 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.

Coursework Requirements: A total of at least 72 credit hours must be completed. A minimum of 42 of these credit hours must be taken as coursework, including the CORE and BREADTH REQUIREMENTS. A minimum of 12 hours of COSC 5980 (Dissertation Research) must be taken. All COSC courses must be at the 5000 level. Courses from other departments, including no more than 12 hours of 4000-level courses, may be included with the approval of the supervising Ph.D. committee. All course requirements MUST be completed or enrolled with satisfactory midterm progress prior to scheduling the Ph.D. Final Examination.

UW Coursework Requirements for Ph.D. Transfer Students: Ph.D. transfer students must complete at least 24 credit hours at the University of Wyoming. At least 12 credits of the CORE and BREADTH REQUIREMENTS must be taken at the University of Wyoming. No more than one class per category of breadth may be counted towards this 12-credit total. The algorithms course credits may be counted toward this 12-credit total.

Program: 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 relevant previously-published works.

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

Qualifying Exam Criteria: The student must complete the CORE REQUIREMENT and pass a closed oral examination on a research area administered by the supervising committee. Although closed to the public, faculty members of the Department of Computer Science are welcome to attend. The exam must be announced to the faculty at least two weeks in advance. The research area will be chosen in consultation with the committee. The student must demonstrate background knowledge of the state of the art in the area and preliminary work. This will involve, but is not limited to, presenting material and answering questions covering the relevant area knowledge. The format of the exam will be defined by the committee prior to the exam to allow for sufficient preparation. This examination is intended to motivate the candidate to review relevant literature extensively prior to pursuing the original and innovative portions of the research. Qualifying exam criteria must be completed within the first two years of enrollment in the Ph.D program. If the student does not pass the qualifying exam, the committee will instruct the student as to what needs to be accomplished (and by when) to pass. The closed oral examination requirement may be waived for a student who has completed an M.S. degree in COSC at UW if their M.S. presentation was at a research level that demonstrated background knowledge of the state of the art in the area, at the discretion of the supervising Ph.D. committee.

Preliminary Exam Criteria: Prior to scheduling the Preliminary Examination, the student must be making satisfactory progress towards completion of their course requirements, including the BREADTH REQUIREMENTS. A Preliminary Examination will consist of

a presentation and defense of the already-completed portion of the dissertation research and the research that is proposed to complete the dissertation. The Preliminary Examination must be open and announced at least two weeks in advance. The preliminary examination must be completed within two years of enrollment in the Ph.D program (within three years of enrollment for students who do not have an M.S. degree). This examination is intended to motivate the candidate to make significant progress on work towards their Ph.D. dissertation and propose milestones for completion. If the nature of the proposed continued research and methodology is deemed to be sufficiently original and innovative by the supervising committee, then the committee will approve the research direction after having administered this examination. If the student does not pass the preliminary exam, the committee will instruct the student as to what needs to be accomplished (and by when) to pass.

Option for M.S. degree en route to Ph.D.: After completing the Qualifying Exam and Preliminary Exam, a Ph.D. student may additionally earn an M.S. degree after completing the remaining M.S. course requirements, including the BREADTH REQUIREMENTS. COSC 5980 may be substituted for COSC 5960 in the M.S. requirements at the discretion of the supervising committee. The M.S. degree will be granted only after completion of the preliminary exam. For an M.S. degree to be granted prior to completion of the preliminary exam, the student should enroll in the M.S. degree program and complete the remaining M.S. requirements.

Final Exam Criteria: Prior to scheduling the Ph.D. Final Examination (often referred to as a "defense"), all course requirements, including the BREADTH REQUIREMENTS, MUST be completed or enrolled with satisfactory midterm progress. 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. The Final Examination must be open and announced at least two weeks in advance. The dissertation must be distributed to the supervising committee at least two weeks in advance of the Final Examination. If the student does not pass the final exam, the committee will instruct the student as to what needs to be accomplished (and by when) to pass.

Time to degree for part-time students: Exceptions to the completion deadlines for the Qualifying Exam and Preliminary Exam may be made for part-time students at the discretion of the supervising committee.

Computer Science Core Requirements

COSC 5110 (Analysis of Algorithms) must be completed with a grade of B or better. A grade of B- is not sufficient. Students are strongly encouraged to take COSC 5110 the first time it is offered after enrollment.

Computer Science Breadth Requirements

Students must earn a grade of B or better in one class from the Theory category, one class from the Artificial Intelligence category, and two classes from the Systems category. A grade of B- is not sufficient. Thus there must be 12 credits taken to satisfy the breadth requirement. A list of courses in each category is available from the Department. Although some courses may be listed under multiple categories, a course may only count once towards the breadth requirement.

Graduate Minor

Requirements for a graduate minor in Computer Science are as follows:

- COSC 5110 Analysis of Algorithms
- 9 additional credits of 5000-level computer science courses

All 12 credits must be completed with a grade of B or better. A grade of B- is not sufficient.

Computer Science (COSC)

USP Codes are listed in brackets by the 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

1010. Introduction to Computer Science I. 4. 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.

1015. Introduction to Programming for Data Science. 3. [(none)◀▶Q] Provides an accelerated introduction to computing in the setting of Data Science. Topics include basic programming techniques; data transformation; computing with vectors, matrices, and data frames; data visualization; and text processing. Credit may not be earned for both COSC 1010 and COSC 1015. Priority given to Engineering Honors students. *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. Continues the introduction to the methodology of programming from an object-oriented perspective. The course emphasizes basic software design, expands the students' knowledge of programming language syntax, expands the students' ability to think and design in an object-oriented paradigm. Introduces the students to UML, pseudocode, and simple planning for the design of software. Also introduces the students to templates and the C++ STL. *Prerequisite:* COSC 1010.

1100. Computer Science Principles and Practice. 3. 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)

1101. First-Year Seminar. 3. [(none)◀▶FYS]

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.

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 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:* junior standing and COSC major.

3100. Computer Science Education Seminar. 2. Provides an overview of the current social and research issues, technical trends and challenges facing computer science educators. *Prerequisites*: COSC 1030 and Education major only.

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:* grade of C or better in 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 2150 and COSC 2030.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ARE/ATSC/CE/CHE/EE/ES/PETE 3890. *Prerequisite:* sophomore standing.

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. Web Application Development. 3. The course covers the basics of developing data driven web applications. Topics include using responsive design for user interfaces, architectural patterns and frameworks, object-relational mapping, language-integrated queries, authentication, authorization, unit testing, using source control for code management, publishing web applications and cloud computing. *Prerequisite:* COSC 3011.

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:* grade of C or better in MATH 2310 and MATH 3340.

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.

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.

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing research mentor, obtaining approval by said mentor, and communicating the student/faculty partnership tot he appropriate staff in their home department. Must be in the Engineering Honors Program. Cross listed with ATSC/BE/CE/CHE/ES/ESE/PETE 4580. *Prerequisite:* junior or senior standing.

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*: six hours of upper division COSC coursework.

4735. Advanced Mobile Programming. 3. Continues the development of applications on mobile devices. The focus is device sensors, such as camera, AR, VR, Bluetooth, embedded and connected devices. Dual listed with COSC 5735. *Prerequisite:* COSC 4730.

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 2150 and 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.

4760. Computer Networks. 3. Examines network protocols using a top-down approach based on the Internet model. Course focuses on the application, transport, network and link layers. Also covers wireless communication. Discusses problems and current solutions regarding the efficient use of network resources in the global, multi-media Internet. *Prerequisites:* COSC 2150 and 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 operational) in the context of functional and imperative programming languages. Students build interpreters to explore the implications of the different constructs on computational behavior. *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. *Prerequisites:* COSC 2150 and COSC 3020.

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 2030.

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.

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.

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.

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.

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.

5735. Advanced Mobile Programming. 3. Continues the development of applications on mobile devices. The focus is device sensors, such as camera, AR, VR, Bluetooth, embedded and connected devices. Dual listed with COSC 4735. *Prerequisite:* COSC 4730.

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.

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. *Prerequisites:* COSC 2150 and 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.

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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Academic Professional:

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Adjunct Faculty:

Farhad Jafari, Elena Oggero, Guido Pagnacco

Professors Emeriti:

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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, biology and medicine. Employment opportunities exist in state and federal agencies, industry and medical institutions. Career placement includes such areas as 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

Computer Engineering is a blend of Computer Science and Electrical Engineering. In fact, a Computer Engineering student can change majors to Computer Science within the first three semesters without losing any credits. More careful planning is required to switch from Computer Science to Computer Engineering. Computer Engineering students receive training that allows them to design complex computer systems and embed them in custom applications such as robots, spacecraft, automobiles, etc. A typical system may interface with a sensor to measure the world, then decide how to best use the information to achieve goals and eventually turn on actuators which perform the needed task. They also develop computer vision systems, high performance computers and software, and the internet of things. They take many of the same required courses as Electrical Engineers, but fill in their electives with computer specific courses. Graduates have the ability to design electric circuits, understand network hardware, design computer systems, and write the software inside those systems. Compared to Electrical Engineers, Computer Engineers have less breadth of knowledge in Electrical Engineering but more depth in software and computer hardware. Compared to Computer Scientists, Computer Engineers know much

more about hardware and signal/system theory. Computer Engineers sometimes also major in either Electrical Engineering or Computer Science to get two degrees.

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 (2.000) or better on courses that are prerequisites for courses within the student's course of study. Students must also achieve a grade of C (2.000) 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.

Program Educational 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, patents, publications).

University of Wyoming, Electrical and Computer Engineering Program, Student Outcomes

All Electrical (Computer) Engineering graduates shall demonstrate:

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

(3) an ability to communicate effectively with a range of audiences

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Electrical Engineering Curriculum[1]

Suggested Course Sequence

FRESHMAN YEAR: Fall		**Hrs.**
CHEM	1020	4
FYS	1101[2]	3
ENGL	1010	3
ES	1060	3
MATH	2200	4
	Total Hrs.	**17**
FRESHMAN YEAR: Spring		**Hrs.**
ES	2110[3]	3
MATH	2205	4
MATH	2250	3
PHYS	1210[4]	4
	Total Hrs.	**14**
SOPHOMORE YEAR: Fall		**Hrs.**
ES	2120[3]	3
ES	2210	3
MATH	2210	4
PHYS	1220	4
Human Culture (H)		3
	Total Hrs.	**17**
SOPHOMORE YEAR: Spring		**Hrs.**
EE	2220	4
EE	2390	4
MATH	2310	3
U.S. & WY Constitutions (V)		3
Math/Science Elective[5]		3
	Total Hrs.	**17**
JUNIOR YEAR: Fall		**Hrs.**
EE	3150	3
EE	3220	3
EE	3310	4
EE	3510	4
Communication II (COM2)		3
	Total Hrs.	**17**
JUNIOR YEAR: Spring		**Hrs.**
EE	3330	4
EE	4075	4
EE	4220	3
EE	4390	3
EE	4620	3
	Total Hrs.	**17**
SENIOR YEAR: Fall		**Hrs.**
EE	4440	3
EE	4820[8]	2
Technical Elective[6]		4
BE or EE Elective[7]		3
Human Culture (H)		3
	Total Hrs.	**15**
SENIOR YEAR: Spring		**Hrs.**
EE	4830[8]	2
BE or EE Elective[7]		3
BE or EE Elective[7]		3
BE or EE Elective[7]		3
BE or EE Elective[7]		3
	Total Hrs.	**14**
	Total Credit Hours	**128**

1-Students must have a minimum cumulative GPA 2.000 in all Engineering courses for graduation. GPA of 2.000 or higher is required for all prerequisite courses. Students must complete a minimum of 42 hours of upper division coursework, 30 of which must from the University of Wyoming.

2-EE 1101 is recommended for EE and CPEN majors

3-Or any ES, EE, BE course (>2000 level), or COSC 3011 or COSC 3750

4-PHYS 1210: no credit can be earned in PHYS 1210 if taken after ES 2120. PHYS 1220 should be taken before or concurrently with ES 2210.

5-One course from the ECE Math/Science Elective List. ABET requires a minimum of 30 hours of Math/Science Electives.

6-Any course marked as technical electives in the ECE. Credit can be earned for professional internships or CO-OPs.

7-A minimum of 15 hours of electives from BE or EE courses (4000-level or above) is required.

8- To meet the COM3 requirement with EE 4820 and 4830 the COM2 course must be taken before EE 4820. Also, EE 4820 and EE 4830 must be taken in sequence. COM 2 grade of C or better is required.

F.M. Long Bioengineering Curriculum[1]

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
CHEM	1020	4
FYS	1101[2]	3
ENGL	1010	3
ES	1060	3
MATH	2200	4
	Total Hrs.	**17**

FRESHMAN YEAR: Spring		Hrs.
CHEM	2300	4
ES	2110[3]	3
MATH	2205	4
PHYS	1210[4]	4
	Total Hrs.	**15**

SOPHOMORE YEAR: Fall		Hrs.
ES	2120[3]	3
ES	2210	3
MATH	2210	4
PHYS	1220	4
Human Culture (H)		3
	Total Hrs.	**17**

SOPHOMORE YEAR: Spring		
EE	2220	4
EE	2390	4
LIFE	1010	4
MATH	2250	3
MATH	2310	3
	Total Hrs.	**18**

JUNIOR YEAR: Fall		Hrs.
EE	3220	3
EE	3310	4
EE	3510	4
Communication II (COM2)		3
Human Culture (H)		3
	Total Hrs.	**17**

JUNIOR YEAR: Spring		Hrs.
EE	3330	4
EE	4075	4
EE	4390	3
MOLB	2021	4
	Total Hrs.	**15**

SENIOR YEAR: Fall		Hrs.
EE 4330 or BE 4810		3-4
EE	3150	3
EE	4820[7]	2
US & WY Constitutions (V)		3
Technical or Cultural Context Elective[5]		3
	Total Hrs.	**14-15**

SENIOR YEAR: Spring		Hrs.
EE 4620 or BE 4820		3
EE	4220	3
EE	4830[7]	2
MOLB	3610	4
BE or EE Elective[6]		3
	Total Hrs.	**15**
	Total Credit Hours	**128**

1-Students must have a minimum cumulative GPA 2.000 in all Engineering courses for graduation. GPA of 2.000 or higher is required for all prerequisite courses. Students must complete a minimum of 42 hours of upper division coursework, 30 of which must from the University of Wyoming.

2-EE 1101 is recommended for EE and CPEN majors

3-Or any ES, EE, BE course (>2000 level), or COSC 3011 or COSC 3750

4-PHYS 1210: no credit can be earned in PHYS 1210 if taken after ES 2120. PHYS 1220 should be taken before or concurrently with ES 2210.

5-Any course marked as technical electives in the ECE. Credit can be earned for professional internships or CO-OPs.

6-A minimum of 19 hours of EE/BE electives (4000-level or above) is required.

7- To meet the COM3 requirement with EE 4820 and 4830 the COM2 course must be taken before EE 4820. Also, EE 4820 and EE 4830 must be taken in sequence. COM 2 grade of C or better is required.

Computer Engineering Curriculum[1]

Suggested Course Sequence

FRESHMAN YEAR: Fall		Hrs.
CHEM	1020	4
COSC	1010	4
FYS	1101[2]	3
ENGL	1010	3
MATH	2200	4
	Total Hrs.	**18**

FRESHMAN YEAR: Spring		Hrs.
COSC	1030	4
ES	2110[3]	3
MATH	2205	4
PHYS	1210[4]	4
	Total Hrs.	**15**

SOPHOMORE YEAR: Fall		Hrs.
COSC	2030	4
ES	2120[3]	3
ES	2210	3
MATH	2210	4
PHYS	1220	4
	Total Hrs.	**18**

SOPHOMORE YEAR: Spring		Hrs.
COSC	2150	3
EE	2220	4
EE	2390	4
MATH	2300	3
MATH	2310	3
	Total Hrs.	**17**

JUNIOR YEAR: Fall		Hrs.
EE	3220	3
EE	3310	4
EE	4490	3
Communication II (COM2)		3
Human Culture (H)		3
	Total Hrs.	**16**

JUNIOR YEAR: Spring		Hrs.
EE	3330	4
EE	4220	3
EE	4390	3
Math/Science Elective[4]		3
Human Culture (H)		3
	Total Hrs.	**16**

SENIOR YEAR: Fall		Hrs.
COSC 4760 or EE 4870		3-4
EE	3150	3
EE	4820[7]	2
EE or BE Elective[6]		3 or 4
U.S. & WY Constitutions (V)		3
	Total Hrs.	**14**

SENIOR YEAR: Spring		Hrs.
EE	4830[7]	2
CPEN Elective[6]		3
CPEN Elective[6]		3
CPEN Elective[6]		3
CPEN Elective[6]		3
	Total Hrs.	**14**
	Total Credit Hours	**128**

1-Students must have a minimum cumulative GPA 2.000 in all Engineering courses for graduation. GPA of 2.000 or higher is required for all prerequisite courses. Students must complete a minimum of 42 hours of upper division coursework, 30 of which must from the University of Wyoming.

2-EE 1101 is recommended for EE and CPEN majors

3-Or any ES, EE, BE course (>2000 level), or COSC 3011 or COSC 3750

4-PHYS 1210: no credit can be earned in PHYS 1210 if taken after ES 2120. PHYS 1220 should be taken before or concurrently with ES 2210.

5-Any course marked as technical electives in the ECE. Credit can be earned for professional internships or CO-OPs.

6-CPEN Option Courses: Choose four (4) classes from this list, at most two of which can be from the Computer Science department. Listing of currently available courses includes: COSC 3020, COSC 4450, COSC 4550, COSC 4555, COSC 4560, COSC 4730, COSC 4740, COSC 4760, EE 4245, EE 4340, EE 4345, EE 4440, EE 4530, EE 4590, EE 4870, EE 4990, EE 5390, EE 5430, EE 5630, and EE 5650. EE 4075 is not an allowed CPEN option course. Other EE and COSC graduate-level classes may be considered upon petition. Prerequisites for upper division electives vary. Consult an academic advisor and the course descriptions in the University Catalog for each course.

7-To meet the COM3 requirement with EE 4820 and 4830 the COM2 course must be taken before EE 4820. Also, EE 4820 and EE 4830 must be taken in sequence. COM 2 grade of C or better is required.

Minor Requirements

Electrical Engineering Minor Requirements:

ES2210 Electric Circuit Analysis (3 credits) plus a total of 20 credits of electrical engineering (EE) or bioengineering (BE) courses. You must have a minimum of 12 credits of EE/BE courses that are not counted toward your major.

Computer Engineering Minor Requirements:

COSC 2150 and EE4490 plus 17 credits of electrical engineering (EE) or CPEN Elective courses. The following COSC courses can also be used: COSC 1010, COSC 1030, COSC 2030, and COSC 4760. You must have a minimum of 12 credits of courses that are not counted toward your major.

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:

- Bio-Engineering
- Controls
- Electrical Energy Systems
- Electronic Systems and Devices
- Robotics
- Signal Processing 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.

Program Specific Admission Requirements

Statement of purpose
Official transcripts from all post-secondary institutions attended
GRE verbal percentile minimum of 45 percent. GRE quantitative percentile minimum of 65 percent.
TOEFL total of 79 iBT or IELTS total 6.5.

Program Specific Graduate Assistantships

Additionally, all international students who are state-funded teaching assistantships or any international student with teaching responsibilities are required to complete an Oral Proficiency Interview (OPI). Students will need to follow the recommendations to improve their English skills. Students on state-funding who fail to follow the recommendations or do not meet the minimum proficiency by the end of their first semester will not be able to receive any state-funding until they have demonstrated proficiency.

Program Specific Degree Requirements

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 http://www.uwyo.edu/electrical/graduate/prospective/ms/quickstart.html.

Master's Programs

Plan A (thesis)

This is a minimum 30 credit hour program, 26 hours coursework and 4 hours of thesis

16 credit hours (minimum) in ECE formal coursework
3 credit hours (minimum) in formal coursework outside the department and approved by the student's committee
7 additional credit hours in or out of the department with committee approval
4 or more credit hours of M.S. thesis research
Of the above credit hours in formal coursework, no more than 12 credit hours 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 (Project)
This is a 30 hour program:
18 (minimum) in ECE formal coursework
3 (minimum) in formal coursework outside the department and approved by the student's committee
9 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

Plan B (Coursework only)
This is a 30 hour program:
18 (minimum) in ECE formal coursework
3 (minimum) in formal coursework outside the department and approved by the student's committee
9 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.

Doctoral Program

Ph.D. Degree Requirements:

Ph.D. Credit Allocation (all at 4000 level minimum)

72 hours (minimum) of acceptable graduate coursework

42 hours (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 hours can be at the 4000 level

Courses required by the department bachelor of science degree may not be applied for graduate credit

6 hours (maximum) of EE 4800 (Problems in ...) can be counted for program of study credit

6 hours (maximum) of EE 5880 (Problems in ...) can be counted for program of study credit

9 hours (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 after completing successfully the oral comprehensive examination and before defending the completed dissertation must present their research work at an ECE department seminar. 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.

Electrical Engineering (EE)

USP Codes are listed in brackets by the 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

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.

1101. First-Year Seminar. 3. [(none)◀▶FYS]

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, or ES 2215 and ES 2216. (Offered spring semester only)

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. *Prerequisites:* COSC 1010 or COSC 1015 or COSC 1030 or ES 1060, and MATH 2205.

2800. Problems In:__. 1-3 (Max. 3). 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.

3150. Electromagnetics. 3. A thorough study of static electric and magnetic fields using vector methods with an introduction to dynamic fields. *Prerequisites:* ES 2210, or ES 2215 and ES 2216, MATH 2210, and PHYS 1220 or concurrent enrollment.

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. (Offered spring semester only)

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:* PHYS 1220 or PHYS 1320 or EE 3150, and EE 2220 or concurrent enrollment. (Offered fall semester only)

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. *Prerequisites:* EE 2220 and EE 3310. (Offered spring semester only)

3510. Electric Machines and Power Systems. 4. Polyphase AC circuits; single phase and polyphase transformers; AC synchronous and induction machines; introduction to power systems and per unit system; transmission line parameters; steady-state operations of transmission lines; power flows; transient stability; synchrophasor system and its applications. *Prerequisite:* ES 2210, or ES 2215 and ES 2216.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ARE/ATSC/CE/CHE/COSC/ES/PETE 3890. *Prerequisite:* sophomore standing.

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, COSC 1015, or ES 1060) and (MATH 2250 or MATH 2310) or consent of instructor.

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. *Prerequisites:* MATH 2210 and EE 3220. EE 3220 may be taken concurrently.

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. 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 or PHYS 1220, EE 3330 or concurrent enrollment, or consent of instructor.

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.

4345. Hardware Digital Signal Processing. 3. Hands-on introduction to real-time digital signal processing. Programming DSP algorithms using C on modern DSP hardware. Students gain deep understanding of fundamental DSP concepts by implementing selected applications including sampling, reconstruction, FIR and IIR filters, signal generation, and FFT. Hardware concepts include EDMA, memory maps, interrupts, buffered serial ports. *Prerequisite:* EE 3220.

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 2390, and EE 3330 or concurrent enrollment.

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. (Normally offered once a year)

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. *Prerequisites:* EE 3220 and EE 4220. (Normally offered once a year)

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.

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. Control theory and design mehtods focused on application. Feedback. Performance limits. Routh-Hurwitz, root locus, Nyquist. Nonminimum-phase systems. State feedback. Proportional-Integral-Derivative control. Lead/lag. High-order compensation. Discrete controllers. *Prerequisite:* EE 2220 or ME 3020.

4621. Honors Automatic Control Systems. 3. Control theory and design mehtods focused on application. Feedback. Performance limits. Routh-Hurwitz, root locus, Nyquist. Nonminimum-phase systems. State feedback. Proportional-Integral-Derivative control. Lead/lag. High-order compensation. Discrete controllers. Honors students will at the end of the semester design a high-performance control system for a sophisticated plant with realistic feedback limitations. *Prerequisite:* EE 2220 or ME 3020.

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 2220, EE 2390, and EE 3310 or concurrent enrollment, plus 6 hours of 4000 level EE/BE classes, or concurrent enrollment. COM2 must be passed with a C or better grade. (Offered fall semester only)

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. (Offered spring semester only)

4870. Computer Network Hardware. 4. Basic LANs, Ethernet LAN architecture, and classical Ethernet CSMA/CD MAC protocol. 10Mbps, 100 Mbps, and gigabit Ethernet architecture. Introduction to switching, queuing theory, architecture, design and performance analysis of switch fabrics. Architecture, design, algorithms and performance analysis of Routing. Cellular Networks. TCP/IP Protocol. *Prerequisites:* EE 2390.

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. 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 4300. *Prerequisite:* EE 3150 or PHYS 1220, EE 3330 or concurrent enrollment, or consent of instructor.

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.

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.

5430. 3-D Computer Vision. 3. This course is intended to provide a mathematical framework for describing three dimensional imaging and computer vision. Topics include 3-D coordinate transforms, image formation, camera calibration, reconstruction from two views, SIFT detection, hidden Markov models, Markov random fields, and "bag-of-words" visual description. *Prerequisites:* EE 4220, MATH 2250.

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.

5460. Probabilistic Robotics. 3. Fundamental theory underlying the robust sensing and planning used in self-driving machines is developed. Topics covered are: Bayesian, Kalman, and Particle Filters; simple ground robot motion models; mobile robot localization; simultaneous localization and mapping; partially observable Markov decision processes. *Prerequisite:* EE 4220.

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 in:. 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.

5620 [4530]. Digital Image Processing. 3. Methodologies and algorithms for processing digital images by computer. Includes gray level transformations, histogram analysis, spatial domain filtering, 2D Fourier transforms, frequency domain filtering, image restoration, and reconstruction of computer tomography (CT) medical images. *Prerequisite:* EE 3220 or equivalent background. (Offered fall of even-numbered years)

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 5620.

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.

5670. Digital Image Formation. 3. This course introduces fundamental aspects of practical digital image formation, using specific applications to demonstrate these principles. Standard CCD and CMOS cameras (both still and video) and standard camera lens systems are assumed. *Prerequisite:* EE 3220 or equivalent background.

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 3510.

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 are 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.

5890. Reliability of Engineering Systems. 3. This course will cover general reliability modeling and evaluation; probability and stochastic processes; system modeling; methods of reliability assessment (state space, frequency balancing, cut-set and tie-set analysis, decomposition, Monte Carlo simulation); and reliability modeling and analysis of electric power systems: bulk power systems, distribution systems, and industrial systems. *Prerequisite:* MATH 2310 with a grade of C or better.

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)

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing research mentor, obtaining approval by said mentor, and communicating the student/faculty partnership tot he appropriate staff in their home department. Must be in the Engineering Honors Program. Cross listed with ATSC/CE/CHE/COSC/ES/ESE/PETE 4580. *Prerequisite:* junior or senior standing.

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. Dual listed with BE 5810. *Prerequisite:* EE 2210 or similar electric circuit course.

4820. Biomedical Signal Processing. 3. Extraction of signals from noise and data analysis. Emphasis on system modeling of physiological functions from experimental data. Dual listed with BE 5820. *Prerequisite:* EE 3220, basic course, or equivalent.

5410. Rehabilitation Engineering. 3. This course covers the engineering principles of multiple rehabilitation technologies, including rehabilitation robots, exoskeletons, wearable sensors, electrical stimulators, implants, and virtual reality. Students will learn the technical and biological principles of all of these technologies via lectures, projects, and literature reviews. *Prerequisite:* graduate standing.

5810. 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. Dual listed with BE 4810. *Prerequisite:* EE 2210 or similar electric circuit course.

5820. Biomedical Signal Processing. 3. Extraction of signals from noise and data analysis. Emphasis on system modeling of physiological functions from experimental data. Dual listed with BE 4820. *Prerequisite:* EE 3220, basic course, or equivalent.

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

3074/4055 Engineering Building, 766-5255/766-2500
E-mail: ceinfo.uwyo.edu; che-info@uwyo.edu
Web site: www.uwyo.edu/chemical/graduate/prospective/environmental/index.html

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 Engineering and the Department of 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

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

1. A GPA of 3.000 (A=4.000), or equivalent;
2. A GRE score of 291 (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 76 (Internet based) or an IELTS score of 6.0.

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.

Program Specific Degree Requirements

All Environmental Engineering M.S. students must take the following Core courses (9 hrs):

1. Environmental Engineering Microbiology (ENVE 5425)
2. Environmental Engineering Chemistry (ENVE 5430)
3. Environmental Transport Processes (CE 5435)

Students should also take at least one of the following Recommended courses (3 hrs):

1. Advanced Biological Wastewater Treatment (ENVE 5410)
2. Advanced Physical Chemical Treatment (ENVE 5450)

Plan A (Thesis) students complete another 14 hours of Approved Elective coursework, at least 4 hours of Thesis Research (ENVE 5960), and write and defend their thesis. Plan B (Project) students complete another 18 hours of Approved Elective coursework and write and present their project.

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.

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. *Prerequisite:* 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.

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. Cross listed with CE 5445. *Prerequisite:* CE 3400.

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.

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.

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,
(307) 766-2122
Web site: www.uwyo.edu/mechanical
E-mail: me.info@uwyo.edu
Department Head: Carl P. Frick

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.

CARL P. FRICK, B.S. University of Colorado at Boulder 1999; M.S. 2003; Ph.D. 2005; Professor of Mechanical Engineering 2019, 2008; Head of Mechanical Engineering 2015.

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.

Associate Professors:

RAY S. FERTIG III, B.S. University of Wyoming 2001; M.S. 2003; Ph.D. Cornell University 2010; Associate Professor of Mechanical Engineering 2017, 2011.

MICHAEL STOELLINGER, M.S. Technical University Munich 2005; Ph.D. University of Wyoming 2010; Associate Professor of Mechanical Engineering 2018, 2012.

Assistant Professors:

DILPUNEET S. AIDHY, B.E. Punjab Engineering College 2004; Ph.D. University of Florida 2009; Assistant Professor of Mechanical Engineering 2015.

ERICA L. BELMONT, B.S. Tufts University 2004; M.S. 2008; Ph.D. University of Texas at Austin 2014; Assistant Professor of Mechanical Engineering 2014.

YANG LIU, B.S. Chongqing University; M.S. Zhejiang University; Ph.D. Pennsylvania State University 2014; Assistant Professor of Mechanical Engineering 2018.

MAYSAM MOUSAVIRAAD, B.S. Sharif University of Technology 2002; M.S. 2004; Ph.D. University of Iowa 2010; Assistant Professor of Mechanical Engineering 2017.

XIANG ZHANG, B.S. Northeastern University (China) 2009; M.S. Beihang University (China) 2012; Ph.D. Vanderbilt University 2017; Assistant Professor of Mechanical Engineering 2019.

Professors Emeriti:
Donald F. Adams, Paul A. Dellenback, Bruce R. Dewey, Andrew Hansen, William R. Lindberg, Kynric M. Pell, Ovid A. Plumb, Donald A. Smith, David E. Walrath, Robert A. Wheasler

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:

- Successfully practice the profession of engineering
- Demonstrate career growth (e.g. increasing complexity of job assignment, career promotions, professional registration, patents, publications, and completion of advanced degrees)

The undergraduate program includes a foundation in mathematics, science, and engineering sciences. The three key elements of the mechanical engineering undergraduate program include core engineering principles, laboratory 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 2.000 (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 (ES) and required mathematics courses.

Mechanical Engineering Success Curriculum

All undergraduate students in the B.S. Mechanical Engineering and B.S. Energy Systems Engineering programs must successfully complete the Mechanical Engineering Success Curriculum prior to enrolling in any upper-division (3000-level or above) courses taught by the Mechanical Engineering Department. The Mechanical Engineering Success Curriculum promotes successful completion of upper-division coursework by assuring a student that their foundational knowledge and skills are strong in mathematics and engineering fundamentals. To successfully complete the Mechanical Engineering Success Curriculum, a student must earn a minimum 3.000 GPA in the following 10 courses: MATH 2200, MATH 2205, MATH 2210, ES 1060, ES 2110, ES 2120, ES 2210, ES 2310, ES 2330, and ES 2410. AP/iB courses are excluded from the GPA calculation, but grades transferred from other institutions will be used in evaluating the ME Success Curriculum GPA.

Policy for Transfer Credit Towards Mechanical Engineering (ME) Core Coursework

In general, transfer of coursework towards a Mechanical Engineering degree will follow University of Wyoming policy. Courses must be shown to be equivalent to its University of Wyoming course (latitude may be given for Mechanical Engineering electives without a direct University of Wyoming equivalent). However, six courses are considered to be the core of the Mechanical Engineering program, and therefore credit cannot be transferred from another institution. These courses are ME 3010, ME 3020, ME 3040, ME 3170, ME 3360, and ME 3450. Exceptions may be made for courses from approved study abroad programs or in extreme circumstances. Please note that failing a prerequisite course resulting in a delay of graduation does not constitute an extreme circumstance. Any transfer of ME courses requires explicit written approval from the Department.

Dual ME/ESE Degrees

In the event that a student desires to double major in ME and ESE, University policy requires that 30 credit hours past the first degree are required to earn the second degree, and college policy dictates that 24 of these credit hours must be technical coursework approved by the Department while up to 6 hours can be any student-chosen electives.

Mechanical Engineering Curriculum*

Chemistry	**Hrs.**
CHEM 1020: Gen Chem 1	4
Engineering Science	
ES 1060: Intro Eng Prob Solv	3
ES 2110: Statics	3
ES 2120: Dynamics	3
ES 2210: Elec Circuit Analysis	3
ES 2310: Thermodynamics	3
ES 2330: Fluid Dynamics	3
ES 2410: Mech of Materials	3
ES 2800* not part of MESC	
Math	
MATH 2200: Calculus 1	4
MATH 2205: Calculus 2	4
MATH 2210: Calculus 3	4
MATH 2310: Appl. Diff. Eqns.	3
Mechanical Engineering	
ME 3005: Engineering Experimentation	3
ME 3010: Intermediate Mechanics of Materials	3
ME 3020: System Dynamics	3
ME 3040: Thermodynamics II	3
ME 3060: Numerical Methods for Engineers	3
ME 3160: Thermal/Fluid Science Lab	3
ME 3170: Machine Design	3
ME 3360: Fundamentals of Transport Phenomena	3
ME 3450: Properties of Materials	3
ME 4060: Systems Design I	3
ME 4070: Systems Design II	3
ME 4150: Mechanical Behavior of Materials	3
Physics	
PHYS 1220: Phys. Engineering Physics II	4
PHYS 2310: Phys Ill or PHYS 2320: Phys IV or CHEM 1030: Gen Chem II (min 3 CH)	
Electives	
Four ME Electives (min 12 CH total, any upper division ME course or EE 4620)	
Two Math/Science Electives (min 6 CH total, select from department-approved list)	
One Business Elective (min 3 CH, select from department-approved list)	
One Technical Elective (min 3 CH, any engineering, math/science or business course approved by the ME Dept)	
(See here for Math, Science and Business Elective options: http://www.uwyo.edu/ceas/academics/advising/_files/advfiles/me_math_science_business_electives.pdf)	

Notes:

i) Before enrolling in any upper division ESE or ME course, students must complete the ME Success Curriculum (3.000 GPA in MATH 2200, MATH 2250, MATH 2210, and the seven ES courses).

ii) Graduates must meet all college requirements and earn a minimum GPA of 2.000 in ME courses taken at UW. A minimum of 48 hours are required, so ME, business, and technical electives should be chosen appropriately.

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. Faculty in Mechanical Engineering conduct research in the areas of aerodynamics, biomaterials, composite materials, computational material science, computational fluid dynamics, combustion, continuum mechanics, heat transfer, materials reliability, mechanical behavior of materials, nanomechanics of surfaces and interfaces, and wind energy.

Department Specific Admission Requirements

Applicants should possess a Bachelor of Science (B.S.) degree or equivalent in Mechanical Engineering with a minimum GPA of 3.000 on a 4.000 grade scale or equivalent. 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, or IELTS 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 TOEFL score of 577 on the written exam or 90 on the Internet-based test (iBT) TOEFL (or a minimum IELTS score of 6.5). Admittance to the graduate program is competitive, and the average applicant that is accepted will likely have well above the minimum qualifications.

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. 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 ME 5960 of the 30-hour Plan A program. 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. Classes must meet the following constraints:

- ME courses (5000-level): minimum of 15 hours
- A maximum of 9 credits at the 4000 level outside of ME may be taken
- Thesis research (ME 5960): 4 credit hours
- Seminar (ME5478): 2 credit hours
- Total: minimum of 30 hour

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:

- ME courses (5000-level); minimum of 15 hours
- A maximum of 9 credits at the 4000 level outside of ME may be taken
- Graduate Project (ME 5961); minimum of 1 hour
- Total: minimum of 31 hours

Courses outside of ME 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. Special topic credits may be earned using ME 5475 (maximum of 6 credits). 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.

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 3.250,
- a minimum GPA of 3.250 in ME courses, and
- a minimum of three letters of recommendation (at least two must be from ME faculty at UW).
- Contact Department for application process.

Students must maintain a GPA of at least 3.250 in their undergraduate and at least 3.000 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.

Until a student in this program has completed a total of 131 credit hours of courses applicable to the BS or MS degree in Mechanical Engineering, he/she will be governed by the regulations applicable to undergraduate students in the Department. After a student has accumulated a total of 131 applicable credit hours, he/she will be governed by the regulations applicable to any graduate student in the ME department. These regulations include the requirement that every student must take the GRE general examination. It is the intention of the department that, to the degree possible, a student in this program is treated on the same basis as any other student in the department at a comparable stage of his/her academic career.

With the recommendation of the student's academic advisor and the approval of the ME Graduate Affairs Committee, as many as 6 credit hours of ME department courses at the 5000 level may be counted towards both the undergraduate degree requirements and the requirements for the MS degree. In principle, therefore, the minimum number of course

credit hours required for the BS/MS degrees will be 151 (for Plan A students + 4 additional hours of thesis research) or 156 (for Plan B students - non-thesis option).

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 Ph.D. requires a minimum of 72 graduate hours, at least 42 of which must be earned in formal coursework. A minimum of 24 in-resident coursework hours is required. No graduate credit is allowed for 4000-level mechanical engineering courses and a maximum of 9 credits at the 4000-level outside of ME may be taken. A minimum of 15 credit hours must be taken from ME courses (5000-level).

In addition to coursework requirements, graduate students pursuing a Ph.D. in Mechanical Engineering must complete three examinations: Qualifying, Preliminary, and Final. In consultation with their advisor, students are allowed to take the Qualifying Exam after declaring pursuit of a Ph.D. degree. Graduate students do not require a M.S. to take the Qualifying Exam. The format is a knowledge-based examination consisting of three subject areas, each with both a written and an oral component. The candidate will be evaluated for each subject area, based on the cumulative performance in both (written and oral) components. Should the student fail a single subject area, at the discretion of the committee, they may repeat the failed portion at the next available opportunity. A third attempt is not permitted. The successful completion of the Qualifying Exam is required before the Preliminary Exam. The purpose of the Preliminary Exam is to evaluate the aptitude of the Ph.D. candidate to perform research based on preliminary results, and to assess the student's plan for completing the research necessary for the Final Exam. The Preliminary Exam follows university regulations and, at a minimum, consists of a seminar attended by the student's committee members. The purpose of the Final Exam is to ensure the Ph.D. candidate has sufficient accomplishments to be awarded a Ph.D. The Final Exam consists of an oral defense of the dissertation in accordance with university policy.

All graduate students in Mechanical Engineering are expected to follow the graduate education policies of the College of Engineering and Applied Sciences.

Mechanical Engineering (ME)

USP Codes are listed in brackets by the 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

3005 [2010; 2020]. Engineering Experimentation. 3. A combined lecture/laboratory course introducing students to experimental methods in the context of dynamics. Written technical communication, intermediate structured programming, experimental design, fundamental statistics, and uncertainty methods (numerical and analytical) are emphasized. Collaborative writing and teamwork is introduced. Cross listed with ESE 3005. *Prerequisites:* Completion of the ME Success Curriculum, ES 1060, ES 2120.

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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, 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 ESE 3040. *Prerequisite:* Completion of the ME Success Curriculum, CHEM 1020 and ES 2310. (Normally offered fall semester)

3060. Numerical Methods for Engineers. 3. Numerical solutions of problems commonly encountered in mechanical engineering including differentiation, integration, differential equations, system of linear and nonlinear equations, and optimization. The structured programming approach will be emphasized and applications from solid mechanics, thermal fluid sciences, materials science, and dynamic systems will be covered. Cross listed with ESE 3060. *Prerequisites:* Completion of the ME Success Curriculum, ES 1060, and MATH 2310 or concurrent enrollment.

3160 [2140; 2160]. Thermal/Fluid Science Lab. 3. A laboratory course to introduce students to experimental methods for temperature measure and pressure/flow characteristics of fluids. Continuation of experience with communication (written, oral, and digital), intermediate programming, experimental design, data analysis, and teamwork skills is emphasized. Cross listed with ESE 3160. *Prerequisites:* Completion of the ME Success Curriculum, ES 2330; ME/ESE 3005.

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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, MATH 2310, ES 2310, and ES 2330.

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, ARE 2410 or ME 3360, ES 2330 or concurrent enrollment.

3450 [ES 3450]. Properties of Materials. 3. Mechanical, electrical, thermal and chemical properties of materials. Theoretical treatment of structure of solids and design for specified properties. *Prerequisite:* Completion of the ME Success Curriculum, CHEM 1020 and ES 2310. (Normally offered spring semester)

3975. Internship. 3. Students may apply for credit for extended work experience (>10 weeks; full-time) engaging in mechanical engineering work and supervised by an engineer in mechanical engineering (or closely related field). Students should apply through their adviser prior to the work experience. Enrollment

is by departmental approval only. Satisfactory/Unsatisfactory only. *Prerequisite:* consent of the department head.

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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, MATH 2310 and (CE/ARE 4200 or MATH 2250 or ME 3010 or ME 3060).

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:* Completion of the ME Success Curriculum, ME 3010 (or concurrent enrollment), ME 3170, and ME/ESE/ARE 3360. (Normally offered fall semester)

4070. Systems Design II. 3. [WC◀▶(none)] 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:* Completion of the ME Success Curriculum, ME/ESE 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:* Completion of the ME Success Curriculum, ME 3010 and ME 3450.

4150. Mechanical Behavior of Materials. 3. Commonly encountered phenomenological and mechanistic behaviors that lead to mechanical failure are examined. Understanding the origin of mechanical failure of components allows for robust design of mechanical systems. Metallic, polymeric, and ceramic materials are covered. *Prerequisite:* Completion of the ME Success Curriculum, ME 3450.

4200. Thermo/Kinetics of Materials. 3. Introduction to the foundations of thermodynamics and kinetics of materials, including Gibbs free energy, ideal solutions, alloy ordering, phase diagrams, atomistic mechanisms of diffusion, interfaces and microstructure, grain growth, solidification, and diffusional and diffusionless transformation in solids. Dual listed with ME 5200. *Prerequisite:* 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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, ES 2310 and 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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, ES 2310 and 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:* Completion of the ME Success Curriculum, ES 2330. (Normally offered spring semester)

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:* ARE/ME 3400 and ARE/ME 3360 or concurrent. (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:* Completion of the ME Success Curriculum, ME 3450. (Normally offered spring semester)

4455. Combustion Engineering. 3. The basic physics and chemistry of combustion engineering and its applications are covered, including thermodynamics, chemical kinetics, multicomponent conservation equations, laminar premixed and nonpremixed flames, detonations, droplet combustion, modern engines and energy systems. Cross-listed with ME 5455 and dual-listed with ESE 4455. *Prerequisite:* Completion of the ME Success Curriculum, ME/ESE 3040 and ME/ARE/ESE 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 ESE 4460. *Prerequisite:* Completion of the ME Success Curriculum, ESE 3360 or ME 3360 or 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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, junior standing in engineering.

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. *Prerequisite:* Completion of the ME Success Curriculum, ARE/ME 4430 with a grade of C or above.

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:* Completion of the ME Success Curriculum, ARE/ME 3360 and 3400.

4580.

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.

5200. Thermo/Kinetics of Materials. 3. Introduction to the foundations of thermodynamics and kinetics of materials, including Gibbs free energy, ideal solutions, alloy ordering, phase diagrams, atomistic mechanisms of diffusion, interfaces and microstructure, grain growth, solidification, and diffusional and diffusionless transformation in solids. Dual listed with ME 4200. *Prerequisite:* ME 3450.

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:* graduate standing.

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 5472 or equivalent.

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.

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.

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. Combustion Engineering. 3. The basic physics and chemistry of combustion engineering and its applications are covered, including thermodynamics, chemical kinetics, multicomponent conservation equations, laminar premixed and nonpremixed flames, detonations, droplet combustion, modern engines and energy systems. Cross-listed with ME 4455 and dual-listed with ESE 4455. *Prerequisite:* Completion of the ME Success Curriculum, ME/ESE 3040 and ME/ARE/ESE 3360.

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 or equivalent.

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:* graduate standing.

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.

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 an ABET-accredited undergraduate degree offering by the Department 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 permitting 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 law, and two electives picked from a list of classes that focus attention on energy and the environment. The SENR courses expose students to issues related to permitting such as preparation of environmental impact studies, and related regulations such as the Endangered Species Act. In addition, there are four technical electives that allow students 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.

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 and must have a minimum GPA of 2.000 (C) in ESE and ME course work. An International Engineering Option similar to that in ME is also available. A grade of C- or better in engineering science, mathematics, and basic sciences courses is required to fulfill prerequisites in Mechanical and Energy Systems engineering courses. A grade of C or better is required for any transfer course from another university.

Energy Systems Engineering Success Curriculum

All undergraduate students in the B.S. Mechanical Engineering and B.S. Energy Systems Engineering programs must successfully complete the Mechanical Engineering Success Curriculum prior to enrolling in any upper-division (3000-level or above) courses taught by the Mechanical Engineering Department. The Mechanical Engineering Success Curriculum promotes successful completion of upper-division coursework by assuring a student that their foundational knowledge and skills are strong in mathematics and engineer-

ing fundamentals. To successfully complete the Mechanical Engineering Success Curriculum, a student must earn a minimum 3.000 GPA in the following 10 courses: MATH 2200, MATH 2205, MATH 2210, ES 1060, ES 2110, ES 2120, ES 2210, ES 2310, ES 2330, and ES 2410. AP courses are excluded from the GPA calculation, but grades transferred from other institutions will be used in evaluating the ME Success Curriculum GPA.

Policy for Transfer Credit Towards Energy Systems Engineering (ESE) Core Coursework

In general, transfer of coursework toward an Energy Systems Engineering degree will follow University of Wyoming policy. Courses must be shown to be equivalent to its University of Wyoming course (latitude may be given for Energy Systems Engineering electives without a direct University of Wyoming equivalent). However, three courses are considered to be the core of the Energy Systems Engineering program, and therefore credit cannot be transferred from another institution. These courses are ESE 3020, ESE 3040, and ESE 3360. Exceptions may be made for courses from approved study abroad programs or in extreme circumstances. Please note that failing a prerequisite course resulting in a delay of graduation does not constitute an extreme circumstance. Any transfer of ESE courses requires explicit written approval from the Department.

Dual ME/ESE Degrees

In the event that a student desires to double major in ME and ESE, University policy requires that 30 credit hours past the first degree are required to earn the second degree, and college policy dictates that 24 of these credit hours must be technical coursework approved by the Department while up to 6 hours can be any student-chosen electives.

Energy Systems Engineering

Atmospheric Science **Hrs.**
ATSC 2100: Global Warming 3

Chemistry
CHEM 1020: Gen Chem I.....4

Engineering Science
ES 1060: Intro Eng Prob Solv.....3
ES 2110: Statics 3
ES 2120: Dynamics 3
ES 2210: Elec Circuit Analysis.....3
ES 2310: Thermodynamics I 3
ES 2330: Fluid Dynamics 3
ES 2410: Mech of Materials.....3

Environment and Natural Resources
ENR 3000: ENR Problem Solving.....3
ENR 4750: ENR Law and Policy.....3
ENR 4900: ENR Assessment Practice.....3

Math
MATH 2200: Calculus I.....4
MATH 2205: Calculus 2 4
MATH 2210: Calculus 3.....4
MATH 2310: Appl. Diff. Eqns. 3

Energy System Engineering
ESE 3005: Engineering Experimentation....3
ESE 3020: System Dynamics 3
ESE 3040: Thermodynamics II.....3
ESE 3060: Numerical Methods for Engineers 3
ESE 3160: Thermal/Fluid Science Lab.....3
ESE 3360: Fundamentals of Transport Phenomena 3
ESE 4060: Energy Systems Design I.....3
ESE 4070: ·Energy Systems Design II.....3

Life Sciences
LIFE 1010: Biology I 4

Physics
PHYS 1220: Phys. Engineering Physics II ...4

Electives
Two ESE Electives (min 6 CH total, Choose 2 from: ECON 1300, ENR 2000, POLS 4051, POLS 4350, GEOL 3500, GEOL 3650, PETE 4000, ENR 4890 {Applied GIS or Econ Nat Resource))
One Math/Science Electives (min 3 CH total, select from department-approved list)
One Business Elective (min 3 CH, select from department-approved list)
Five Technical Electives (min 15 CH, Choose 5 from: PETE 2050, GEOL 4190, CE 3400, CE 4430, ME 3400, ME 3450, ME 4320, ME 4470, ME 4460, ESE 4330, ESE 4360, ESE 4380, ES 2800, ES 4455)
(See here for Math, Science and Business Elective options: http://www.uwyo.edu/ceas/academics/advising/_files/advfiles/me_math_science_business_electives.pdf)

Notes:

i) Before enrolling in any upper division ESE or ME course, students must complete the ME Success Curriculum (3.000 GPA in MATH 2200, MATH 2250, MATH 2210, and the seven ES courses).

ii) Graduates must meet all college requirements and earn a minimum GPA of 2.000 in ME courses taken atUW. A minimum of 48 hours are required, so ME, business, and technical electives should be chosen appropriately.

Energy Systems Engineering (ESE)

USP Codes are listed in brackets by the 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

3005 [2010; 2020]. Engineering Experimentation. 3. A combined lecture/laboratory course introducing students to experimental methods in the context of dynamics. Written technical communication, intermediate structured programming, experimental design, fundamental statistics, and uncertainty methods (numerical and analytical) are emphasized. Collaborative writing and teamwork is introduced. Cross listed with ME 3005. *Prerequisites:* Completion of the ME Success Curriculum, ES 1060; ES 2120; corequisite ME/ENGL 2005.

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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, CHEM 1020 and ES 2310. (Normally offered fall semester)

3060. Numerical Methods for Engineers. 3. Numerical solutions of problems commonly encountered in mechanical engineering including differentiation, integration, differential equations, system of linear and nonlinear equations, and optimization. The structured programming approach will be emphasized and applications from solid mechanics, thermal fluid sciences, materials science, and dynamic systems will be covered. Cross listed with ME 3060. *Prerequisites:* Completion of the ME Success Curriculum, ES 1060 and corequisite of MATH 2310.

3160 [2140; 2160]. Thermal/Fluid Science Lab. 3. A laboratory course to introduce students to experimental methods for temperature measure and pressure/flow characteristics of fluids. Continuation of experience with communication (written, oral, and digital), intermediate programming, experimental design, data analysis, and teamwork skills is emphasized. Cross listed with ME 3160. *Prerequisites:* Completion of the ME Success Curriculum, ES 2330; ME/ESE 3005.

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:* Completion of the ME Success Curriculum, MATH 2310, ES 2310 and ES 2330.

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:* Completion of the ME Success Curriculum, ESE 3040 and ESE 3360. (Normally offered fall semester)

4070. Energy Systems Design II. 3. [WC◀▶(none)] 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:* Completion of the ME Success Curriculum, ME/ESE 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:* Completion of the ME Success Curriculum, ME/ESE 3040 and ME/ARE/ESE 3360.

4455. Combustion Engineering. 3. The basic physics and chemistry of combustion engineering and its applications are covered, including thermodynamics, chemical kinetics, multicomponent conservation equations, laminar premixed and nonpremixed flames, detonations, droplet combustion, modern engines and energy systems. Cross-listed with ME 4455 and dual-listed with ME 5455. *Prerequisite:* Completion of the ME Success Curriculum, ME/ESE 3040 and ME/ARE/ESE 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:* Completion of the ME Success Curriculum, ESE 3360 or ME 3360 or 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:* Completion of the ME Success Curriculum, 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:* Completion of the ME Success Curriculum, ME/ESE 3005.

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing faculty research mentor. *Prerequisite:* junior or senior standing.

Department of Petroleum Engineering

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(307) 766-4258
Web site: www.uwyo.edu/petroleum
Department Head: Dennis Coon, Ph.D., Interim

Professors:

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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; Professor of Chemical Engineering 2015, 2008.

KHALED A.M. GASEM, B.Sc. University of California at Berkley 1976; M.Sc. Colorado School of Mines 1979; Ph.D. Oklahoma State University 1986; Professor of Chemical Engineering 2014.

MOHAMMAD PIRI, B.Sc. Azad University, Arak 1995; M.Sc. Azad University, Tehran 1998; M.Sc. Imperial College, London 2000; Ph.D. 2004; Professor of Petroleum Engineering 2017, 2005.

Associate Professor:

LAMIA GOUAL, B.Sc. Ecole Nationale Polytechnique 1993; M.Sc. Imperial College London 1998; Ph.D. 2003; Associate Professor of Chemical and Petroleum Engineering 2014, 2007.

Assistant Professors:

MORTEZA DEJAM, B.Sc. Petroleum University of Technology 2007; M.Sc. Sharif University of Technology 2009; Ph.D. University of Calgary 2016; Assistant Professor of Petroleum Engineering 2017.

PEJMAN TAHMASEBI, B.S. Sahand University of Technology 2007; M.Sc. Amirkabir University 2009; Ph.D. University of Southern California/Amirkabir University 2012; Assistant Professor of Petroleum Engineering 2016.

SOHEIL SARAJI, B.S. Petroleum University of Technology 2004; M.S. Sharif University of Technology 2007; Ph.D. University of Wyoming 2013; Assistant Professor of Petroleum Engineering 2016.

Professors of Practice:

DOUGLAS N. CUTHBERTSON, B.S. University of Wyoming 1985; Professor of Practice in Petroleum Engineering 2016

BRIAN TOELLE, B.S. Texas A&M University 1978; M.S. Austin State University 1981; Ph.D. West Virginia University 2013; Professor of Practice in Petroleum Engineering 2015.

Associate Lecturer:

TAWFIK ELSHEHABI, B.Sc. Suez Canal University 2003; M.Sc. 2008; Ph.D. West Virginia University 2017; Associate Lecturer 2017.

Professors Emeriti:

Jack Evers
H. Gordon Harris
Norman R. Morrow
Mrityunjai P. Sharma
Brian Towler

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 must have a GPA of 2.000 in Petroleum Engineering (PETE) 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 advisor and department head. Courses must be chosen from a list provided by the department. Students must complete a minimum of 48 upper division (junior/senior) or graduate-level semester credit hours for this program.

Petroleum Engineering Program Educational Objectives

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

- Successfully practice the profession/ field of Petroleum Engineering or related discipline; and
- Demonstrate civic engagement and 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 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; and
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Petroleum Engineering Undergraduate Curriculum

*CHEM 1020. Gen Chemistry I. 4
CHEM 1030. Gen Chemistry II. 4
CHEM 2300. Intro Org Chem. 4
ES 2110. Statics. 3
ES 2120. Dynamics. 3
ES 2310. Thermodynamics. 3
ES 2330. Fluid Dynamics. 3
ES 2410. Mechanics of Materials. 3
*GEOL 1100. Physical Geology. 4
GEOL 4190. Petroleum Geology. 3
GEOL Technical Elective. 3
*MATH 2200. Calculus I. 4
MATH 2205. Calculus II. 4
MATH 2210. Calculus III. 4
MATH 2310. Appl Diff Eqns. 3
PHYS 1220. Eng Physics II. 4
PETE 1060. Intro PETE. 1
PETE 2050. Fund of PETE. 3
PETE 2060. PETE Computing. 3
PETE 3025. Heat/Mass Transfer. 3
PETE 3100. Rock & Fluids Lab. 2
PETE 3255. Basic Drilling Eng. 3
PETE 3015. Multicomp Thermo. 3
PETE 3200. Reservoir Eng. 3
PETE 3265. Drilling Fluids Lab. 3
PETE 3715. Production Eng. 3
PETE 3725. Well Bore Ops. 3
PETE 4320. Well Log Interp. 3
PETE 4225. Well Test Analysis. 3
PETE 4340. PETE Economics. 3
* PETE 4736. PETE Design. 4
PETE Technical Electives. 15

*Course meets USP requirement.

Undergraduate "Major Only" Courses

Upper division PETE core courses are restricted to petroleum engineering majors only.

Technical Electives Policy

The technical electives in the PETE curriculum can be used to complete a curriculum emphasis option or a minor. The number of credits of upper division courses must be satisfied, therefore, 13 elective credits must be 3000-level courses or higher.

Notes: Technical Electives must be selected with your advisor's documented approval.

Curriculum Emphasis

The Department of Petroleum Engineering has established curriculum emphases that could shape your interest further or acquire some useful transferable skills. A curriculum emphasis is not a minor or concentration and will not be stated on your diploma. If you choose to follow a curriculum emphasis option, you should discuss it with your academic advisor so they can assist you in planning your courses.

Petroleum Engineering offers the following curriculum emphasis options:

- Unconventional Reservoirs
- Chemical Engineering
- Mechanical Engineering
- Graduate School Preparation

Minimum Grade Requirements

A grade of C or better is required for the following courses:

- USP designated courses: FYS, COM1, COM2, COM3
- All Engineering Science (ES) courses
- MATH courses that are prerequisites to ES & PETE courses
- PETE 1060-Introduction to Petroleum Engineering Problem Solving
- PETE 2050-Fundamentals of Petroleum Engineering
- PETE 4736-Petroleum Engineering Design (COM3)

Academic Suspension

Students who have been academically suspended from UW twice are no longer eligible to enroll in PETE courses.

Repeating a Course

Students who fail a PETE class three times can no longer enroll in that class.

Transfer Credit Limit

To graduate with a degree in Petroleum Engineering from UW, students must successfully complete at least 20 credit hours of required PETE courses at UW.

1. Once a student has transferred to UW's Department of Petroleum Engineering from another institution, they may transfer no more than 9 additional credits from other institutions.
2. Non-transfer students may transfer up to 18 credits from other institutions.

BS/MS Quick Start Program

The BS/MS Quick Start program in Petroleum Engineering (PETE) 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 Petroleum 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 Petroleum Engineering degree. Students who enter the Quick Start program must accept primary responsibility for actively planning their Programs of Study to assure timely completion of their course work and research programs.

The Quick Start program contains two essential elements:

1. Qualified students may receive provisional admission to the Petroleum 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.
2. Students in the program may apply up to 6 credit hours of 5000-level courses toward both the B.S. and M.S. degree programs. By completing successfully up to 6 credit hours of graduate classes during their senior year, these students will have demonstrated their ability to do graduate-level course work as undergraduates, easing their transition to the Petroleum Engineering graduate program.

For additional information, visit our website for admissions information http://www.uwyo.edu/petroleum/undergraduate/current-students/quickstart.html or contact our graduate admissions coordinator at pete-info@uwyo.edu.

Graduate Study

The Department of Petroleum Engineering offers graduate programs leading to the M.S. and Ph.D. degrees in petroleum engineering. The M.S. degree is offered with Plan A and Plan B options.

In addition, the Department offers an M.B.A./M.S. in Petroleum Engineering Dual Degree Program, in conjunction with the College of Business M.B.A. Program. Students pursuing this option must apply to and be offered admission from both programs.

Program Specific Admission Requirements

A. Admission Process and Requirements

Standard Admission

Admission is open to students with at least a B.S. degree in petroleum engineering who meet the minimum requirements:

1. A GPA of 3.000, or equivalent;

2. A GRE score;

3. A TOEFL score of 600 (paper-based), 250 (computer-based), or 80 (Internet based) or an IELTS score of 6.5 in each category for international applicants.

Complete official transcripts of all prior college-level coursework, current resume or curriculum vitae, recommendations from three references, and a statement of purpose must be uploaded as parts of the application.

The deadline to submit applications is February 1 each year (to be considered for Fall semester), and September 15 each year (to be considered for Spring semester).

Applications will not be processed until all required documents have been submitted.

B. Graduate Courses of Study

Incoming graduate students, not preselected by a faculty member, must meet with Petroleum faculty members to obtain information regarding research areas and current availability. The students must formally request a Petroleum faculty member of their choosing to oversee their degree study program.

Masters Program

1. All Petroleum M.S. students with a B.S. in Petroleum Engineering from an accredited program must take the following required courses:

Required Courses		**Hrs.**
PETE	5355	3
PETE	5890	2

At least three Core Courses from the following:

PETE	5010	3
PETE	5020	3
PETE	5060	3
PETE	5080	3
PETE	5310	3
PETE	5350	3
	Total Credits	**14**

Plan A Thesis Additional Course Requirements:

4000-level or above approved electives		12
PETE	5960	4
	Total Credits	**30**

Plan B Non-Thesis Additional Course Requirements:

4000-level or above approved electives		14
PETE	5100 or 5970	2
	Total Credits	**30**

2. All Petroleum M.S. students with a B.S. in Chemical or Mechanical Engineering from an accredited program must take the following required courses:

Required Courses:

PETE	5340	3
PETE	5055	3
PETE	5715	3

At least four Core Courses from the following:

PETE	5010	3
PETE	5020	3
PETE	5060	3
PETE	5080	3
PETE	5310	3
PETE	5350	3
	Total Credits	**26**

Plan A Thesis Additional Course Requirements:

4000-level or above approved electives		7
GEOL	4190	3
PETE	5960	4

Total Credits **40**

Plan B Non-Thesis Additional Course Requirements:

4000-level or above approved electives.....9
GEOL 4190.....3
PETE 5100 or 5970.....2
Total Credits **40**

Dual Degree Program - M.B.A./M.S. degree in Petroleum Engineering

3. All Dual Degree M.S. students with a B.S. in Petroleum Engineering from an accredited program must take the following required courses:

Required Courses **Hrs.**
PETE 5355.....3
PETE 5890.....2

At least three Core Courses from the following:
PETE 5010.....3
PETE 5020.....3
PETE 5060.....3
PETE 5080.....3
PETE 5310.....3
PETE 5350.....3
Total Credits **14**

Plan A Thesis Additional Course Requirements:

4000-level or above approved electives.....3
M.B.A. approved electives, MBAM 5XXX, MBAM 5301, MBAM 5305.....9
PETE 5960.....4
Total Credits **30**

Plan B Non-Thesis Additional Course Requirements:

4000-level or above approved electives.....5
M.B.A. approved electives, MBAM 5XXX, MBAM 5301, MBAM 5305.....9
PETE 5100 or 5970.....2
Total Credits **30**

4. All Dual Degree students with a B.S. in Chemical or Mechanical Engineering from an accredited program must take the following required courses:

Required Courses:
PETE 5340.....3
PETE 5055.....3
PETE 5715.....3
PETE 5355.....3
PETE 5890.....2

At least four Core Courses from the following:
PETE 5010.....3
PETE 5020.....3
PETE 5060.....3
PETE 5080.....3
PETE 5310.....3
PETE 5350.....3
Total Credits **26**

Plan A Thesis Additional Course Requirements:

GEOL 4190.....3
M.B.A. approved electives, MBAM 5XXX, MBAM 5301, MBAM 5305.....9
PETE 5960.....4
Total Credits **42**

Plan B Non-Thesis Additional Course Requirements:

4000-level or above approved electives.....2
GEOL 4190.....3
M.B.A. approved electives, MBAM 5XXX, MBAM 5301, MBAM 5305.....9
PETE 5100 or 5970.....2
Total Credits **42**

Note: For a student with a B.S. in another discipline, upon acceptance into the M.S. program, the Graduate Program Committee will develop a plan of study with the consent of the advisor.

Doctoral Program

1. All Petroleum Ph.D. students with a B.S. in Petroleum Engineering must take the following required courses:

Required Courses
PETE 5090.....3
PETE 5355.....3
PETE 5890.....6

At least three Core Courses from the following:
PETE 5010.....3
PETE 5020.....3
PETE 5060.....3
PETE 5080.....3
PETE 5310.....3

Electives
4000-level or above approved electives..... 21

Research
PETE 5980..... 30
Total Credits **72**

2. All Petroleum Ph.D. students with an M.S. in Petroleum Engineering from UW must take the following required courses:

Plan A MS Courses..... **26**

Required Courses
PETE 5090.....3
PETE 5890.....4

Electives
4000-level or above approved electives.....9

Research
PETE 5980..... 30
Total Credits **72**

3. All Petroleum Ph.D. students with an M.S. in Petroleum Engineering from another institution must take the following required courses:

Transferred MS Courses approved by student's committee.....**14**

Required Courses
PETE 5090.....3
PETE 5890.....4

At least four Core Courses from the following:*
PETE 5010.....3
PETE 5020.....3
PETE 5060.....3
PETE 5080.....3
PETE 5310.....3
PETE 5350.....3
PETE 5355.....3

Electives
4000-level or above approved electives.....9

Research
PETE 5980..... 30
Total Credits **72**

*Some or all of these credit hours can be transferred by petition, provided they are non-degree credits.

4. All Petroleum Ph.D. students with an M.S. degree in a geoscience from another accredited institution must take the following required courses:

Transferred MS Courses approved by student's committee.....**12**

Required Courses
PETE 5090.....3
PETE 5890.....4

At least six Core Courses from the following:*
PETE 5010.....3
PETE 5020.....3
PETE 5060.....3
PETE 5080.....3
PETE 5310.....3
PETE 5350.....3
PETE 5355.....3

At least eight additional courses:
Six (6) credits in advanced mathematics.....6
and 18 credits in petroleum engineering, including PETE 5340, PETE 5055, PETE 5715 18

Electives
4000-level or above approved electives.....9

Research

PETE 5980 30

Total Credits 100

*Some or all of these credit hours can be transferred by petition, provided they are non-degree credits.

Graduate Seminar Requirements

All petroleum engineering graduate students must enroll in PETE 5890, Petroleum Engineering Seminar, every semester. All seminars, including the required presentations described below, must be scheduled by the seminar coordinator. Graduate students enrolled in continuous registration are exempt from having to enroll in PETE 5890 in their final semester.

Graduate Teaching Requirement

All Petroleum Engineering graduate students must complete at least one semester as a teaching assistant within the Petroleum Engineering curriculum. Students receiving a state-funded graduate assistantship will be required to serve as a teaching assistant every semester of their award. Students funded by a faculty mentor will work with their mentor to determine an appropriate time to complete this requirement.

Program of Study Requirement

All Petroleum Engineering graduate students must complete their Program of Study worksheet at the beginning of their second academic year of study or 3rd semester of enrollment, and PhD students must submit it prior to their preliminary examination.

Ph.D. Preliminary Examination

Candidacy in the doctorate occurs upon certification of successful completion of the preliminary examination. The preliminary examination will be held at least 15 weeks prior to the final examination. The preliminary examination may not be given before: (a) the research tool requirements, if any, have been met and certification approved; (b) at least 30 hours of coursework have been completed; and (c) the doctoral program of study has been approved.

The goal of the preliminary exam is for the student to present the research proposition that is being investigated and will lead to the final dissertation, and demonstrate progress to-date. The preliminary exam consists of three components:

- a written document provided to each member of the student's graduate committee at least three weeks 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 an option to conditionally pass the student while requiring an interim committee meeting prior to the final Ph.D. examination. The Report on Preliminary Examination for Admission to Candidacy form sent to the Office of the Registrar reports the results of the examination.

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

All M.S. and Ph.D. students must orally defend their final report, 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 defense in oral presentation format. At least three weeks before the examination, the student must provide each member of the graduate committee with a copy of the written thesis or dissertation and provide the department an announcement of their defense for public advertisement. The results of the defense are reported by the committee on the Report of Final Examination form. Often, graduate committee members request changes in the final thesis or dissertation, and they may postpone signing this 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 Registrar's web site. This copy will be rejected if the format standards specified by the Thesis or Dissertation Format Guide are not met. This guide allows for a publication-ready format. An electronic copy must also be submitted to the department for the departmental library. Most students will want copies for their own use. Students should consult with their chair to determine if they also want a copy of the final paper or other research documentation.

Petroleum Engineering (PETE)

USP Codes are listed in brackets by the 2003 USP code followed by the 2015 USP code (e.g. [QB◀▶Q]).

1060. Introduction to Petroleum Engineering Problem Solving. 1. Covers elements of Petroleum Engineering calculations associated with typical computations in Drilling, Production, and Reservoir Engineering, Rock and Fluids properties, to simultaneously train the student on basic computing skills as well as basic language of Petroleum Engineering. The preferred computing tool is Matlab, which will be introduced through simple calculations on the computer. Notions of the petroleum engineering curriculum will also be provided through examples of the different subjects. *Prerequisite:* Math placement 5 or concurrent enrollment in MATH 2200.

2050 [3000]. Fundamentals of Petroleum Engineering. 3. General introduction to petroleum engineering, including petroleum geology, exploration, reservoir rocks, and fluid flow through porous media, drilling fundamentals, completion technology, well logging and testing, methods of production, stimulation methods, enhanced oil recovery, reserves and economics. *Prerequisites:* grade of C or better in both MATH 2205 and PETE 1060.

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:* C or better in PETE 1060, and either a D or better in MATH 2310 or concurrent enrollment in MATH 2310.

3015 [3010]. Multicomponent Thermodynamics. 3. Introduces mixture properties, such as chemical potentials, excess proper-

ties, 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. *Prerequisite*: C or better in ES 2310 and concurrent enrollment in PETE 2060. Students must be a Petroleum Engineering major. (Normally offered fall semester)

3025. Heat and Mass Transfer. 3. Introduces energy and mass transfer concepts and the development of mathematical models of physical phenomena, including convection, conduction, radiation, and mass diffusion and convection. *Prerequisites:* C or better in ES 2330 and MATH 2310. Student must be a Petroleum Engineering major.

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:* C or better in PETE 2050. Students must be a Petroleum Engineering major.

3200 [4010]. Reservoir Engineering. 3. Covers rock and fluid properties, reserve estimation using volumetric and material balance methods, discussion of different reservoir drive mechanisms, aquifer models, Darcy's law and single-phase flow through porous media, introduction to well testing, solution of radial diffusivity equation, immiscible displacement, decline rate analysis, and reservoir simulation. *Prerequisites:* PETE 3025, C or better in PETE 2050. Students must be a Petroleum Engineering major. (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:* C or better in PETE 2050. Student must be a Petroleum Engineering major.

3265. Drilling Fluids Laboratory. 3. Measurement of physical and chemical properties of drilling fluids, including experiments on mud density control, viscosity control, theological properties, mud hydraulics, filtration properties, mud contaminants and their treatments. Includes design of experiments, data processing, interpretation and writing technical reports. *Prerequisites:* PETE 3255, C or better in both ES 2310 and ES 2330. Students must be a Petroleum Engineering major.

3715. Production Engineering. 3. Provides elements for calculating the production rate of oil or gas wells, including reservoir inflow performance, which is determined by the reservoir rock and fluids properties and calculated based on Darcy's law, and tubing performance, which is determined by tubing parameters and calculated based on Newtonian dynamics. Basic design of artificial lift systems, reservoir stimulations and optimization of production systems are also included. *Prerequisites:* C or better in ES 2310, ES 2330 and PETE 2050. Students must be a Petroleum Engineering major.

3725. Well Completions. 3. Covers many facets of completion and intervention in oil and gas wells, including design and procedures to meet deliverability, safety, and integrity, starting with completion, stimulation, workover, and intervention, ending with plug and abandonment requirements. *Prerequisites:* C or better in both PETE 2050 and ES 2410. Students must be a Petroleum Engineering major.

3890. Engineering Honors Program Research Methods. 3. A general approach to scientific research and graduate school preparation. Topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem and developing a research methodology, writing a research funding proposal, delivering a research presentation and selecting and applying for graduate school. Restricted to College of Engineering Honors Program students. Cross listed with ARE/ATSC/CE/CHE/COSC/EE/ES 3890. *Prerequisite:* sophomore standing.

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. Requires a written research proposal to be approved by instructor prior to course start. *Prerequisites:* junior standing as a petroleum engineering major and consent of instructor.

4000. Environment, Technology and Society. 3. 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 lab sciences.

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. 3. Covers knowledge of well test interpretation techniques. Theory for well testing include drawdown and buildup tests, single-rate and multi-rate testing, derivative analysis, wellbore storage, type curve matching, fall off and injectivity, fractured wells, fractured reservoirs, interference and pulse testing, and horizontal well analysis. *Prerequisite:* PETE 3200. Students must be a Petroleum Engineering major.

4300. 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 5300. *Prerequisites:* PETE 3200, MATH 2210, MATH 4440.

4310. 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 5310. *Prerequisite:* PETE 3200.

4320. Well Log Interpretation. 3. Studies use of various types of open hole logs for quantitative evaluation of formations. *Prerequisite:* C or better in PETE 2050. Students must be a Petroleum Engineering major. (Normally offered spring semester)

4330. Geostatistics and Subsurface Characterization. 3. An advanced skills course about subsurface modeling using diverse data (e.g. well data, seismic info, etc.), including model development, techniques, and practical applications. Students must have basic knowledge of mathematical and statistical modeling. Dual listed with PETE 5320. *Prerequisite:* Junior standing and PETE 3200 or consent of instructor.

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. Students must be a Petroleum Engineering major. (Normally offered fall semester)

4400. Tight Gas Sand/Coalbed Methane. 3. This course provides information needed to understand geoscience and engineering considerations concerning the development of Fractured, Tight Gas Sands and Coalbed Methane reservoirs. Subjects include the origin and accumulation of hydrocarbons within these reservoirs, and the tools, methods and workflows used for locating, characterizing, and developing these reservoir types. Dual listed with PETE 5400. *Prerequisites:* PETE 3200; student must be a Petroleum Engineering major.

4450.

4580. Honors Undergraduate Research. 3. An independent research experience for undergraduate students enrolled in the Engineering Honors Program. Before registering for this class, students are responsible for discussing their interests with faculty, identifying a willing research mentor, obtaining approval by said mentor, and communicating the student/faculty partnership tot he appropriate staff in their home department. Must be in the Engineering Honors Program. Cross listed with ATSC/BE/CE/CHE/COSC/ES/ESE 4580. *Prerequisite:* junior or senior standing.

4736. Petroleum Engineering Design. 3. [(none)◆▸COM3] 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. *Prerequisites:* PETE 3200, PETE 3255, PETE 3715, PETE 3725, and C or better in COM2. Students must be a Petroleum Engineering major.

4800 [4850]. Shale Reservoir Development. 3. Provides an overview of the geoscience and engineering aspects involved in the exploration and development of shale reservoirs. Topics covered include organic geochemistry, geomechanics, petrophysics, geophysics, reservoir and completion engineering, and drilling. The primary phases involved in obtaining hydrocarbon production from shale reservoirs are detailed. Dual listed with PETE 5800. *Prerequisites:* C or better in both PETE 2050 and PETE 3200.

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:* 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.

4860. Energy, Environment, and Materials. 3. Understanding the connection between materials, energy and environment, including the history of climate and different types of energy in use for a greener planet. Provides broad knowledge in the areas of energy, material science, chemical, petroleum, and environmental engineering. Dual listed with PETE 5860. *Prerequisite:* Junior standing and PETE 2050 or consent of instructor.

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. Requires a written project proposal to be approved by instructor prior to course start. *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. *Prerequisite:* Student must be a Petroleum Engineering major.

5010. Transport Phenomena. 3. Examines the modeling of momentum, heat and mass transport. Cross listed with CHE 5010. *Prerequisite:* graduate standing.

5020. Thermodynamics. 3. Utilizing the laws of thermodynamics to a wide variety of process applications. Evaluating current methods for predicting thermodynamic properties of pure fluids and mixtures. Modeling multiphase, multicomponent equilibria. Cross listed with CHE 5020. *Prerequisite:* graduate standing.

5055.

5060. Flow through 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:* 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. *Prerequisite:* graduate standing or consent of instructor.

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. *Prerequisite:* graduate standing.

5090. Research Methods. 2. A general approach to scientific research and graduate school. Topics include: purpose of graduate school, career options with graduate degrees, communication basics, literature search skills, presentations, research instrumentation, the scientific method, developing hypotheses, grant proposals, paper writing, research ethics, copyrights, patents, research notebooks, and classroom teaching techniques. *Prerequisite:* graduate standing.

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

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. *Prerequisite:* graduate standing.

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. *Prerequisite:* graduate standing.

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:* graduate standing.

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:* graduate standing.

5320. Geostatistical/Subsurface Characterization. 3. Providing practical way for building realistic subsurface models. Students must have basic knowledge of mathematical and statistical modeling. Both fundamental and practical aspects are covered. Students will be able to take real data derived from subsurface modeling and build geostatistical models, which will be performed deterministically and stochastically. *Prerequisite:* graduate standing.

5320.

5340.

5350. Advanced Reservoir Engineering. 3. Covers high-level understanding of modern reservoir engineering. Provides knowledge of scientific principles to formulate fluid flow, heat and mass transport in permeable media. Use analytical and computational tools to resolve research-oriented problems. Develop competence in interpreting results of modeling. *Prerequisite:* graduate standing.

5355. Mathematical Methods. 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. *Prerequisite:* graduate standing.

5400. Tight Gas Sand/Coalbed Methane. 3. This course provides information needed to understand geoscience and engineering considerations concerning the development of Fractured, Tight Gas Sands and Coalbed Methane reservoirs. Subjects include the origin and accumulation of hydrocarbons within these reservoirs, and the tools, methods and workflows used for locating, characterizing, and developing these reservoir types. Dual listed with PETE 4400. *Prerequisites:* graduate standing.

5450.

5715. Production Engineering. 3. Provides elements for calculating production rate of oil/gas wells, including reservoir inflow performance, determined by reservoir rock and fluids properties using Darcy's law, and tubing performance, determined by tubing parameters and using Newtonian dynamics. Basic design of artificial life systems, reservoir stimulations and optimization of production systems are included. *Prerequisite:* graduate standing.

5800. Shale Reservoir Development. 3. Provides an overview of the geoscience and engineering aspects involved in the exploration and development of shale reservoirs. Topics covered include organic geochemistry, geomechanics, petrophysics, geophysics, reservoir and completion engineering, and drilling. The primary phases involved in obtaining hydrocarbon production from shale reservoirs are detailed. Dual listed with PETE 4850. *Prerequisite:* graduate standing.

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 standing 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:* graduate standing or consent of instructor.

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. *Prerequisites:* PETE 5310 and graduate standing or consent of instructor.

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:* graduate standing.

5860. Energy, Environment, and Materials. 3. Understanding the connection between materials, energy and environment, including the history of climate and different types of energy in use for a greener planet. Provides broad knowledge in the areas of energy, material science, chemical, petroleum, and environmental engineering. Dual listed with PETE 4860. *Prerequisite:* graduate standing.

5890. Petroleum Engineering Graduate Seminar. 1 (Max. 9). Departmental seminar on current research with formal training for student presentation of technical papers. *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). 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.