College of Engineering

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College of Engineering (CoE)

Founded in 1889, our college endeavors to create solutions that promote strong economies, healthy people, and a sustainable natural environment. Our program has a long history of graduating world-class engineers who have made major impacts on civilization through significant contributions in science and technology. Alumni achievements include breakthrough innovations such as the first artificial heart valve, the computer mouse, and the concept of email.

By emphasizing authentic, experiential engineering experiences within our curriculum, we equip students with the knowledge, skills, and passion to advance innovative solutions to today’s most complex engineering challenges. Through nearly 30 unique degree programs at the graduate and undergraduate level, we produce top-notch engineers who are grounded in integrity, ingenuity, and a keen understanding of the interrelatedness of global economies, cultures, and natural systems. Our faculty collaborates across disciplines to leverage synergies in teaching, research, and innovation. And we cultivate strategic partnerships to turn research results into new companies and products that create jobs while helping people to lead better lives.

The College of Engineering offers degrees in engineering, computer science, construction engineering management, energy systems engineering, and radiation health physics. Students may choose engineering majors from biological, chemical, civil, ecological, electrical and computer, environmental, industrial, manufacturing, mechanical, and nuclear engineering. Educational preparation for land surveying, a licensed profession in all states, is offered through civil engineering. Forest engineering is offered by the College of Forestry.

The Engineering Profession

Engineering is the profession in which knowledge of the mathematical and natural sciences gained through education and practice is applied with judgment to develop ways to economically utilize the materials and forces of nature for the benefit of humankind. It is a licensed profession in all of the states of the USA, and educational programs must meet high professional standards. Engineers are not only responsible for planning, designing, manufacturing, construction, and management, but also for the safety and welfare of the public that relies on their work.

Mission and Goals

The college’s undergraduate educational mission is to provide high quality engineering programs that prepare students for successful careers, lifelong learning, and service to their profession and society. OSU engineering graduates will be known for their technical competence and creativity; for their ability to apply, adapt, and extend their knowledge to solve a wide variety of problems; and for their effective communication skills. Their education will provide them with an understanding of the ways in which the humanities, social sciences, basic sciences, and technology interact to affect society. These programs will foster an environment that stimulates learning and promotes diversity.

The college’s undergraduate programs have four goals:

1. Educate students thoroughly in mathematics, basic science and engineering sciences relevant to their discipline’s professional work, including fundamental concepts, experimental techniques, methods of analysis, and computational applications.
2. Develop the ability of students to communicate effectively and to work collaboratively in diverse team environments.
3. Develop in students an awareness of the historical evolution of knowledge and technical applications, the state of current professional practice, their need for lifelong learning, contemporary issues, and the impact of engineering actions and solutions in a societal and global context; and to develop an understanding of their professional and ethical responsibilities.
4. Develop the ability of students to formulate and solve problems, to integrate and synthesize knowledge, and to think creatively, leading to the capability to analyze and design components, processes, or systems; plan and carry out experiments effectively; and troubleshoot and modify processes and systems.

Preparing for an Engineering Career

To prepare for the practice of engineering, students complete an accredited program of study leading to a bachelor of science degree in an established engineering field. Most engineering curricula require 180 credits; exceptions include programs in chemical, ecological, environmental and bioengineering. All programs include a balance of course work in mathematics, science, liberal arts, engineering science, and engineering design.

Upon graduation, engineering students are eligible to take the Fundamentals of Engineering Examination of the State Board of Engineering Examiners in any state. After passing the examination and completing four years of progressively responsible engineering
work, graduates are eligible to take the professional engineering license examination of the state in which they intend to practice.

Although some fields of industrial and government employment do not require formal professional licensure, the educational preparation for the bachelor’s degree is a necessity for virtually all such employment.

Preparation for the professional practice of land surveying follows a pattern of education, experience, examination, and professional licensure similar to that required for professional engineering practice.

Students completing the BS in Radiation Health Physics degree will be eligible to take part I of the Certified Health Physics (CHP) Examination of the American Board of Health Physics after one year of applied health physics practice. After six years of responsible professional experience in health physics, graduates will be eligible to take part II of the CHP examination.

Admission Requirements
Admission to the college requires that students meet general university admission requirements, as published in the OSU Academic Catalog. Students are assigned to the department or school of their choice after their first year for advising and program planning. Information on policies and programs is available from the College of Engineering.

FOREST ENGINEERING
See College of Forestry. Also see College of Forestry for information on the Forest Engineering-Civil Engineering (http://catalog.oregonstate.edu/college-departments/forestry/forest-engineering-resources-management/forest-engineering-civil-engineering-bs-hbs/) program.

GENERAL ENGINEERING
The first year of the General Engineering curriculum meets the requirements of all engineering curricula except bioengineering, chemical engineering, environmental engineering, and ecological engineering, which require a different chemistry sequence. To meet requirements for bioengineering, chemical engineering, environmental engineering, and ecological engineering, CH 201 and CH 202 may be substituted for CH 231/CH 261, CH 232/CH 262 and CH 233/CH 263. Students who have not decided upon a major prior to enrolling are encouraged to register for General Engineering.

CURRICULUM
The General Engineering curriculum below will prepare students to enter many of the engineering programs. Students may transfer into any program at any time during the first year; they must transfer by the end of the year.

General Engineering (One-year Program, Major Code: 827)

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td></td>
<td>First Year</td>
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<tr>
<td>CH 201</td>
<td>CHEMISTRY FOR ENGINEERING MAJORS</td>
<td>6</td>
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<tr>
<td>&amp; CH 202</td>
<td>and CHEMISTRY FOR ENGINEERING MAJORS</td>
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<tr>
<td>COMM 111</td>
<td>*PUBLIC SPEAKING</td>
<td>3</td>
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<tr>
<td>or COMM 114</td>
<td>*ARGUMENT AND CRITICAL DISCOURSE</td>
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<tr>
<td>ENGR 111</td>
<td>ENGINEERING ORIENTATION I</td>
<td>3</td>
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<tr>
<td>ENGR 112</td>
<td>INTRODUCTION TO ENGINEERING COMPUTING</td>
<td>3</td>
</tr>
<tr>
<td>HHS 231</td>
<td>*LIFETIME FITNESS FOR HEALTH</td>
<td>2</td>
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<tr>
<td>HHS 241</td>
<td>*LIFETIME FITNESS (or any PAC course)</td>
<td>1-2</td>
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<tr>
<td>MTH 251</td>
<td>*DIFFERENTIAL CALCULUS</td>
<td>4</td>
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MTH 252  INTEGRAL CALCULUS  4
MTH 254  VECTOR CALCULUS I  4
PH 211  *GENERAL PHYSICS WITH CALCULUS  4
WR 121  *ENGLISH COMPOSITION  3

Total Credits 50-51

* Baccalaureate Core Course

1 Must be selected to satisfy the requirements of the baccalaureate core

College of Engineering Grading and GPA Requirements
All technical, writing and communications courses must be taken for letter grades (A through F). C or better grades are passing.

SATISFACTORY ACADEMIC PROGRESS FOR ENGINEERING STUDENTS
A student in good academic standing satisfies university, college, and program academic requirements. The university may change a student’s status to warning, probation, or suspension following guidelines contained in the Schedule of Classes. The College of Engineering has a similar, but independent, process.

At the conclusion of each term, term and cumulative GPA are calculated and academic standings are determined for students according to the criteria outlined below. Students whose standings evidence a lack of satisfactory progress will be warned of this condition and advised to seek help from their academic advisors. Students who fail to improve may be removed from the college.

1. COE Warning: Students with either an OSU term GPA below 2.5 or an OSU term completion percentage below 65% will be placed on College of Engineering Warning. Students must meet with their academic program advisor before they can register for subsequent terms.

2. COE Probation: Students who are on College of Engineering Warning, and have attempted 24 or more credits at OSU, and either have an OSU cumulative GPA below 2.5 or an OSU cumulative completion percentage below 65%, will be placed on College of Engineering Probation. Students must meet with their program advisor and complete an Academic Success Agreement before they can register for subsequent terms. To get off COE Probation, the student will need to meet the terms of the academic success agreement.

3. COE Suspension: Students who are on College of Engineering Probation and have a subsequent term of OSU term GPA below 2.5, or have a subsequent OSU term completion percentage below 65% will be suspended from the College of Engineering (removed from their major), and unable to take major restricted courses in the College.

4. Reinstatement to the College: Suspended students may be reinstated to the program after one year, or completion of a minimum of 24 quarter credits of acceptable transferable college-level work at an accredited college or university, with a GPA of 2.5 or above. These 24 credits must be pre-approved in writing by the program head advisor. Students reinstated to the program who are subsequently suspended may only apply for reinstatement under the ‘one year’ option.

Reinstatement requests from students will be considered by the College Committee on Reinstatement (CCR) made up of three College of Engineering school advisors and college head advisor (or their
designee). Reinstatement guidelines are available electronically in the College of Engineering Undergraduate Policy Manual (http://engineering.oregonstate.edu/undergraduate-policy-manual/).

**Graduation Requirements**

To graduate with a baccalaureate degree in any of the engineering or computer science majors, a student must complete 180 credits; exceptions include programs in chemical, environmental, ecological, and bioengineering, which require 192 credits. In addition, students must have a minimum 2.5 institutional GPA and minimum 2.5 GPA in all required and elective classes in their chosen major. A student must also meet all university degree requirements published each year in the Academic Regulations (http://catalog.oregonstate.edu/regulations/).

**Academic Dishonesty Policy**

Students that violate the academic honesty policy a second time will be suspended from the College of Engineering for a period of one year.

**Aeronautical & Astronautical Engineering (AAE)**

**AAE 210, INTRODUCTION TO AEROSPACE ENGINEERING, 3 Credits**

Topics will include the engineering fundamentals of aeronautics and astronautics, including an introduction to aerodynamics, propulsion, structures, orbital mechanics and mission planning. Current industry practices in aerospace vehicle specifications, manufacturing, flight testing and certification will be presented.

**Prerequisite:** ENGR 211 with C or better

**AAE 411, AEROSPACE APPLICATIONS IN MECHANICAL ENGINEERING, 4 Credits**

Explores the fundamentals of mechanical engineering applications to aerospace. Features an overview of modern aircraft and spacecraft analysis, with an emphasis on performance, stability, structures, materials, FAA and FAR standards. Applies current professional practices in the conceptual design of aerospace vehicles.

**Prerequisite:** ME 316 (may be taken concurrently) with C- or better

**Equivalent to:** ME 411

**Recommended:** ME 311

**AAE 412, SPACE SYSTEMS ENGINEERING, 4 Credits**

Introduction to space systems engineering. Topics will include the fundamentals of astronautics, orbital mechanics and trajectory design, flight dynamics, guidance and navigation, stability and control of spacecraft. Rocket propulsion concepts, including chemical rockets (liquid, gas and solid propellants), hybrid rocket engines and modern advances in satellite power systems will be discussed. Current design practices in space systems engineering will be emphasized.

**Prerequisite:** (ME 373 [C] or ME 373H [C]) and (ME 317 [C] or ME 317H [C])

**Recommended:** (ME 373 or ME 373H) and (ME 317 or ME 317H)

**AAE 413, AERO VEHICLES COMPONENTS DESIGN, 4 Credits**

Develop mechanical design of aircraft subcomponents. Analyze and model aircraft components and evaluate their integration on aircraft. Apply real-world aircraft component design project with associated deliverables to customer, including basic requirements for Federal Aviation Administration (FAA) certification.

**Prerequisite:** ME 316 with C or better and ME 317 [C] and ME 331 [C] and ME 373 [C]

**AAE 415, UAV ENGINEERING, 4 Credits**

Develop a strong foundation in Unmanned Aerial Vehicles (UAV) systems technologies. Engineering evaluation of UAV systems, subcomponents, aircraft missions, operations and Federal Aviation Administration (FAA) requirements. Apply actual UAV models and subsystems to a real-world project on UAV deployment for humanitarian and environmental missions. Write a technical report as a team-project, developing and demonstrating critical thinking and engineering reporting skills in the subject. CROSSTLISTED as AAE 415/HEST 415.

**Prerequisite:** ME 316 with C or better and ME 317 [C] and ME 331 [C] and ME 373 [C]

**Equivalent to:** HEST 415

**Architectural Engineering (ARE)**

**ARE 301, ARE JUNIOR SEMINAR, 1 Credit**

Professional practices of architectural engineering.

**ARE 352, DESIGN OF ELECTRICAL AND ILLUMINATION SYSTEMS FOR BUILDINGS, 0-4 Credits**

Design of electrical and illumination systems in buildings, including consideration of energy usage.

**Prerequisite:** CEM 471 with C or better

**ARE 353, DESIGN OF HVAC SYSTEMS FOR BUILDINGS, 4 Credits**

Design and engineering of heating, ventilating, and air conditioning (HVAC) systems in buildings, including consideration of energy usage and indoor environmental conditions.

**Prerequisite:** CEM 472 with C or better
ARE 418, ^ARCHITECTURAL ENGINEERING PROFESSIONAL PRACTICE, 4 Credits
Principles and methods of solving architectural engineering problems in a studio setting, with considerations of space, form, function, and technology. Lec/rec. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: ARE 351 with C or better and ARE 352 [C] and CE 382 [C]

ARE 419, ^ARCHITECTURAL ENGINEERING DESIGN, 3 Credits
A capstone design project experience exposing students to problems and issues similar to those encountered in the practice of architectural engineering. Use of Building Information Modeling (BIM) in design, construction management, and integration of architectural, structural, mechanical, electrical and lighting systems. Lec/rec. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: ARE 418 with C or better

ARE 451, ADVANCED BUILDING CONSTRUCTION METHODS, 4 Credits
Advanced building construction methods, including integration of building components in building envelopes. Lec/rec.
Prerequisite: CEM 442 with C or better

ARE 499, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

ARE 501, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ARE 503, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ARE 506, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ARE 599, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

ARE 601, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ARE 603, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ARE 699, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

Biological & Ecological Engineering (BEE)

BEE 101, ECOLOGICAL ENGINEERING I, 3 Credits
Introduction to engineering at OSU and the field of ecological engineering. Topics include engineering analysis and problem solving, professional ethics, the design process and teamwork.
Recommended: MTH 112

BEE 102, ECOLOGICAL ENGINEERING II, 3 Credits
Introduction to common problems and solutions in ecological engineering, emphasizing the multiplicity of approaches to constraining, analyzing, and resolving challenges of ecosystem management. Two overnight field trips to local ecological monitoring and engineering sites will be required.

BEE 103, ECOLOGICAL ENGINEERING III, 3 Credits
Programming hardware/software for sensing and control with applications in Ecological Engineering. Introduction to computational thinking strategies.

BEE 199, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

BEE 221, FUNDAMENTALS OF ECOLOGICAL ENGINEERING, 3 Credits
Introduction to the concepts and practice of ecological engineering. Covers chemical behavior and cycling in the environment, chemical kinetics, and unit processes of conventional treatment systems. Topics are applied to develop ecological treatment alternatives that meet the needs of human societies.

BEE 222, ECOLOGICAL ENGINEERING COMPUTATION, 2 Credits
Develops programming skills in Python, including basic programming tasks, data analysis, data visualization, and optimization, with applications in Ecological Engineering. Builds computational thinking skills.

BEE 270, ECOLOGY FOR ENGINEERS, 3 Credits
The study of ecology in the context of engineering. Develops an understanding of the patterns associated with species distribution in the natural world. Examines the theories of competition, predation, disease and mutualism that help explain the functioning of biological communities. Discusses interactions between abiotic and organismal factors, the environment, and ecological properties and processes.

BEE 299, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

BEE 311, ECOLOGICAL FLUID MECHANICS, 4 Credits
Fluid properties, fluid statics, fluid motion, conservation of mass, momentum and energy for incompressible fluids, dimensional analysis, ecological engineering applications. Lec/rec.
Prerequisite: (PH 212 with C or better or PH 212H with C or better) and (MTH 254 [C] or MTH 254H [C]) and (ENGR 211 [C] or ENGR 211H [C])

BEE 312, ECOHYDRAULICS, 4 Credits
Theory and design of hydraulic systems for ecological engineering applications. Lec/rec.
Prerequisite: BEE 311 with C or better or CE 311 with C or better or CHE 331 with C or better or CHE 331H with C or better
BEE 313, ECOHYDROLOGY, 4 Credits
Provides a quantitative description of fundamental ecohydrologic processes, the interactions of between water and the atmosphere, soils, and plants, as well as techniques for estimating the movement of water in the though ecosystems.
Prerequisite: BEE 312 with C or better and BEE 320 [C]

BEE 320, BIOSYSTEMS ANALYSIS AND MODELING, 4 Credits
An introduction to simulation modeling and analysis of a variety of biological and ecological systems. Systems approaches to describing ecological systems.
Prerequisite: BEE 222 with C or better and (MTH 256 [C] or MTH 256H [C])
Recommended: MTH 256

BEE 322, ECOLOGICAL ENGINEERING THERMODYNAMICS AND TRANSFER PROCESS, 4 Credits
A study of the transport processes of fluid flow, heat transfer and mass transfer applied to biological organisms and ecological systems.
Prerequisite: BEE 320 with C or better

BEE 361, ECOLOGICAL ENGINEERING LABORATORY, 3 Credits
Introduction to modern measurement methods for ecological and environmental applications includes sensors and systems for measuring soil, water and atmospheric properties. No final exam; field trip required.
Lec/lab.
Prerequisite: BEE 312 with C or better

BEE 362, ECOLOGICAL ENGINEERING MICROBIAL PROCESSES, 3 Credits
Applies ecological engineering principles to the modeling, analysis and design of microbial processes in the environment.
Prerequisite: BEE 320 with C or better or ENVE 322 with C or better

BEE 399, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

BEE 401, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

BEE 405, READING AND CONFERENCE, 1-16 Credits
Equivalent to: BRE 405
This course is repeatable for 16 credits.

BEE 407, SEMINAR, 1-16 Credits
Departmental seminars. Graded P/N.
Equivalent to: BEE 407H, BRE 407
This course is repeatable for 16 credits.

BEE 407H, SEMINAR, 1-16 Credits
Departmental seminars. Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: BEE 407
This course is repeatable for 16 credits.

BEE 410, ECOCLOGICAL ENGINEERING INTERNSHIP, 1-12 Credits
Internship in ecological engineering to provide students with an opportunity to apply course work and theory to the real world. Requires internship opportunity identification by student.
This course is repeatable for 12 credits.

BEE 411, GLOBAL ENVIRONMENTAL CHANGE: USING DATA TO INFORM DECISIONS, 3 Credits
Empowers students interested in global change research to focus on the interactions between changes in human land use and climate. Using an innovative online data and mapping tool called Data Basin, students will explore topics accessing the highest quality datasets available in an all-in-one platform.
Prerequisite: FE 257 with C or better
Available via Ecampus

BEE 415, PROFESSIONAL DEVELOPMENT, 1 Credit
Preparation for student professional careers. Students will interact with and hear seminars from professionals working in the ecological engineering field to learn from their experiences.
Corequisites: BEE 469

BEE 433, IRRIGATION SYSTEM DESIGN, 4 Credits
Principles of soil physics and plant water use applied to irrigation system design. Design of gravity, pressurized, and trickle irrigation systems, improving on-farm water management, performance characteristics of pumps and other irrigation equipment. Lec/lab. Offered alternate years.
Prerequisite: BEE 312 with C or better or CE 313 with C or better
Equivalent to: BRE 433

BEE 438, ECOLOGICAL SYSTEMS ANALYSIS, 4 Credits
An introduction to sustainability with a focus on case studies that are relevant to biological and ecological engineers. An introduction to tools that perform technical feasibility analysis, economic viability analysis, environmental risk assessment, resource sustainability assessment and life cycle assessment (LCA). Course will consist of theory and case studies highlighting the use of LCA methods to assess sustainability.
Prerequisite: ENGR 391 with C or better or ENGR 391H with C or better

BEE 439, IRRIGATION PRINCIPLES AND PRACTICES, 4 Credits
Survey of irrigation systems, system configurations, factors that influence irrigation efficiency, crop water requirements, energy requirements, pumps, irrigation scheduling. For non-engineers. Lec/lab/rec.
Prerequisite: MTH 111 with C or better
Equivalent to: BEE 439
BEE 446, RIVER ENGINEERING, 4 Credits
Multipurpose river use; natural physical processes in alluvial rivers; channel modification practices; river structures; design practices; impact of river modification; problem analysis; and impact minimization. Offered alternate years.
Prerequisite: BEE 312 with C or better or CE 313 with C or better
Recommended: CE 313

BEE 458, NONPOINT SOURCE POLLUTION ASSESSMENT AND CONTROL, 3 Credits
Problem solving in nonpoint source pollution. Methods for evaluating the extent, rate, timing, and fate of Non-Point Source (NPS) pollutants in agricultural and urban environments.
Prerequisite: BEE 313 with C or better or CE 412 with C or better
Available via Ecampus

BEE 468, BIOREMEDIATION ENGINEERING, 4 Credits
Examines strategies for using a variety of biological processes for treating municipal, agricultural and industrial contaminants. Lec/lab.
Prerequisite: BEE 221 with C or better or ENVE 322 with C or better
Available via Ecampus

BEE 469, *ECOLOGICAL ENGINEERING DESIGN I, 4 Credits
Engineering design processes for ecological engineering applications, including specifications, performance criteria, timelines, and project logistics, principles and practices of working in engineering teams. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: BEE 322 with C or better
Recommended: ENGR 391 or ENGR 391H
Equivalent to: BEE 469

BEE 470, ECOLOGICAL ENGINEERING DESIGN II, 4 Credits
Engineering design processes for ecological engineering applications, including specifications, performance criteria, timelines, and project logistics, principles and practices of working in engineering teams.
Prerequisite: BEE 469 with C or better
Equivalent to: BEE 499

BEE 472, INTRODUCTION TO FOOD ENGINEERING PRINCIPLES, 5 Credits
Fundamental engineering principles for scientists and non-process engineers. Topics include fluid flow, mass and energy transfer, and material and energy balances. Directed at food scientists and other majors who need or would like a working knowledge of food engineering principles.
Prerequisite: MTH 112 with C- or better and (MTH 227 [C-] or MTH 251 [C-] or MTH 251H [C-]) and PH 201 [C-]
Equivalent to: BEE 452

BEE 473, INTRODUCTION TO FOOD ENGINEERING PROCESS DESIGN, 3 Credits
Fundamental engineering process design principles for food scientists and non-process engineers. Directed at those who need or would like a working knowledge of applied food engineering process design. Lec/rec.
Equivalent to: BEE 453
Recommended: BEE 472 or BEE 572

BEE 481, *ECOLOGICAL ENGINEERING DESIGN II, 3 Credits
Explores engineering design processes for ecological engineering applications, including specifications, performance criteria, timelines, and project logistics, principles and practices of working in engineering teams. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: BEE 481 with C or better
Equivalent to: BEE 469

BEE 482, ECOLOGICAL ENGINEERING DESIGN III, 3 Credits
Designs engineering processes for ecological engineering applications, including specifications, performance criteria, timelines, and project logistics, principles and practices of working in engineering teams.
Prerequisite: BEE 482 with C or better

BEE 483, ECOLOGICAL ENGINEERING DESIGN IV, 2 Credits
Designs engineering processes for ecological engineering applications, including specifications, performance criteria, timelines, and project logistics, principles and practices of working in engineering teams.
Prerequisite: BEE 483 with C or better

BEE 499, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

BEE 499H, SPECIAL TOPICS, 1-16 Credits
Attributes: HNSR – Honors Course Designator
This course is repeatable for 16 credits.

BEE 501, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

BEE 503, THESIS, 1-16 Credits
Equivalent to: BEE 503
This course is repeatable for 999 credits.

BEE 505, READING AND CONFERENCE, 1-16 Credits
Equivalent to: BEE 505
This course is repeatable for 16 credits.

BEE 506, PROJECTS, 1-16 Credits
Equivalent to: BEE 506
This course is repeatable for 16 credits.
BEE 507, SEMINAR, 1 Credit
Section 1: Graduate Student Orientation Seminar to acquaint new graduate students with graduate school and departmental requirements, policies and expectations, and departmental research programs.
Section 2: Graduate Research Publication Seminar to expose students to requirements for successful proposals and publication of research results. Section 3: Oral Presentation Improvement--A highly participatory educational effort designed to improve performance in presenting research reports, technical papers and in responding to oral examination questions. Graded P/N.
Equivalent to: BRE 507
This course is repeatable for 99 credits.

BEE 511, GLOBAL ENVIRONMENTAL CHANGE: USING DATA TO INFORM DECISIONS, 3 Credits
Empowers students interested in global change research to focus on the interactions between changes in human land use and climate. Using an innovative online data and mapping tool called Data Basin, students will explore topics accessing the highest quality datasets available in an all-in-one platform.
Available via Ecampus

BEE 512, PHYSICAL HYDROLOGY, 3 Credits
Principles of hydrologic processes and the integration of these processes into the hydrologic cycle. Topics include atmospheric processes, precipitation and runoff, storm response in streamflow on a watershed scale, and major concepts in groundwater systems.
Equivalent to: BRE 512
Recommended: One year of calculus.
Available via Ecampus

BEE 522, DATA ANALYSIS AND VISUALIZATION USING PYTHON, 3 Credits
Foundation course in computational thinking and computational skills relevant to data analysis and visualization of environmental data.

BEE 525, STOCHASTIC HYDROLOGY, 3 Credits
Introduction to fundamental concepts that are needed for stochastic modeling of hydrologic processes in presence of nonstationarity and uncertainty. CROSSLISTED as BEE 525/CE 525.
Prerequisite: CE 512 with C or better or BEE 512 with C or better
Equivalent to: CE 525

BEE 529, BIOSYS MODELING TECHNIQUES, 3 Credits
Development of mathematical models of biological and ecological systems; linear and nonlinear systems analysis; stochastic modeling and random processes; model solution and analysis techniques.

BEE 533, IRRIGATION SYSTEM DESIGN, 4 Credits
Principles of soil and plant water use applied to irrigation system design. Design of gravity, pressurized, and trickle irrigation systems, improving on-farm water management, performance characteristics of pumps and other irrigation equipment. Lec/lab. Offered alternate years.
Equivalent to: BRE 533
Recommended: ENGR 332

BEE 538, ECOLOGICAL SYSTEMS ANALYSIS, 4 Credits
An introduction to sustainability with a focus on case studies that are relevant to biological and ecological engineers. An introduction to tools that perform technical feasibility analysis, economic viability analysis, environmental risk assessment, resource sustainability assessment and life cycle assessment (LCA). Course will consist of theory and case studies highlighting the use of LCA methods to assess sustainability.
Recommended: ENGR 391 or ENGR391H

BEE 540, ENVIRONMENTAL TRANSPORT PROCESSES, 3 Credits
Mixing and transport processes in the environment.

BEE 542, VADOSE ZONE TRANSPORT, 4 Credits
Introduction to the physical and hydraulic properties involved in flow from the soil surface to groundwater. Classical infiltration equations will be derived and presented with exact and approximate solutions. Attention is focused on application to pollutant transport and recent advances in non-ideal flow.
Equivalent to: BRE 542
Recommended: MTH 254

BEE 544, OPEN CHANNEL HYDRAULICS, 4 Credits
Steady, uniform, and nonuniform flow in natural and artificial open channels; unsteady flow; interaction of flow with river structures; and computational methods. Offered alternate years.
Equivalent to: BRE 544, CE 544
Recommended: CE 313

BEE 545, SEDIMENT TRANSPORT, 4 Credits
Principles of sediment erosion, transportation and deposition in rivers, reservoirs, and estuaries; measurement, analysis, and computational techniques. Offered even years in winter term. CROSSLISTED as BEE 545/FE 545.
Equivalent to: BRE 545, FE 545
Recommended: CE 313 or FE 330

BEE 546, RIVER ENGINEERING, 4 Credits
Multipurpose river use; natural physical processes in alluvial rivers; channel modification practices; river structures; design practices; impact of river modification; problem analysis; and impact minimization. Offered alternate years.
Equivalent to: CE 546
Recommended: CE 313
BEE 549, REGIONAL HYDROLOGIC MODELING, 3 Credits
Challenges in regional-scale water resource analysis and management with emphasis on application to production agriculture. Application of geostatistical techniques to spatially variable systems and remote sensing to large-scale water resource systems. Development of soil-water-atmosphere-plant models. Analysis of evapotranspiration estimating methods. Offered alternate years.
Equivalent to: BRE 549
Recommended: BEE 512 and MTH 256

BEE 558, NONPOINT SOURCE POLLUTION ASSESSMENT AND CONTROL, 3 Credits
Problem solving in nonpoint source pollution. Methods for evaluating the extent, rate, timing, and fate of Non-Point Source (NPS) pollutants in agricultural and urban environments.
Available via Ecampus

BEE 568, BIOREMEDIATION ENGINEERING, 4 Credits
Examines strategies for using a variety of biological processes for treating municipal, agricultural and industrial contaminants. Lec/lab.
Available via Ecampus

BEE 572, INTRODUCTION TO FOOD ENGINEERING PRINCIPLES, 5 Credits
Fundamental engineering principles for scientists and non-process engineers. Topics include fluid flow, mass and energy transfer, and material and energy balances. Directed at food scientists and other majors who need or would like a working knowledge of process engineering principles.
Recommended: MTH 112 and (MTH 227 or MTH 251 or MTH 251H) and PH 201

BEE 573, INTRODUCTION TO FOOD ENGINEERING PROCESS DESIGN, 3 Credits
Fundamental engineering process design principles for food scientists and non-process engineers. Directed at those who need or would like a working knowledge of applied food engineering process design. Lec/rec.
Equivalent to: BEE 553
Recommended: BEE 472 or BEE 572

BEE 585, METABOLIC SYSTEMS ENGINEERING, 3 Credits
Quantitative and experimental approaches for describing and engineering biological networks and an introduction to the principles and methodologies of metabolic engineering and synthetic biology.
Equivalent to: BIOE 585
Recommended: Statistics, biology, biochemistry or microbiology.

BEE 586, PROBLEM SOLVING FOR METABOLIC SYSTEMS ENGINEERING, 1 Credit
Corequisites: BEE 585
Recommended: MTH 251 and MTH 252

BEE 599, SPECIAL TOPICS, 0-16 Credits
Equivalent to: BRE 599
This course is repeatable for 16 credits.

BEE 601, RESEARCH, 1-16 Credits
Equivalent to: BRE 601
This course is repeatable for 16 credits.

BEE 603, THESIS, 1-16 Credits
Equivalent to: BRE 603
This course is repeatable for 999 credits.

BEE 605, READING AND CONFERENCE, 1-16 Credits
Equivalent to: BRE 605
This course is repeatable for 16 credits.

BEE 606, PROJECTS, 1-16 Credits
Equivalent to: BRE 606
This course is repeatable for 16 credits.

BEE 607, SEMINAR, 1-16 Credits
Graded P/N.
Equivalent to: BRE 607
This course is repeatable for 16 credits.

BIOE 199, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 299, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 340, BIOMEDICAL ENGINEERING PRINCIPLES, 3 Credits
Application of engineering concepts (mass and energy conservation, thermodynamics, and transport phenomena) to cellular- and system-level human physiology; design considerations for biomedical interventions and devices.
Prerequisite: BI 231 with C or better and BI 233 (may be taken concurrently) [C] and CBEE 213 (may be taken concurrently) [C] and (CHE 333 (may be taken concurrently) [C] or CHE 333H (may be taken concurrently) [C])
Recommended: Completion or concurrent enrollment in BI 233 and (CHE 333 or CHE 333H)
BIOE 351, BIOMATERIALS AND BIOINTERFACES, 3 Credits
Material interactions with human tissue, with emphasis on the role of interfacial chemistry and physics in cell adhesion, infection, blood coagulation and thrombosis. Preparation of functional hydrogels, material coatings, and derivitizations, including immobilized bio-active molecules. Issues surrounding regulation of implants and device failure.
**Prerequisite:** (BB 451 (may be taken concurrently) with C or better or BB 451H (may be taken concurrently) with C or better) and (CHE 333 (may be taken concurrently) [C] or CHE 333H (may be taken concurrently) [C])

BIOE 399, SPECIAL TOPICS, 0-16 Credits
Equivalent to: BIOE 399H
This course is repeatable for 16 credits.

BIOE 401, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 405, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 406, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 407, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 415, BIOENGINEERING LABORATORY, 3 Credits
Laboratory experimentation with unit operations and processes in bioengineering; preparation of technical reports.
**Prerequisite:** CBEE 414 with C or better

BIOE 420, SOCIAL JUSTICE, ETHICS, AND ENGINEERING, 3 Credits
Examination of difference, power, and discrimination in engineering education and practice. Lec/rec.
**Prerequisite:** CBEE 320 with C or better

BIOE 440, BIOCONJUGATION, 3 Credits
Survey of theory and practical current methods for chemical modification and conjugation of proteins and other biomolecules. Topics include permanent and cleavable cross-linkers, protein modification reagents, immobilization of enzymes/DNA, enzyme-antibody conjugates, protein-protein interactions, PEGylation and labeling of proteins, and solid-phase peptide synthesis.
**Prerequisite:** BB 450 with C or better

BIOE 445, SURFACE ANALYSIS, 3 Credits
The characterization of molecular, biological, and engineered surfaces by modern surface analytical techniques. Topics include surface sensitive modes of electron spectroscopy, vibrational spectroscopy, and mass spectrometry. Students will interpret surface analytical data and gain access to the surface science literature.
**Prerequisite:** BIOE 351 (may be taken concurrently) with C or better

BIOE 457, BIOREACTORS, 3 Credits
Design and analysis of bioreactors using suspension and immobilized microbial cultures.
**Prerequisite:** (BB 451 with C or better or BB 451H with C or better) and (CHE 333 [C] or CHE 333H [C])

BIOE 459, CELL ENGINEERING, 3 Credits
Application of engineering methods and principles to the study of mammalian cells. Emphasis on mathematical models of cellular processes (e.g., cellular mass transport, protein-ligand interactions, cellular mechanics) and methods for probing the physical characteristics of biological molecules and cells.
**Prerequisite:** (BB 451 with C or better or BB 451H with C or better) and (CHE 333 [C] or CHE 333H [C])
**Recommended:** BB 451 and CHE 333

BIOE 462, BIOSEPARATIONS, 3 Credits
Application of basic mass transfer, reaction kinetics and thermodynamic principles to understanding, selection, and development of strategies for the recovery of products from bioreactors.
**Prerequisite:** (BB 451 with C or better or BB 451H with C or better) and (CHE 333 [C] or CHE 333H [C])

BIOE 490, BIOENGINEERING PROCESS DESIGN, 4 Credits
**Prerequisite:** BIOE 415 with C or better and BIOE 457 [C] and BIOE 462 [C]

BIOE 491, BIOENGINEERING PRODUCT DESIGN, 4 Credits
Design of biomedical and biotechnology-based products by a structured design process that considers customer and regulatory needs.
**Prerequisite:** BIOE 340 with C or better and (BB 451 [C] or BB 451H [C])

BIOE 492, BIOENGINEERING CAPSTONE DESIGN, 4 Credits
Culminating experience in bioengineering design of processes and devices. Includes capstone project prototyping, testing and documentation, and constraints in ethics, intellectual property, standards, regulatory, and manufacturing.
**Prerequisite:** BIOE 491 with C or better

BIOE 499, SPECIAL TOPICS, 1-16 Credits
**This course is repeatable for 16 credits.**

BIOE 503, THESIS, 1-16 Credits
Graded P/N.
**This course is repeatable for 999 credits.**

BIOE 507, SEMINAR, 1 Credit
Graded P/N.
**This course is repeatable for 3 credits.**
BIOE 511, CELLULAR AND MOLECULAR BIOENGINEERING, 3 Credits
Fundamentals of mammalian cell biology, with an emphasis on biomedical applications and engineering approaches to study and manipulate cells and tissues.
Recommended: A working knowledge of cell biology and biochemistry

BIOE 512, MODELING OF PHYSIOLOGICAL SYSTEMS, 4 Credits
Integration of engineering principles and human physiology in the areas of: transport phenomena in the cardiopulmonary and renal systems, bioelectricity in the nervous system, and mechanics of the musculoskeletal system.

BIOE 513, DRUG AND MEDICAL DEVICE REGULATIONS IN TECHNOLOGY DEVELOPMENT, 2 Credits
Overview of the processes by which drugs and devices are regulated by the Food and Drug Administration. Topics include drug and device classifications, approval routes for different classes of drugs and devices, current good manufacturing practices, process validation, and quality assurance and control.
Available via Ecampus

BIOE 520, SOCIAL JUSTICE, ETHICS, AND ENGINEERING, 3 Credits
Examination of difference, power, and discrimination in engineering education and practice. Lec/rec.

BIOE 540, BIOCONJUGATION, 3 Credits
Survey of theory and practical current methods for chemical modification and conjugation of proteins and other biomolecules. Topics include permanent and cleavable cross-linkers, protein modification reagents, immobilization of enzymes/DNA; enzyme-antibody conjugates, protein-protein interactions, PEGylation and labeling of proteins, and solid-phase peptide synthesis.
Recommended: BB 450

BIOE 545, SURFACE ANALYSIS, 3 Credits
The characterization of molecular, biological, and engineered surfaces by modern surface analytical techniques. Topics include surface sensitive modes of electron spectroscopy, vibrational spectroscopy, and mass spectrometry. Students will interpret surface analytical data and gain access to the surface science literature.
Recommended: BIOE 351

BIOE 557, BIOREACTORS, 3 Credits
Design and analysis of bioreactors using suspension and immobilized microbial cultures.
Recommended: (BB 451 or BB 451H) and (CHE 333 or CHE 333H)

BIOE 562, BIOSEPARATIONS, 3 Credits
Application of basic mass transfer, reaction kinetics and thermodynamic principles to understanding, selection, and development of strategies for the recovery of products from bioreactors.
Recommended: BB 451 and CHE 332

BIOE 599, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

BIOE 603, THESIS, 1-16 Credits
Graded P/N. This course is repeatable for 999 credits.

Chemical, Biological & Environmental Engineering (CBEE)

CBEE 101, CHEMICAL, BIOLOGICAL, AND ENVIRONMENTAL ENGR ORIENTATION, 3 Credits
Introduction to the engineering profession in general and in particular the CHE, BIOE, and ENVE programs; development of problem solving strategies and teamwork; analysis and presentation of experimental data, basic process calculations, and design methodologies.
Equivalent to: CBEE 101H

CBEE 101H, CHEMICAL, BIOLOGICAL, AND ENVIRONMENTAL ENGR ORIENTATION, 3 Credits
Introduction to the engineering profession in general and in particular the CHE, BIOE, and ENVE programs; development of problem solving strategies and teamwork; analysis and presentation of experimental data, basic process calculations, and design methodologies.
Attributes: HNRS – Honors Course Designator
Equivalent to: CBEE 101

CBEE 102, ENGINEERING PROBLEM SOLVING AND COMPUTATIONS, 3 Credits
Elementary programming and problem-solving concepts implemented using MATLAB software; emphasis on problem analysis and development of algorithms in engineering including dimensional analysis; application experiences are established through team-based activities including projects using the LEGO-NXT microprocessor for data acquisition.
Prerequisite: MTH 112 with C or better or MTH 251 with C or better or MTH 251H with C or better
Equivalent to: BIOE 102, CBEE 102H, CHE 102, ENVE 102

CBEE 102H, ENGINEERING PROBLEM SOLVING AND COMPUTATIONS, 3 Credits
Elementary programming and problem-solving concepts implemented using MATLAB software; emphasis on problem analysis and development of algorithms in engineering including dimensional analysis; application experiences are established through team-based activities including projects using the LEGO-NXT microprocessor for data acquisition.
Attributes: HNRS – Honors Course Designator
Prerequisite: MTH 112 with C or better or MTH 251 with C or better or MTH 251H with C or better
Equivalent to: CBEE 102

CBEE 111, ENGINEERING PROBLEM SOLVING FUNDAMENTALS, 3 Credits
Engineering problem solving, dimensional analysis, sketches and drawings, algorithmic thinking, arrays and indexing, understanding the operating system and file handling, the concepts of programming languages and syntax, troubleshooting approaches to coding. Lec/Studio
This course is repeatable for 3 credits.
CBEE 211, MATERIAL BALANCES AND STOICHIOMETRY, 3 Credits
Material balances, thermophysical, and thermochemical calculations. Lec/rec.
Prerequisite: MTH 252 with C or better or MTH 252H with C or better
Equivalent to: BIOE 211, CBEE 211H, CHE 211, ENVE 211
Recommended: General chemistry and second-year standing in engineering

CBEE 211H, MATERIAL BALANCES AND STOICHIOMETRY, 3 Credits
Material balances, thermophysical, and thermochemical calculations. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisite: MTH 252 with C or better or MTH 252H with C or better
Equivalent to: CBEE 211
Recommended: General chemistry and second-year standing in engineering

CBEE 212, ENERGY BALANCES, 3 Credits
Energy balances, thermophysical and thermochemical calculations. Lec/rec.
Prerequisite: (CBEE 211 with C or better or CBEE 211H with C or better) and (MTH 256 (may be taken concurrently) [C] or MTH 256H (may be taken concurrently) [C])
Equivalent to: BIOE 212, CBEE 212H, CHE 212, ENVE 212
Recommended: One year general chemistry and second-year standing in engineering

CBEE 212H, ENERGY BALANCES, 3 Credits
Energy balances, thermophysical and thermochemical calculations. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisite: (CBEE 211 with C or better or CBEE 211H with C or better) and (MTH 256 (may be taken concurrently) [C] or MTH 256H (may be taken concurrently) [C])
Equivalent to: CBEE 212
Recommended: One year general chemistry and second-year standing in engineering

CBEE 213, PROCESS DATA ANALYSIS, 4 Credits
Applications of material and energy balances, with an emphasis on data analysis important to chemical engineers, bioengineers, and environmental engineers. Contextual learning is emphasized through the laboratory component and the use of process flow simulation modeling and analysis software.
Prerequisite: CBEE 212 (may be taken concurrently) with C or better or CBEE 212H (may be taken concurrently) with C or better
Equivalent to: BIOE 213, CHE 213, ENVE 213

CBEE 280, MATERIAL AND ENERGY BALANCES, 0-6 Credits
Material balances, thermophysical, and thermochemical calculations. Energy balances, thermophysical and thermochemical calculations.
Prerequisite: MTH 256 (may be taken concurrently) with C or better or MTH 256H (may be taken concurrently) with C or better
This course is repeatable for 6 credits.
Available via Ecampus

CBEE 320, PROFESSIONALISM AND ENGINEERING ETHICS, 3 Credits
Introduction to engineering ethics. Topics include ethical theory, professional engineering responsibility, codes of ethics, ethical assessment, conflicts of interest, risk and safety, loyalty and dissent, as well as overarching professional concerns.
Prerequisite: CBEE 212 with C or better or CBEE 212H with C or better
Equivalent to: CBEE 280 with C or better

CBEE 414, ^PROCESS ENGINEERING LABORATORY, 3 Credits
Unit operations and unit processes; preparation of technical reports. Lec/lab. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: CBEE 213 (may be taken concurrently) with C or better and CHE 311 [C] and (CHE 333 [C] or CHE 333H [C])
Equivalent to: BIOE 414, CBEE 414H, CHE 414, CHE 414H, ENVE 414

CBEE 414H, ^PROCESS ENGINEERING LABORATORY, 3 Credits
Unit operations and unit processes; preparation of technical reports. Lec/lab. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC; HNRS – Honors Course Designator
Prerequisite: CBEE 213 (may be taken concurrently) with C or better and CHE 311 [C] and (CHE 333 [C] or CHE 333H [C])
Equivalent to: CBEE 414

CBEE 416, CBEE LABORATORY II, 3 Credits
Integration of overall knowledge of chemical, biological, and environmental engineering through group project activities culminating with public demonstration or display of project results.
Prerequisite: CHE 415 with C or better or CHE 415H with C or better or BIOE 415 with C or better or ENVE 415 with C or better
Equivalent to: CHE 416

CBEE 507, SEMINAR, 1 Credit
Graded P/N.
This course is repeatable for 6 credits.

Civil & Construction Engineering (CCE)
CCE 101, CIVIL AND CONSTRUCTION ENGINEERING ORIENTATION, 2 Credits
Introduction to civil and construction engineering professions; problem solving, communication skills. This course is required by the CE, CEM and FE programs.
Equivalent to: CE 101
Recommended: MTH 111 and completion or concurrent enrollment in MTH 112 or MTH 251
CCE 102, CIVIL AND CONSTRUCTION ENGINEERING: PROBLEM-SOLVING AND TECHNOLOGY, 3 Credits
A skills-based course that focuses on introducing freshman students to the use of hand calculation and computer technology in solving civil engineering and construction engineering problems. Topics to be covered include structured approach to problem solving, use of Excel for engineering applications, internet tools and data bases, homework professionalism. Opportunities for involvement with ASCE and AGC student chapters. Lec/lab.
Equivalent to: CE 102
Recommended: Completion or concurrent enrollment in MTH 112 or MTH 251

CCE 201, CIVIL AND CONSTRUCTION ENGINEERING GRAPHICS AND DESIGN, 3 Credits
Introduces the engineering design process and graphic skills that are used by civil and construction engineers. Topics include design process, geometric construction, multiviews, auxiliary views, sections, dimensioning, tolerances and engineering drawing standards. Students participate in team design projects and presentations. Graphic and design projects from the areas of civil and construction engineering. Lec/lab.
Prerequisite: MTH 111 with C or better or MTH 241 (may be taken concurrently) with C or better or MTH 251 (may be taken concurrently) with C or better
Equivalent to: CE 201

CCE 203, INTRODUCTION TO VIRTUAL DESIGN AND CONSTRUCTION, 3 Credits
Basic principles of virtual design and construction (VDC) focusing on skills required for generating design and construction information models. Parametric modeling and design constraints are introduced. Students will utilize construction drawings and documentation to create accurate 3D models. Use of design and construction information models for making estimates of quantities and cost, and for determination of constructability problems. Lec/lab.
Prerequisite: CCE 201 with C or better or ENGR 248 with C or better

CCE 207, CCE SEMINAR, 1 Credit
Professional practices of civil and construction engineering.
Prerequisite: CCE 102 with C or better or ENGR 112 with C or better or CBEE 102 with C or better or NSE 115 with C or better or CS 162 with C or better or BEE 102 with C or better
Recommended: Sophomore standing

CCE 321, CIVIL AND CONSTRUCTION ENGINEERING MATERIALS, 4 Credits
Highway materials; aggregate, concrete and asphalt. Standard test methods.
Prerequisite: (ENGR 213 with C or better or ENGR 213H with C or better) and (ST 314 [C] or BA 276 [C])
Equivalent to: CCE 321H, CE 321

CCE 321H, CIVIL AND CONSTRUCTION ENGINEERING MATERIALS, 4 Credits
Highway materials; aggregate, concrete and asphalt. Standard test methods.
Attributes: HNRS – Honors Course Designator
Prerequisite: (ENGR 213 with C or better or ENGR 213H with C or better) and (ST 314 [C] or BA 276 [C])
Equivalent to: CCE 321

CCE 422, GREEN BUILDING MATERIALS, 3 Credits
Introduces concepts of construction with green building materials. Specific concepts include evaluation of what truly makes a material ‘green’, long-term performance (e.g., durability) of materials, material production and life cycle cost analysis. Concepts of green building programs, guidelines and specifications will be introduced.
Prerequisite: CE 321 with C or better or CCE 321 with C or better
Recommended: (ECON 201 or ECON 201H or ECON 202 or ECON 202H) and ST 314
Available via Ecampus

CCE 423, CONCRETE FUNDAMENTALS, 4 Credits
Portland cement hydration, microstructural development, fresh and hardened properties, testing standards, durability, alternative cements.
Recommended: CCE 321

CCE 424, ASPHALT FUNDAMENTALS, 3 Credits
Focuses on characterization of asphalt materials and mixtures, current laboratory testing technology for asphalt binders and mixes, engineering of asphalt mixes to meet design requirements, asphalt recycling process, environmental impacts of asphalt pavements, and recent developments in asphalt technology.
Prerequisite: CCE 321 with C or better

CCE 520, SELECTED TOPICS IN INFRASTRUCTURE MATERIALS, 0-4 Credits
A critical examination of in-depth topics selected by the instructor from among topics not covered in other infrastructure materials courses. This course is repeatable for 16 credits.

CCE 522, GREEN BUILDING MATERIALS, 3 Credits
Introduces concepts of construction with green building materials. Specific concepts include evaluation of what truly makes a material ‘green’, long-term performance (e.g., durability) of materials, material production and life cycle cost analysis. Concepts of green building programs, guidelines and specifications will be introduced.
Recommended: (CE 321 or CCE 321) and (ECON 201 or ECON 201H or ECON 202 or ECON 202H) and ST 314
Available via Ecampus
CCE 523, CONCRETE FUNDAMENTALS, 4 Credits
Portland cement hydration, microstructural development, fresh and hardened properties, testing standards, durability, alternative cements. Recommended: CCE 321 or similar introductory materials course or CCE 421

CCE 524, ASPHALT FUNDAMENTALS, 3 Credits
Focuses on characterization of asphalt materials and mixtures, current laboratory testing technology for asphalt binders and mixes, engineering of asphalt mixes to meet design requirements, asphalt recycling process, environmental impacts of asphalt pavements, and recent developments in asphalt technology.

CCE 525, CONSTRUCTION SITE SYSTEMS ENGINEERING, 3 Credits
Design and planning of construction site field operations and engineered systems. Systems analysis and design as it applies to civil engineering projects. Design of construction systems: blasting; rock crushing and conveying; dewatering; cranes, pile driving, and rigging; and concrete pumping and placement. Construction site design and process design.

CCE 526, DESIGN FOR SAFETY, 3 Credits
Theoretical concepts and industry practices used to model, evaluate, and improve construction worker safety through the design of the project features, construction operations, and site safety program elements. Causes of construction site accidents, hazard recognition and comprehension, safety risk valuation and mitigation, and the true costs of injuries and fatalities.

CCE 528, ADVANCED VIRTUAL DESIGN AND CONSTRUCTION, 4 Credits
Focusing 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 project based course where students gain knowledge on the implementation of BIM concepts throughout the lifecycle of a building, from planning and design, to construction and operations. Recommended: CCE 203 [D-]

CCE 529, LEAN CONSTRUCTION, 3 Credits
Introduction to the basics of lean production management, especially about how they are applied to the AEC industry to improve the operation management and product development. Class topics include theory of manufacturing science, principles of the lean production system, application of production management to project management, variability management in design and construction, improving project performance in the AEC industry, data gathering and process evaluation for productivity improvement.

CCE 552, PROJECT RISK MANAGEMENT, 4 Credits
An introduction to the concept of project risk in producing constructed engineering projects. Course content includes project baselining, risk definition and identification, risk assessment and management techniques, risk control, risk response, and risk management. CROSSLISTED as CCE 552/IE 586. Equivalent to: IE 586 Available via Ecampus

CCE 554, PROFESSIONAL RESPONSIBILITY AND ETHICS, 3 Credits
An in-depth exploration of professional engineering ethics. Course content includes conceptual theoretical basis of ethics, ethics among professional organizations, ethical consideration of design, critical analysis of ethical situations, ethics in the workplace, and ethical considerations regarding the broader environment. CROSSLISTED as CCE 554/IE 589. Equivalent to: IE 589 Available via Ecampus

CCE 561, HYDROGRAPHIC SURVEYING, 3 Credits
Covers the fundamentals of hydrographic surveys performed to measure the depth and bottom configuration of water bodies in support of nautical charting and other areas of marine geomatics, as well as marine construction, benthic habitat mapping, marine spatial planning, and bathymetric mapping of rivers and lakes. Topics include underwater acoustics, sound velocity, the sonar equation, types of sonar systems (e.g., single-beam, multibeam, side scan sonar), water levels and tidal datums, positioning and motion sensing for hydrographic surveying, bathymetric lidar, and applications of hydrographic surveying.

CCE 599, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

CCE 621, DURABILITY AND CONDITION ASSESSMENT OF REINFORCED CONCRETE, 4 Credits
Concrete durability including freeze-thaw attack, sulfate attack, corrosion, alkali-silica reaction, long-term performance, durability modeling, durability of alternative cements. Non-destructive condition assessment; model-assisted testing; corrosion detection and monitoring; multi-scale assessment; service/remaining life predictions. Prerequisite: CCE 523 with C or better Recommended: CCE 321
CCE 623, CORROSION OF METALS AND CORROSION CONTROL, 4 Credits
Recommended: CH 202 or CH 231 or CH 231H or CCE 321

CCE 624, SERVICE LIFE MODELING OF INFRASTRUCTURE MATERIALS, 4 Credits
Recommended: Undergraduate level calculus and chemistry courses

Civil Engineering (CE)
CE 199, SPECIAL TOPICS, 1-4 Credits
CE 202, CIVIL ENGINEERING: GEOSPATIAL INFORMATION AND GIS, 3 Credits
Introductory design principles presented with the use of GIS and geospatial information (remote sensing, GPS, surveying, and aerial photography) for civil engineering problem solving. Introduction to the integration of geospatial data and analysis for decision making and management for site selection, mitigation, change analysis, modeling and assessment. Standard software and custom programming used in course. Students participate in both individual and team projects and presentations. Projects from the area of civil engineering. Lec/lab.
Prerequisite: CCE 201 with C or better or ENGR 248 with C or better

CE 299, SPECIAL TOPICS, 1-4 Credits
Graded P/N.
Equivalent to: CE 299H

CE 299H, SPECIAL TOPICS, 1-4 Credits
Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: CE 299

CE 301, CE JUNIOR SEMINAR, 1 Credit
Professional practices of civil engineering.

CE 311, FLUID MECHANICS, 4 Credits
Fluid properties, fluid statics, fluid motion, conservation of mass, momentum and energy for incompressible fluids, dimensional analysis, civil engineering applications.
Prerequisite: (MTH 256 with C or better or MTH 256H with C or better) and PH 213 [C] and ENGR 213 [C] and ENGR 212 [C]

CE 313, HYDRAULIC ENGINEERING, 4 Credits
Analysis of large civil engineering fluid systems including conduit flow, multiple reservoirs, pipe networks, pumps, turbines, open channel flow, and hydraulic structures.
Prerequisite: CE 311 with C or better or CHE 331 with C or better or CHE 331H with C or better

CE 361, SURVEYING THEORY, 4 Credits
Use of surveying equipment, Gaussian error theory applied to measurements, calculations of position on spherical and plane surfaces, state plane coordinate systems, introduction to global positioning systems.
Prerequisite: (CCE 201 with C or better or CE 202 with C or better) and ENGR 213 [C] and PH 213 [C] and ST 314 [C]

CE 365, HIGHWAY LOCATION AND DESIGN, 3 Credits
Curve problems in highway design, including circular, vertical, compound curves and spirals; earth distribution analysis; preliminary office studies; paper location procedures and field layout problems.
Prerequisite: CE 361 with C or better or CEM 263 with C or better or FE 208 with C or better

CE 372, GEOTECHNICAL ENGINEERING I, 4 Credits
Basic soil mechanics including the identification and classification of soil, principles of compaction and consolidation, flow through porous media, effective stress, and shear strength. Lec/lab.
Prerequisite: ENGR 213 with C or better or ENGR 213H with C or better and (CE 311 (may be taken concurrently) [C] or CEM 311 (may be taken concurrently) [C] or CHE 331 (may be taken concurrently) [C] or CHE 331H (may be taken concurrently) [C] and CH 201 [C] and PH 212 [C]

CE 373, GEOTECHNICAL ENGINEERING II, 4 Credits
Application of fundamental soil mechanics principles to analyses of slope stability, retaining structures, and foundation support. Lec/rec.
Prerequisite: CE 372 with C or better or FE 315 with C or better

CE 381, STRUCTURAL THEORY I, 4 Credits
Analysis of statically determinate structures (beams, frames, trusses, arches, and cables). Approximate analysis, influence lines, deflections.
Prerequisite: ENGR 213 with C or better or ENGR 213H with C or better

CE 382, STRUCTURAL THEORY II, 4 Credits
Analysis of statically indeterminate structures (beams, frames, trusses). Deflections. Energy methods, introduction to matrix methods.
Prerequisite: CE 381 with C or better and (MTH 306 [C] or MTH 306H [C] or MTH 264 [C] and MTH 265 [C])

CE 383, DESIGN OF STEEL STRUCTURES, 4 Credits
Introduction to design of steel members, connections and structural systems. Lec/lab.
Prerequisite: CE 382 with C or better
CE 392, INTRODUCTION TO HIGHWAY ENGINEERING, 4 Credits
Highway engineering standards, geometric design, cross section and roadside design, highway surfaces, pavement design, highways and the environment, highway construction and maintenance.
Prerequisite: (ENGR 212 with C or better or ENGR 212H with C or better) and CE 361 [C]

CE 401, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

CE 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

CE 405, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

CE 406, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

CE 407, SEMINAR, 1-3 Credits
Understanding complexity and systems thinking.
Equivalent to: CE 407H
This course is repeatable for 16 credits.

CE 407H, SEMINAR, 1-3 Credits
Understanding complexity and systems thinking.
Attributes: HNRS – Honors Course Designator
Equivalent to: CE 407
This course is repeatable for 16 credits.

CE 408, WORKSHOP, 1-3 Credits
This course is repeatable for 3 credits.

CE 410, INTERNSHIP, 1-12 Credits
This course is repeatable for 16 credits.

CE 411, OCEAN ENGINEERING, 4 Credits
Introduction to linear wave theory and wave forces on piles. Guided design of wave gauge facility at Coos Bay, Oregon, that requires synthesizing fluid mechanics, structural design and foundation design.
Prerequisite: CE 313 with C or better or CEM 311 with C or better

CE 412, HYDROLOGY, 4 Credits
Fundamentals of hydrology, the hydrologic cycle, precipitation, streamflow, hydrograph analysis and hydrologic measurements.
Prerequisite: CE 313 with C or better

CE 413, GIS IN WATER RESOURCES, 3 Credits
Course presents Geographic Information System (GIS) technology for developing solutions to water resource problems: water quality, availability, flooding, the natural environment, and management of water resources. Typical GIS data models for hydrologic information are presented. Synthesis of geospatial and temporal water resources to support hydrologic analysis and modeling are covered.
Recommended: Senior standing or a previous introductory GIS course

CE 415, COASTAL INFRASTRUCTURE, 3 Credits
Planning and design criteria of coastal infrastructure, including breakwaters, jetties, sea walls, groins, piers, submerged pipelines, harbor design, and tsunami defense. Use of laboratory models, numerical simulations, and field observations for design.
Prerequisite: CE 313 with C or better

CE 417, HYDRAULIC ENGINEERING DESIGN, 4 Credits
Theory, planning, analysis, and design of hydraulic structures. Application of basic principles detailed analysis and design. Engineering planning and design of water resource systems.
Prerequisite: CE 313 with C or better

CE 418, CIVIL ENGINEERING PROFESSIONAL PRACTICE, 3 Credits
Engineering career paths; ethics and professionalism, project planning, execution and delivery; team building/management; marketing proposals; engineering overseas; dispute resolution; partnering; effective decision making; uncertainty and risk analysis; and current industry design and construction methods. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: CE 382 with C or better and CE 313 [C] and (CE 372 [C] or FE 315 [C])
Equivalent to: CE 454

CE 419, CIVIL INFRASTRUCTURE DESIGN, 3 Credits
A capstone design project experience exposing students to problems and issues similar to those encountered in the practice of civil engineering. Students should have completed ALL other required courses in their degree program prior to registering for this course. Lec/rec.
Attributes: CWIC – Core, Skills, WIC
Prerequisite: CE 418 with C or better

CE 420, ENGINEERING PLANNING, 4 Credits
The application of systems analysis to structuring, analyzing, and planning for civil engineering projects. Concept of the system and its environment; setting goals, objectives, and standards; evaluation criteria; solution generation and analysis; evaluation and optimization. Project management using precedence node diagramming; resource allocation and leveling; time-cost trade-off; and PERT.

CE 424, CONTRACTS AND SPECIFICATIONS, 4 Credits
Fundamentals of construction industry contracts, including technical specifications, and issues related to time, money, warranty, insurance, and changed conditions.
Prerequisite: CEM 442 with C or better

CE 427, TEMPORARY CONSTRUCTION STRUCTURES, 4 Credits
Design and construction of temporary structures including formwork, shoring, and earth retaining structures.
Prerequisite: (CE 321 with C or better or CCE 321 with C or better) and (FE 315 [C] or CE 372 [C]) and (CEM 383 [C] or CE 383 [C])
CE 429, OPTIMIZATION IN WATER RESOURCES ENGINEERING, 3 Credits
Introduction to problem formulation and optimization techniques for design of complex water resources systems.
**Recommended:** CE 412

CE 461, PHOTOGRAMMETRY, 3 Credits
Geometry of terrestrial and vertical photographs, flightline planning, stereoscopy and parallax, stereoscopic plotting instruments, analytical photogrammetry, orthophotography, introduction to photo interpretation, and aerial cameras.
**Prerequisite:** CE 361 with C or better or CEM 263 with C or better or FE 208 with C or better

CE 463, CONTROL SURVEYING, 4 Credits
Global Positioning Systems (GPS) theory, networks, and fieldwork; control specifications, methods and problems in obtaining large area measurements; precise leveling; network adjustments using least square techniques; field instrument adjustments.
**Prerequisite:** CE 361 with C or better or CEM 263 with C or better or FE 208 with C or better

CE 465, OREGON LAND SURVEY LAW, 3 Credits
Introduction to U.S. public land survey; Oregon state statutes, common law decisions, and administrative rules dealing with boundary law; case studies; unwritten land transfers; original and resurvey platting laws; guarantees of title; deed descriptions.
**Prerequisite:** CE 361 with C or better or CEM 263 with C or better or FE 208 with C or better

CE 469, PROPERTY SURVEYS, 3 Credits
U.S. public land survey: restoration of corners, subdivision of sections; topographic mapping; subdivision and partition plats, resurvey plats, subdivision design; introduction to LIS/GIS; field astronomy.
**Prerequisite:** CE 361 with C or better or CEM 263 with C or better or FE 208 with C or better

CE 471, FOUNDATIONS FOR STRUCTURES, 3 Credits
Criteria, theory, design, and construction for foundations of structures; use of in-situ tests for geotechnical engineering; computer applications.
**Prerequisite:** CE 373 with C or better or FE 316 with C or better

CE 479, SLOPE AND EMBANKMENT DESIGN, 3 Credits
A comprehensive overview of evaluating stability and performance for natural and engineered slopes. Design aspects include construction of road embankments, slope remediation techniques and application of geosynthetics for slope stabilization, slope and wall construction, and drainage. CROSSLISTED as CE 479/FE 479 and CE 579/FE 579.
**Prerequisite:** CE 373 with C or better or FE 316 with C or better
**Equivalent to:** FE 479

CE 481, REINFORCED CONCRETE I, 4 Credits
Basic principles of reinforced concrete design; strength, stability, and serviceability criteria; design of reinforced concrete members for flexure and shear. Detailing, development length and splices.
**Prerequisite:** CE 382 with C or better

CE 482, MASONRY DESIGN, 3 Credits
A critical examination in depth of masonry design topics.
**Prerequisite:** CE 481 with C or better

CE 484, WOOD DESIGN, 4 Credits
Study of basic wood properties and design considerations. Design and behavior of wood connectors, beams, columns and beam columns. Introduction to plywood and glued laminated members. Analysis and design of structural diaphragms and shear walls. Lec/lab.
**Prerequisite:** CE 383 with C or better or CE 481 with C or better
**Equivalent to:** WSE 458

CE 486, PRESTRESSED CONCRETE, 3 Credits
Prestressed concrete analysis and design, systems of prestressing, materials, economics.
**Prerequisite:** CE 481 with C or better

CE 489, SEISMIC DESIGN FUNDAMENTALS, 3 Credits
Fundamentals of earthquake engineering, introduction to structural dynamics principles, response spectra, and ASCE 7 design and analysis provisions.
**Prerequisite:** CE 481 with C- or better and CE 383 [C-]

CE 491, TRANSPORTATION ENGINEERING, 3 Credits
Introduction to transportation engineering systems characteristics, traffic estimation, comprehensive transportation planning, highway economics, driver and vehicle characteristics, highway operations and capacity, signalization and control. Introduction to intelligent transportation.
**Prerequisite:** CE 392 with C or better and ST 314 [C]

CE 492, PAVEMENT STRUCTURES, 3 Credits
Design and rehabilitation of pavement structures for streets, highways, and airports.
**Prerequisite:** CE 392 with C or better

CE 499, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

CE 501, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

CE 503, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

CE 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.
CE 506, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

CE 507, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

CE 508, WORKSHOP, 1-3 Credits
Graded P/N.
This course is repeatable for 3 credits.

CE 510, INTERNSHIP, 1-16 Credits
This course is repeatable for 16 credits.

CE 511, OCEAN ENGINEERING, 4 Credits
Introduction to linear wave theory and wave forces on piles. Guided design of wave gauge facility at Coos Bay, Oregon, that requires synthesizing fluid mechanics, structural design and foundation design. Recommended: CE 313 or CEM 311

CE 512, HYDROLOGY, 4 Credits
Fundamentals of hydrology, the hydrologic cycle, precipitation, streamflow, hydrograph analysis and hydrologic measurements.

CE 513, GIS IN WATER RESOURCES, 3 Credits
Course presents Geographic Information System (GIS) technology for developing solutions to water resource problems: water quality, availability, flooding, the natural environment, and management of water resources. Typical GIS data models for hydrologic information are presented. Synthesis of geospatial and temporal water resources to support hydrologic analysis and modeling are covered. Recommended: Senior standing or a previous introductory GIS course

CE 514, GROUNDWATER HYDRAULICS, 4 Credits
Principles of groundwater flow and chemical transport in confined and unconfined aquifers, aquifer testing and well construction. Design of dewatering and contaminant recovery systems. Prerequisite: CE 547 with B or better Equivalent to: BEE 514 Recommended: CE 313 and MTH 252

CE 515, COASTAL INFRASTRUCTURE, 3 Credits
Planning and design criteria of coastal infrastructure, including breakwaters, jetties, sea walls, groins, piers, submerged pipelines, harbor design, and tsunami defense. Use of laboratory models, numerical simulations, and field observations for design. Recommended: CE 313

CE 516, STORMWATER DESIGN AND MANAGEMENT, 4 Credits
Introduction to urban stormwater drainage systems; urban hydrologic analysis; water quality in urban storm water; design of stormwater control systems; low impact development; storm water monitoring; and computer modeling of urban storm water systems. Prerequisite: CE 512 with C or better or BEE 512 with C or better

CE 517, HYDRAULIC ENGINEERING DESIGN, 4 Credits
Theory, planning, analysis, and design of hydraulic structures. Application of basic principles detailed analysis and design. Engineering planning and design of water resource systems. Recommended: CE 313

CE 518, GROUNDWATER MODELING, 4 Credits
Application of numerical methods to the solution of water flow and solute transport through saturated and unsaturated porous media. Analysis of confined and unconfined aquifers. Computer solution of large-scale field problems including groundwater contamination and aquifer yield. Prerequisite: CE 514 with C or better

CE 520, ENGINEERING PLANNING, 4 Credits
The application of systems analysis to structuring, analyzing, and planning for civil engineering projects. Concept of the system and its environment; setting goals, objectives, and standards; evaluation criteria; solution generation and analysis; and evaluation and optimization. Project management using precedence node diagramming; resource allocation and leveling; time-cost trade-off; and PERT.

CE 524, CONTRACTS AND SPECIFICATIONS, 4 Credits
Fundamentals of construction industry contracts, including technical specifications, and issues related to time, money, warranty, insurance, and changed conditions.

CE 525, STOCHASTIC HYDROLOGY, 3 Credits
Introduction to fundamental concepts that are needed for stochastic modeling of hydrologic processes in presence of nonstationarity and uncertainty. CROSSLISTED as BEE 525/CE 525. Prerequisite: CE 512 with C or better or BEE 512 with C or better Equivalent to: BEE 525

CE 527, TEMPORARY CONSTRUCTION STRUCTURES, 4 Credits
Design and construction of temporary structures including formwork, shoring, and earth retaining structures. Recommended: (CE 321 or CCE 321) and (FE 315 or CE 372) and (CEM 383 or CE 383)

CE 529, OPTIMIZATION IN WATER RESOURCES ENGINEERING, 3 Credits
Introduction to problem formulation and optimization techniques for design of complex water resources systems. Recommended: CE 512 or BEE 512
CE 530, SELECTED TOPICS IN STRUCTURAL ANALYSIS AND MECHANICS, 3 Credits
A critical, in-depth examination of topics selected by the instructor from among topics not covered in other structural analysis and mechanics courses.
Prerequisite: CE 585 with C or better
This course is repeatable for 16 credits.

CE 531, STRUCTURAL MECHANICS, 3 Credits
Theories of failure, multi-axial stress conditions, torsion, shear distortions, energy methods of analysis, beams on elastic foundations. Nonlinear and inelastic behavior.

CE 532, FINITE ELEMENT ANALYSIS, 4 Credits
Applications of the finite element method to structural analysis, fluid flow and elasticity problems. Use and development of large finite element computer programs.
Prerequisite: (CE 585 with C or better or ME 520 with C or better)

CE 533, STRUCTURAL STABILITY, 3 Credits
Stability theory and applications, with emphasis on design of steel structures.
Recommended: CE 383

CE 534, STRUCTURAL DYNAMICS, 4 Credits
Analytical and numerical solutions for single, multi-degree of freedom and continuous vibrating systems. Behavior of structures, dynamic forces and support motions. Seismic response spectra analysis.
Recommended: CE 382

CE 535, INTRODUCTION TO RANDOM VIBRATIONS, 4 Credits
Introduction to probability theory and stochastic processes. Correlation and spectral density functions. Response of linear systems to random excitations. First excursion and fatigue failures. Applications in structural and mechanical system analysis and design.
Prerequisite: CE 534 with C or better or ME 522 with C or better

CE 536, MATRIX METHODS OF STRUCTURAL ANALYSIS, 4 Credits
Equivalent to: CE 585
Recommended: CE 382 with a minimum grade of C
Available via Ecampus

CE 537, NONLINEAR STRUCTURAL ANALYSIS, 4 Credits
Available via Ecampus

CE 538, STRUCTURAL RELIABILITY AND RISK ANALYSIS, 4 Credits
Application of probability and statistics in the reliability-based analysis and design of civil and mechanical engineering systems. Probabilistic modeling of loading and resistance including load and resistance factor design. Introduction to risk analysis and robustness.
Prerequisite: (CE 536 with C or better or ME 520 with C or better)
Recommended: ST 314

CE 540, SPECIAL TOPICS IN HYDRAULIC ENGINEERING, 3-4 Credits
Introduction to the tools and methods employed to characterize hydrologic properties of subsurface systems. Hands-on use of GPR, TDR, resistivity, and methods of determining hydraulic conductivity, sorptivity, bulk density, and other fundamental hydrologic properties.
Equivalent to: BRE 540
This course is repeatable for 16 credits.

CE 543, APPLIED HYDROLOGY, 4 Credits
Advanced treatment of hydrology covering major components of the hydrological cycle with special emphasis on surface water; hydrologic analysis and design of water resource systems; runoff prediction; and simulation of surface water systems. Offered alternate years.
Equivalent to: BRE 543
Recommended: BEE 512 and CE 412

CE 544, OPEN CHANNEL FLOW, 3 Credits
Steady, uniform, and nonuniform flow in natural and artificial open channels; unsteady flow; interaction of flow with river structures; and computational methods.
Equivalent to: BEE 544, BRE 544
Recommended: (CE 311 and CE 313) or CE 547

CE 547, WATER RESOURCES ENGINEERING I: PRINCIPLES OF FLUID MECHANICS, 4 Credits
Fluid mechanics for water resources engineers, classifications of fluid flows; fluid statics and dynamics, incompressible viscous flows; dimensional analysis; applications to fluid machinery, flow through porous media, fluid motion in rivers, lakes, oceans.

CE 552, ISOLATED SIGNALIZED INTERSECTIONS, 3 Credits
Relationships between signal display, user response, vehicle detection, and signal timing parameters are examined in detail. Traffic simulation is introduced to visualize and design the various elements of isolated signalized intersections.
Recommended: CE 595
CE 553, RAILROAD ENGINEERING, 3 Credits
The principal subject of this course is the railway infra-structure and operational issues related to high speed passenger rail and freight rail (class 1 and regional rail). The course will cover the techniques used to design, construct, monitor and maintain railway track. Class will include field trips.
Corequisites: CE 392

CE 554, DRIVING SIMULATION, 3 Credits
Relationships between the functional elements of driving simulation (simulation computer processing, sensory feedback generation, sensory display devices, and the human operator) are examined in detail. The role of driving simulation in transportation engineering research and practice is also considered in depth. Students will design experiments, analyze and interpret data, and extrapolate simulator results to real-world scenarios.
Recommended: CE 595

CE 556, TRANSPORTATION SAFETY ANALYSIS, 3 Credits
Provides students with a general knowledge of major transportation safety issues and a general background in the application of various statistical and econometric safety analysis techniques. In addition, this course presents a number of model-estimation methods used in transportation safety data analysis, and other subject areas that deal with safety analysis.
Recommended: CE 392 with a minimum grade of C and ST 511

CE 557, NETWORK FLOW ANALYSIS AND OPTIMIZATION, 3 Credits
Acquaints students with the basic elements of operations research through transportation networks, optimal paths in transportation networks, vehicle routing and scheduling problems on networks, facility location problems, transportation network design problems, transportation network flow patterns, and to indicate the directions for future research in this area. Although the course utilizes examples from transportation, the techniques and models are generalizable to other areas of engineering, e.g., water networks, computer networks, energy networks, agricultural, power, telecommunication, etc.
Recommended: CE 392 with a minimum grade of C

CE 560, SELECTED TOPICS IN GEOMATICS ENGINEERING, 0-4 Credits
Selected topics on contemporary problems in geomatics engineering; application of ongoing research from resident and visiting faculty. This course is repeatable for 16 credits.

CE 561, PHOTOGRAMMETRY, 3 Credits
Geometry of terrestrial and vertical photographs, flighline planning, stereoscopy and parallax, stereoscopic plotting instruments, analytical photogrammetry, orthophotography, introduction to photo interpretation, and aerial cameras.
Recommended: CE 361 or CEM 263 or FE 208

CE 562, DIGITAL TERRAIN MODELING, 4 Credits
Fundamentals of LIDAR and creating digital terrain models. Computational geometry, Delaunay triangulations, spline interpolations, statistical gridding methods, ground filtering, data optimizations, and advanced topics in 3D modeling.
Recommended: CE 361 or CEM 263 or equivalent surveying or GIS course.

CE 563, CONTROL SURVEYING, 4 Credits
Global Positioning Systems (GPS) theory, networks, and fieldwork; control specifications, methods and problems in obtaining large area measurements; precise leveling; network adjustments using least square techniques; field instrument adjustments.
Recommended: CE 361 or CEM 263 or FE 208

CE 564, GLOBAL NAVIGATION SATELLITE SYSTEM, 4 Credits
Theories and applications of surveying using satellites, focusing on the use of Global Navigation Satellite System (GNSS). The course will begin with the comprehensive overviews of the GNSS, reference and time systems as well as basic orbital mechanics. A description of the satellite signals and the data collected by GNSS receivers will also be covered. Different positioning and navigation techniques for using GNSS data (absolute/relative positioning, static/kinematic positioning, stand-alone/network based positioning) and different user applications will be reviewed, followed by practices of data collections and processing techniques.
Recommended: CE 361 or CE 202

CE 565, OREGON LAND SURVEY LAW, 3 Credits
Introduction to U.S. public land survey; Oregon state statutes, common law decisions, and administrative rules dealing with boundary law; case studies; unwritten land transfers; original and resurvey platting laws; guarantees of title; deed descriptions.
Recommended: CE 361 or CEM 263 or FE 208

CE 566, 3D LASER SCANNING AND IMAGING, 4 Credits
Fundamentals of lidar acquisition, registration, processing, modeling, analysis, and verification. Use of sensor platforms for 3D acquisition. Effective data management procedures. Introduction to other imaging techniques including structure from motion and structured light. Lec/lab.

CE 567, COASTAL REMOTE SENSING, 4 Credits
Application of remote sensing technologies (e.g., unmanned aircraft systems, multi- and hyperspectral imagery, high-resolution commercial satellite imagery, synthetic-aperture radar, and topographic and bathymetric lidar) to coastal mapping and charting, coastal engineering and coastal zone management. Both the theory and applications of advanced remote sensing technologies are covered. Lec/lab.
Recommended: An undergraduate surveying course, such as CE 361, CEM 263 or FE 208 and some exposure to MATLAB.
CE 568, LEAST SQUARES ADJUSTMENTS, 3 Credits
Examines the theory of random error and statistical testing. Discusses the propagation of error in both indirect observations and direct observations from survey. Studies weights of observations and the principles of least squares. Explains how to adjust redundant observations in level nets, horizontal surveys, GNSS networks, and GNSS and terrestrial survey networks by least squares. Estimates the error ellipses of the adjusted observations. Evaluates methods for performing coordinate transformations.
Recommended: CE 361 or CEM 263 or FE 208

CE 569, PROPERTY SURVEYS, 3 Credits
U.S. public land survey; restoration of corners, subdivision of sections; topographic mapping; subdivision and partition plats, resurvey plats, subdivision design; introduction to LIS/GIS; field astronomy.
Recommended: CE 361 and CEM 263 or FE 208

CE 570, GEOTECHNICAL SPECIAL TOPICS, 1-16 Credits
Development and management of actual projects through the examination of case histories; evaluation of geotechnical data; development of design recommendations and preparation of project reports.
This course is repeatable for 16 credits.

CE 571, ADVANCED FOUNDATION ENGINEERING, 4 Credits
Presents the planning, analysis, and design of shallow and deep foundations from the geotechnical engineering perspective. Topics supporting course objectives include planning and execution of subsurface investigations, interpretation of in-situ tests, analysis and design of deep and shallow foundations, including geotechnical capacity, and immediate settlement. Assessment of deep foundation installation, axial and lateral loading tests, and group effects is presented. Evaluation of foundation performance is conducted under deterministic and probabilistic frameworks.
Recommended: CE 373 and CE 471

CE 572, ADVANCED GEOTECHNICAL LABORATORY, 4 Credits
Examination of soil composition and engineering properties of soils including volume change, pore pressure generation, strength, and deformation behavior of soils in the laboratory. Advanced static and cyclic shear strength testing of soils will also be discussed. Lec/lab.
Recommended: CE 373 and CE 471

CE 575, EARTH RETENTION AND SUPPORT, 4 Credits
Presents the theory and practice of design and construction of earth retaining structures. Topics include rigid and flexible retaining structures, ranging from gravity and cantilever systems, cantilever and anchored sheet piling, tied-back shoring elements, soil nailing, and mechanically stabilized earth walls. These topics are developed with a view on compaction stresses and surface loading, and invokes approaches that range from the static equations of equilibrium to empirical rules of thumb.
Recommended: CE 373

CE 576, GROUND IMPROVEMENT, 3 Credits
Presents the analysis and design of ground improvement techniques. Topics supporting course objectives include design for accelerated settlement (surcharge design) with and without pre-fabricated vertical drains, vibro-compaction, vibro-replacement (stone columns) and aggregate piers, deep soil mixing, jet grouting, EPS geofoam, and other improvement techniques for improving soil strength and stability, and limiting deformations and the effects of liquefaction.
Prerequisite: CE 572 with C or better and CE 577 [C]

CE 577, STATIC AND DYNAMIC SOIL BEHAVIOR, 3 Credits
An advanced coverage of volume change and strength behavior of soil. Specific course topics include effective stress, one-dimensional compression of soil, rate of soil consolidation, Mohr circle analysis, shear strength of sands, clays, and silts, and dynamic soil properties, strength, and testing.
Recommended: CE 372 and CE 373

CE 578, GEOTECHNICAL EARTHQUAKE ENGINEERING, 4 Credits
Major course topics include engineering seismology, strong ground motion, seismic hazard analysis, soil dynamics, seismic site response, earthquake motion selection, liquefaction, and seismic slope stability. Attention will be given to earthquakes created by the Cascadia Subduction Zone. Lec/lab.
Recommended: CE 373 and CE 471

CE 579, SLOPE AND EMBANKMENT DESIGN, 3 Credits
A comprehensive overview of evaluating stability and performance for natural and engineered slopes. Design aspects include construction of road embankments, slope remediation techniques and application of geosynthetics for slope stabilization, slope and wall construction, and drainage. CROSSLISTED as CE 479/FE 479 and CE 579/FE 579.
Equivalent to: FE 579
Recommended: CE 373 or FE 316

CE 580, SELECTED TOPICS IN STRUCTURAL DESIGN, 3 Credits
A critical examination in depth of topics selected by the instructor from among topics not covered in other structural design courses.
This course is repeatable for 18 credits.

CE 581, REINFORCED CONCRETE I, 4 Credits
Basic principles of reinforced concrete design; strength, stability, and serviceability criteria; design of reinforced concrete members for flexure and shear. Detailing, development length and splices.
Recommended: CE 382

CE 582, MASONRY DESIGN, 3 Credits
A critical examination in depth of masonry design topics.
Recommended: CE 581
CE 583, BRIDGE DESIGN, 3 Credits
AASHTO specifications for bridge design; load models; design for moving loads; design and analysis of bridge decks and simple and continuous bridge spans.
Recommended: Completion of CE 381 and CE 382 and (CE 481 or CE 581) and concurrent enrollment in CE 383

CE 584, WOOD DESIGN, 4 Credits
Study of basic wood properties and design considerations. Design and behavior of wood connectors, beams, columns and beam columns. Introduction to plywood and glued laminated members. Analysis and design of structural diaphragms and shear walls. Lec/lab. CROSSTLISTED as CE 584/WSE 558.
Equivalent to: WSE 558
Recommended: CE 383 or CE 481 with a minimum grade of C

CE 586, PRESTRESSED CONCRETE, 3 Credits
Prestressed concrete analysis and design, systems of prestressing, materials, economics.
Recommended: CE 581

CE 589, SEISMIC DESIGN, 4 Credits
Design of structures to resist the effects of earthquakes. Introduction to structural dynamics, dynamic analysis, seismic design philosophy, code requirements, and detailing for steel and reinforced concrete.
Recommended: CE 383 or CE 481

CE 590, SELECTED TOPICS IN TRANSPORTATION ENGINEERING, 1-3 Credits
Selected topics on contemporary problems in transportation engineering; application of ongoing research from resident and visiting faculty. This course is repeatable for 9 credits.

CE 591, TRANSPORTATION SYSTEMS ANALYSIS, PLANNING, AND POLICY, 3 Credits

CE 592, PAVEMENT STRUCTURES, 3 Credits
Design and rehabilitation of pavement structures for streets, highways, and airports.
Recommended: CE 392

CE 593, TRAFFIC FLOW ANALYSIS AND CONTROL, 4 Credits
Traffic operations and control systems; traffic flow theory and stream characteristics; capacity analysis; traffic models and simulation; accident and safety improvement. Offered alternate years.

CE 594, TRANSPORT FACILITY DESIGN, 4 Credits
Location and design of highways, and other surface transportation terminals; design for safety, energy efficiency, and environmental quality. Offered alternate years. Lec/rec.
Recommended: CE 392

CE 595, TRAFFIC OPERATIONS AND DESIGN, 3 Credits
Traffic operations and engineering; human and vehicular characteristics; traffic stream characteristics; highway capacity analysis; intersection operation, control and design.
Recommended: Completion or concurrent enrollment in CE 491

CE 596, PAVEMENT EVALUATION AND MANAGEMENT, 3 Credits
Advanced topics in pavement evaluation techniques and pavement management procedures.
Recommended: CE 492

CE 597, PUBLIC TRANSPORTATION, 3 Credits
Characteristics and nature of public transportation systems, including bus, light and heavy rail; financing policy considerations; planning transit service; managing and operating transit systems for small and large urban areas. Offered alternate years.

CE 598, AIRPORT PLANNING AND DESIGN, 3 Credits
Characteristics and nature of the air transport system. Airport financing, air traffic control. Analysis and design of airports and the airport planning processes. Airport appurtenances. Airport pavement design, environmental facilities and drainage. Offered alternate years.

CE 599, INTELLIGENT TRANSPORTATION SYSTEMS, 3 Credits
Introduction to intelligent transportation systems, including enabling surveillance, navigation, communication and computer technologies. Application of technologies for monitoring, analysis evaluation and prediction of transportation system performance. Intervention strategies, costs and benefits, safety, human factors, institutional issues and case studies. Offered alternate years.
Recommended: CE 491 for new graduate students

CE 601, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

CE 603, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

CE 605, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

CE 606, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.
CE 607, OCEAN ENGINEERING SEMINAR, 1 Credit
Presentations from on-campus and off-campus speakers discussing state of technology topics in ocean engineering research, development, and construction. Graded P/N. This course is repeatable for 16 credits.

CE 630, OCEAN WAVE MECHANICS I, 3 Credits
Linear wave boundary value problem formulation and solution, water particle kinematics, shoaling, refraction, diffraction, and reflection. Linear long wave theory with applications to tides, seiching, and storm surge. CROSSLISTED as CE 630/OC 630. Equivalent to: OC 630

CE 631, OCEAN WAVE MECHANICS II, 3 Credits
Second in the sequence of ocean wave engineering mechanics, covers the following topics: introduction to long wave theory, wave superposition, wave height distribution, and the wind-wave spectrum, introduction to wave forces, and basic nonlinear properties of water waves. May include additional selected topic in wave mechanics. CROSSLISTED as CE 631/OC 631. Prerequisite: (CE 630 with C or better or OC 630 with C or better) Equivalent to: OC 631

CE 634, LONG WAVE MECHANICS, 3 Credits
Theory of long waves. Depth-integrated Euler's equation and its jump conditions. Evolution equations and their solutions. Nonlinear shallow-water waves, the Korteweg-deVries equation and Boussinesq equation. Boundary-layer effects. Shallow-water waves on beaches. Applications of the fundamentals to problems of tsunamis. CROSSLISTED as CE 634/OC 634. Prerequisite: (CE 630 with C or better and CE 631 [C]) Equivalent to: OC 670

CE 639, DYNAMICS OF OCEAN STRUCTURES, 3 Credits
Dynamic response of fixed and compliant structures to wind, wave and current loading; Morison equation and diffraction theory for wave and current load modeling, time and frequency domain solution methods; application of spectral and time series analyses; system parameter identification; and stochastic analysis of fatigue and response to extreme loads. Offered alternate years.

CE 640, SELECTED TOPICS IN OCEAN AND COASTAL ENGINEERING, 1-3 Credits
Selected topics on contemporary problems in ocean and coastal engineering; application of ongoing research from resident and visiting faculty. Offered alternate years. This course is repeatable for 9 credits. Recommended: CE 630

CE 642, RANDOM WAVE MECHANICS, 3 Credits
Random wave theories, probability and statistics of random waves and wave forces, time series analyses of stochastic processes, ocean wave spectra. Offered alternate years. Prerequisite: CE 630 with C or better

CE 643, COASTAL ENGINEERING, 3 Credits
Coastal sediment transport including nearshore currents, longshore onshore-offshore transport, and shoreline configuration; equilibrium beach profile concept with application to shore protection; shoreline modeling; tidal inlet hydrodynamics and inlet stabilization; design criteria for soft structures. Offered alternate years. Prerequisite: CE 630 with C or better

CE 645, WAVE FORCES ON STRUCTURES, 3 Credits
Wave forces on small and large members, dimensional analyses and scaling of equations, identification and selection of force coefficients for Morison equation; compatibility of wave kinematics and force coefficients in Morison equation, diffraction and radiation of surface gravity waves by large floating bodies, wavemaker problem, and reciprocity relations. Prerequisite: CE 630 with C or better

CE 647, OCEAN AND COASTAL ENGINEERING MEASUREMENTS, 3 Credits
Hands-on experience in the conduct of field and laboratory observations, including waves, currents, wind, tides, tsunami, sediments, bathymetry, shore profiles, wave forces on structures, and structural response. Online data archival and retrieval systems. Prerequisite: CE 630 with C or better

CE 661, KINEMATIC POSITIONING AND NAVIGATION, 3 Credits
Application of Global Navigation Satellite System (GNSS) aided Inertial Navigation Systems (INS) to directly georeference survey data acquired from a moving platform, such as an unmanned aircraft system (UAS), conventional aircraft, survey boat, or all-terrain vehicle. Topics include 3D coordinate transformations, dead-reckoning, inertial navigation, kinematic GNSS, Kalman filtering, and sensor modeling. Recommended: Undergraduate surveying course, such as CE 361, CE 263 or FE 208, and some exposure to MATLAB

CE 663, GEODESY, 4 Credits
Covers the geometrical aspects of terrestrial and celestial reference systems as well as modern realizations of these coordinate systems. In addition, an introductory level of the physical geodesy is also included, such as gravitational and gravity fields in order to deal with the geoid and heights. From this course, students are expected to understand the core elements of geometric and physical earth, which will assist them to have a solid background for other geospatial related studies. Recommended: CE 202 or CE 361

CE 808, WORKSHOP, 1-16 Credits
This course is repeatable for 16 credits.
College of Engineering

Construction Engineering Management (CEM)

**CEM 263, PLANE SURVEYING, 3 Credits**
Use of field surveying equipment; error analysis; plane surveying methods applied to construction; plane coordinate computations; topographic mapping; and introduction to GPS. Lec/lab.
Prerequisite: ENGR 211 with C or better or ENGR 211H with C or better

**CEM 311, HYDRAULICS, 4 Credits**
Pressure and energy concepts of fluids, fluid measurements, flow in pipes and open channels.
Prerequisite: ENGR 211 with C or better or ENGR 211H with C or better

**CEM 326, CONSTRUCTION SAFETY, 3 Credits**
Training in construction safety with emphasis on hazard identification, avoidance, control, and prevention.
Prerequisite: CCE 207 with C or better or CEM 407 with C or better

**CEM 341, CONSTRUCTION ESTIMATING I, 4 Credits**
Fundamentals of estimating and bidding construction projects; plan reading, specification interpretation; quantity take-off; types of estimates; estimating and methods of construction for sitework, concrete, and carpentry; estimating subcontracts, estimating job overhead and home office overhead; estimating profit, and computer-aided estimating.
Prerequisite: CEM 442 with C or better
Recommended: CCE 102 and CCE 201

**CEM 342, CONSTRUCTION ESTIMATING II, 4 Credits**
Fundamentals of estimating and bidding construction projects; plan reading, specification interpretation; quantity take-off; types of estimates; estimating and methods of construction for sitework, concrete, and carpentry; estimating subcontracts, estimating job overhead and home office overhead; estimating profit, and computer-aided estimating.
Prerequisite: CEM 341 with C or better

**CEM 343, CONSTRUCTION PLANNING AND SCHEDULING, 4 Credits**
Principles of construction planning, scheduling, and resource optimization; scheduling techniques and calculations; methods for integrating project resources (materials, equipment, personnel, and money) into the schedule.
Prerequisite: CEM 342 (may be taken concurrently) with C or better

**CEM 381, STRUCTURES I, 4 Credits**
Introduction to statically determinate analysis and design of steel structures. Lec/rec.
Prerequisite: ENGR 213 with C or better or ENGR 213H with C or better
Available via Ecampus

**CEM 383, STRUCTURES II, 4 Credits**
Analysis and design of building elements of concrete and timber; detailing and fabrication. Lec/rec.
Prerequisite: CCE 321 (may be taken concurrently) with C or better and CEM 381 [C]

**CEM 403, THESIS, 1-16 Credits**
This course is repeatable for 16 credits.

**CEM 405, READING AND CONFERENCE, 1-16 Credits**
This course is repeatable for 16 credits.

**CEM 406, PROJECTS, 1-16 Credits**
This course is repeatable for 16 credits.

**CEM 407, SEMINAR, 1 Credit**
Professional practices of construction engineering management.

**CEM 431, OBTAINING CONSTRUCTION CONTRACTS, 4 Credits**
Preparing and effectively presenting detailed and complete proposals for the execution of construction projects.
Prerequisite: CEM 341 with C or better
Equivalent to: CEM 432

**CEM 432, CONSTRUCTION PROJECT PLANNING, 3 Credits**
Planning and preparing cost estimates, schedules, site logistics plans for executing construction projects; presenting written and oral construction proposals.
Prerequisite: CEM 341 with C or better
Equivalent to: CEM 431

**CEM 441, HEAVY CIVIL CONSTRUCTION MANAGEMENT, 4 Credits**
Heavy civil construction management methods. Construction equipment types, capabilities, costs, productivity, and the selection and planning of equipment needed for a project. Soil characteristics, quantity analysis, and movement on construction sites.
Prerequisite: FE 315 with C or better or CE 372 with C or better

**CEM 442, BUILDING CONSTRUCTION MANAGEMENT, 4 Credits**
Building construction management and methods.
Prerequisite: CCE 207 with C or better or CEM 407 with C or better

**CEM 443, PROJECT MANAGEMENT FOR CONSTRUCTION, 4 Credits**
Project management concepts for construction; concepts, roles and responsibilities, labor relations and supervision, administrative systems, documentation, quality management, and process improvement. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: CEM 341 with C or better and CEM 343 [C]

**CEM 471, ELECTRICAL FACILITIES, 4 Credits**
Principles and applications of electrical components of constructed facilities; basic electrical circuit theory, power, motors, controls, codes, and building distribution systems. Lec/lab.
Prerequisite: CCE 207 with C or better or CEM 407 with C or better
CEM 472, MECHANICAL FACILITIES, 3 Credits
Principles and applications of mechanical components of constructed facilities; heating, ventilating, air conditioning, plumbing, fire protection, and other mechanical construction.
Prerequisite: CCE 207 with C or better or CEM 407 with C or better

CEM 541, HEAVY CIVIL CONSTRUCTION MANAGEMENT, 4 Credits
Heavy civil construction management methods. Construction equipment types, capabilities, costs, productivity, and the selection and planning of equipment needed for a project. Soil characteristics, quantity analysis, and movement on construction sites.
Recommended: FE 315 or CE 372

CEM 543, PROJECT MANAGEMENT FOR CONSTRUCTION, 4 Credits
Project management concepts for construction; concepts, roles and responsibilities, labor relations and supervision, administrative systems, documentation, quality management, and process improvement.

CEM 550, CONTEMPORARY TOPICS IN CONSTRUCTION ENGINEERING MANAGEMENT, 4 Credits
Contemporary topics of emerging technologies and processes, construction engineering and management, how industry environmental change causes development of new technologies, and the applications of the technologies in the field.

CEM 551, PROJECT CONTROLS, 4 Credits
Advanced methods of project controls including advanced technologies and methodologies for quality, time, and cost management; project management organization models, and intra-organizational relationships.

Chemical Engineering (CHE)
CHE 199, SPECIAL TOPICS, 1-16 Credits
Equivalent to: CHE 199H
This course is repeatable for 99 credits.

CHE 199H, SPECIAL TOPICS, 1-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: CHE 199

CHE 299, PROFESSIONAL WORKSKILLS, 1-16 Credits
Equivalent to: CHE 299H
This course is repeatable for 99 credits.
Available via Ecampus

CHE 311, THERMODYNAMICS, 3 Credits
Entropy, the second law of thermodynamics, equations of state, and thermodynamic network.
Prerequisite: (CBEE 212 with C or better or CBEE 212H with C or better or CBEE 280 with C or better) and (MTH 256 [C] or MTH 256H [C])

CHE 312, CHEMICAL ENGINEERING THERMODYNAMICS, 3 Credits
Thermodynamic mixtures, fugacity, phase equilibrium, and chemical reactions equilibrium.
Prerequisite: CHE 311 with C or better

CHE 320, SAFETY, ENGINEERING ETHICS AND PROFESSIONALISM, 3 Credits
Introduction to engineering ethics and safety concepts. Topics include professional engineering responsibility, codes of ethics, ethical assessment, conflicts of interest, loyalty and dissent, life-long learning, hazard identification, risk and safety, and process safety management. Lec/rec.
Prerequisite: CBEE 212 with C or better or CBEE 212H with C or better or CBEE 280 with C or better

CHE 331, TRANSPORT PHENOMENA I, 4 Credits
Fundamentals and application of momentum and energy transfer phenomena to fluid flow for the design of industrial chemical engineering equipment.
Prerequisite: (MTH 256 with C or better or MTH 256H with C or better) and (CHE 311 [C] or CHE 311H [C])
Equivalent to: CHE 323, CHE 331H

CHE 331H, TRANSPORT PHENOMENA I, 4 Credits
A unified treatment using control volume and differential analysis of heat transfer, prediction of heat transport properties, and introduction to heat transfer operations.
Attributes: HNRS – Honors Course Designator
Prerequisite: (MTH 256 with C or better or MTH 256H with C or better) and (CHE 311 [C] or CHE 311H [C])
Equivalent to: CHE 332H

CHE 332, TRANSPORT PHENOMENA II, 3 Credits
A unified treatment using control volume and differential analysis of heat transfer, prediction of heat transport properties, and introduction to heat transfer operations.
Attributes: HNRS – Honors Course Designator
Prerequisite: CHE 311 with C or better and (CHE 331 [C] or CHE 331H [C])
Equivalent to: CHE 332
CHE 333, TRANSPORT PHENOMENA III, 3 Credits
A unified treatment using control volume and differential analysis of binary mass transfer, prediction of mass transport properties, and introduction to mass transfer operations. Lec/studio.
Prerequisite: CHE 331 with C or better or CHE 331H with C or better or CHE 332 with C or better or CHE 332H with C or better
Equivalent to: CHE 333H

CHE 333H, TRANSPORT PHENOMENA III, 3 Credits
A unified treatment using control volume and differential analysis of binary mass transfer, prediction of mass transport properties, and introduction to mass transfer operations. Lec/studio.
Attributes: HNRS – Honors Course Designator
Prerequisite: CHE 331 with C or better or CHE 331H with C or better or CHE 332 with C or better or CHE 332H with C or better
Equivalent to: CHE 333

CHE 334, TRANSPORT PHENOMENA LABORATORY, 3 Credits
Engineering lab practices and the application of the macroscopic balances of mass, energy, and chemical species; fluid flow, heat and mass transfer experiments by teams for demonstrations of principles established in previous transport phenomena courses.
Prerequisite: CBEE 213 (may be taken concurrently) with C or better and (CHE 333 (may be taken concurrently) [C] or CHE 333H (may be taken concurrently) [C])

CHE 361, CHEMICAL PROCESS DYNAMICS AND SIMULATION, 3 Credits
Fundamental principles for process dynamic modeling used in the control of process variables such as pressure, temperature, flow rate and chemical composition.
Prerequisite: (MTH 256 with C or better or MTH 256H with C or better) and (CHE 331 [C] or CHE 331H [C])
Recommended: CBEE 102 and completion of concurrent enrollment in (CHE 331 or CHE 331H)

CHE 399, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

CHE 401, RESEARCH, 1-16 Credits
Equivalent to: CHE 401H
This course is repeatable for 16 credits.

CHE 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

CHE 405, READING AND CONFERENCE, 1-16 Credits
Equivalent to: CHE 405H
This course is repeatable for 16 credits.

CHE 405H, READING AND CONFERENCE, 1-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: CHE 405
This course is repeatable for 16 credits.

CHE 406, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

CHE 408, WORKSHOP, 1-16 Credits
This course is repeatable for 16 credits.

CHE 410, INTERNSHIP, 1-16 Credits
Available via Ecampus

CHE 411, MASS TRANSFER OPERATIONS, 4 Credits
Mass transfer operations; design of separation processes. Lec/rec.
Prerequisite: CHE 312 with C or better and (CHE 333 [C] or CHE 333H [C])

CHE 415, CHEMICAL ENGINEERING LABORATORY I, 3 Credits
Theoretical and empirical analysis of several unit operations, use of formal work processes, safety, teamwork, oral and written communication, and personal accountability. Lec/lab/rec.
Prerequisite: CBEE 414 with C or better and CHE 411 [C] and CHE 443 [C] and CHE 361 (may be taken concurrently) [C]
Equivalent to: CHE 415H, ENVE 415

CHE 417, INSTRUMENTATION IN CHEMICAL, BIOLOGICAL, AND ENVIRONMENTAL ENGINEERING, 4 Credits
Equips students with a toolbox of instrumental techniques important in chemical, biological, and environmental engineering and the background required to determine the appropriate instrumental technique to address a specific problem. Lec/lab/rec.
Prerequisite: CH 332 with C or better or CH 335 with C or better
Recommended: (CH 231 or CH 231H) and (CH 261 or CH 261H) and (CH 232 or CH 232H) and (CH 262 or CH 262H) and (CH 233 or CH 233H) and (CH 263 or CH 263H)

CHE 431, CHEMICAL PLANT DESIGN I, 3 Credits
Short-cut techniques and other abbreviated and useful methods for specifying equipment sufficient for the preliminary design of processes and equipment; estimating capital and manufacturing costs based on equipment specifications.
Prerequisite: CHE 312 with C or better and CHE 411 [C] and CHE 443 [C]

CHE 432, CHEMICAL PLANT DESIGN II, 3 Credits
Transformation of preliminary design to detailed design; introduction to safety, ethical, economical, and environmental considerations in chemical plant design.
Prerequisite: CHE 431 with C or better
CHE 443, CHEMICAL REACTION ENGINEERING, 4 Credits
Design of chemical reactors for economical processes and waste minimization. Contacting patterns, kinetics and transport rate effects in single phase and catalytic systems.
Prerequisite: CHE 312 with C or better and (CHE 333 [C] or CHE 333H [C])

CHE 444, THIN FILM MATERIALS PROCESSING, 4 Credits
Solid state devices are based on the patterning of thin films. This lecture and lab course is primarily an introduction to the technology associated with processing thin films. Topics include chemical vapor deposition, physical vapor deposition, plasma etching, and thin-film characterization. Lec/lab/rec.
Prerequisite: CHE 443 (may be taken concurrently) with C or better
Recommended: CHE 443

CHE 445, POLYMER ENGINEERING AND SCIENCE, 4 Credits
Polymer engineering and science with an emphasis on practical applications and recent developments. Topics include polymer synthesis, characterization, mechanical properties, rheology, and processing at a level suitable for most engineering and science majors. Lec/lab/rec.
Recommended: CH 334 and CH 335 and CH 336 and (MTH 256 or MTH 256H) and/or junior standing in engineering or science

CHE 450, CONVENTIONAL AND ALTERNATIVE ENERGY SYSTEMS, 3 Credits
Principles of energy conversion from chemical/mechanical energy to electrical energy including an overview of conventional energy systems and of likely renewable energy systems with a focus on the fundamental physico-chemical and thermodynamic concept for each technology. The economics of energy systems will also be discussed.
Prerequisite: CHE 311 (may be taken concurrently) with C or better or ME 311 (may be taken concurrently) with C or better or ME 311H (may be taken concurrently) with C or better or CH 440 (may be taken concurrently) with C or better

CHE 451, SOLAR ENERGY TECHNOLOGIES, 3 Credits
A foundation in the principles of solar energy processes is provided. Topics covered include photovoltaics and solar thermal, and will cover the fundamental solid state physics of semiconductors to applied heat transfer analysis of solar collectors. The course objective is to equip students with an adequate depth of understanding of the operational principles of solar energy systems, and to cover the breadth of the various approaches employed in active solar energy systems.
Prerequisite: CHE 311 (may be taken concurrently) with C or better or ME 311 (may be taken concurrently) with C or better or ME 311H (may be taken concurrently) with C or better or CH 440 (may be taken concurrently) with C or better
Recommended: CHE 311

CHE 452, ELECTROCHEMICAL ENERGY SYSTEMS, 3 Credits
Introduces principles and processes of electrochemical energy storage and conversion systems. Topics include fundamentals of electrochemistry and concepts of electrochemical energy storage systems. Examples from batteries, fuel cells, supercapacitors devices will be discussed. Lec/rec.
Prerequisite: CHE 311 with C or better and (CHE 333 [C] or CHE 333H [C])

CHE 461, PROCESS CONTROL, 3 Credits
Principles of PID feedback control based on models of chemical processes; analysis and implementation of proportional, integral and derivative tuning; cascade, feedforward, ratio and deadtime compensation; multivariable control and control system design issues and methods.
Prerequisite: (CHE 331 with C or better or CHE 331H with C or better) and (CHE 332 (may be taken concurrently) [C] or CHE 332H (may be taken concurrently) [C]) and CHE 361 [C]

CHE 499, SPECIAL TOPICS, 0-4 Credits
This course is repeatable for 8 credits.

CHE 501, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

CHE 503, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

CHE 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

CHE 506, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

CHE 510, INTERNSHIP, 1-16 Credits
This course is repeatable for 16 credits.

CHE 514, FLUID FLOW, 4 Credits
Fundamentals of fluid dynamics for Newtonian and non-Newtonian fluids; flow through porous media; two-phase flow. Lec/rec.

CHE 517, INSTRUMENTATION IN CHEMICAL, BIOLOGICAL, AND ENVIRONMENTAL ENGINEERING, 4 Credits
Equips students with a toolbox of instrumental techniques important in chemical, biological, and environmental engineering and the background required to determine the appropriate instrumental technique to address a specific problem. Lec/lab/rec.
Recommended: (CH 231 and CH 261 and CH 232 and CH 262 and CH 233 and CH 263)

CHE 520, MASS TRANSFER I, 4 Credits
CHE 525, CHEMICAL ENGINEERING ANALYSIS, 4 Credits
Modeling of physical and chemical processes; mathematical analysis of models with appropriate advanced techniques.

CHE 537, CHEMICAL ENGINEERING THERMODYNAMICS I, 4 Credits
Applications of the fundamental laws of thermodynamics to complex systems. Properties of solutions of non-electrolytes. Phase and chemical equilibrium.

CHE 540, CHEMICAL REACTORS I, 4 Credits
Catalysis, reactions coupled with transport phenomena. Reactors for high tech applications.

CHE 541, CATALYSIS, 3 Credits
Introduction to topics related to catalysts and catalytic reactions. Course covers catalytic reaction mechanisms and kinetics, catalyst characterization and testing, and catalyst preparation and manufacturing processes.

CHE 542, MOLECULAR ASPECTS OF HETEROGENEOUS CATALYSIS, 3 Credits
Introducing the principles of heterogeneous catalysis from the molecular aspect with emphasis on computational molecular approaches and surface science. The role of surface structure in heterogeneous catalytic reactions and surface interactions, development and analysis of reaction kinetics through microkinetic modeling approaches will be covered. A class project will utilize Density Functional Theory software to calculate catalytic properties of model systems.
Prerequisite: CHE 540 with C or better

CHE 544, THIN FILM MATERIALS PROCESSING, 4 Credits
Solid state devices are based on the patterning of thin films. This lecture and lab course is primarily an introduction to the technology associated with processing thin films. Topics include chemical vapor deposition, physical vapor deposition, plasma etching, and thin-film characterization. Lec/lab/rec.
Recommended: CHE 443 or CHE 543

CHE 545, POLYMER ENGINEERING AND SCIENCE, 4 Credits
Polymer engineering and science with an emphasis on practical applications and recent developments. Topics include polymer synthesis, characterization, mechanical properties, rheology, and processing at a level suitable for most engineering and science majors. Lec/lab/rec.
Recommended: CH 334 and CH 335 and CH 336 and MTH 256

CHE 550, CONVENTIONAL AND ALTERNATIVE ENERGY SYSTEMS, 3 Credits
Principles of energy conversion from chemical/mechanical energy to electrical energy including an overview of conventional energy systems and of likely renewable energy systems with a focus on the fundamental physico-chemical and thermodynamic concept for each technology. The economics of energy systems will also be discussed.
Recommended: CHE 311 or ME 311 or ME 311H

CHE 551, SOLAR ENERGY TECHNOLOGIES, 3 Credits
A foundation in the principles of solar energy processes is provided. Topics covered include photovoltaics and solar thermal, and will cover the fundamental solid state physics of semiconductors to applied heat transfer analysis of solar collectors. The course objective is to equip students with an adequate depth of understanding of the operational principles of solar energy systems, and to cover the breadth of the various approaches employed in active solar energy systems.
Recommended: CHE 311

CHE 552, ELECTROCHEMICAL ENERGY SYSTEMS, 3 Credits
Introduces principles and processes of electrochemical energy storage and conversion systems. Topics include fundamentals of electrochemistry and concepts of electrochemical energy storage systems. Examples from batteries, fuel cells, supercapacitors devices will be discussed. Lec/rec.
Recommended: CHE 311 AND (CHE 333 or CHE 333H)

CHE 581, SELECTED TOPICS, 3 Credits
Non-sequence course designed to acquaint students with recent advances in chemical engineering. Topics vary from term to term and from year to year. May be repeated for credit.
This course is repeatable for 9 credits.
Available via Ecampus

CHE 599, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

CHE 601, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

CHE 603, THESIS, 1-16 Credits
This course is repeatable for 99 credits.

CHE 605, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

CHE 606, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.
CHE 611, ELECTRONIC MATERIALS PROCESSING, 3 Credits
Technology, theory, and analysis of processing methods used in integration circuit fabrication. Offered alternate years. CROSSLISTED as CHE 611/ECE 611.
Equivalent to: CHE 571, ECE 611

CHE 612, PROCESS INTEGRATION, 3 Credits
Process integration, simulation, and statistical quality control issues related to integrated circuit fabrication. Offered alternate years. CROSSLISTED as CHE 612/ECE 612.
Equivalent to: CHE 572, ECE 612
Recommended: CHE 611 or ECE 611

CHE 613, ELECTRONIC MATERIALS AND CHARACTERIZATION, 3 Credits
Physics and chemistry of electronic materials and methods of materials characterization. Offered alternate years. CROSSLISTED as CHE 613/ECE 613.
Equivalent to: CHE 573, ECE 613

Computer Science (CS)

CS 101, COMPUTERS: APPLICATIONS AND IMPLICATIONS, 4 Credits
The varieties of computer hardware and software. The effects, positive and negative, of computers on human lives. Ethical implications of information technology. Hands-on experience with a variety of computer applications. Lec/lab.
Available via Ecampus

CS 160, COMPUTER SCIENCE ORIENTATION, 3 Credits
Introduction to the computer science field and profession. Team problem solving. Introduction to writing computer programs. Approaches to teaching course topics vary across sections. Lec/lab.
Equivalent to: CS 160H
Available via Ecampus

CS 160H, COMPUTER SCIENCE ORIENTATION, 3 Credits
Introduction to the computer science field and profession. Team problem solving. Introduction to writing computer programs. Approaches to teaching course topics vary across sections. Lec/lab.
Attributes: HNRS – Honors Course Designator
Equivalent to: CS 160

CS 161, INTRODUCTION TO COMPUTER SCIENCE I, 4 Credits
Overview of fundamental concepts of computer science. Introduction to problem solving, software engineering, and object-oriented programming. Includes algorithm design and program development. Lec/lab/rec.
Prerequisite: MTH 112 (may be taken concurrently) with C or better or Math Placement Test with a score of 33 or Math Placement - ALEKS with a score of 061
Equivalent to: EECS 161
Available via Ecampus

CS 162, INTRODUCTION TO COMPUTER SCIENCE II, 4 Credits
Basic data structures. Computer programming techniques and application of software engineering principles. Introduction to analysis of programs. Lec/lab/rec.
Prerequisite: CS 161 with C or better or EECS 161 with C or better
Equivalent to: EECS 162

Available via Ecampus

CS 165, ACCELERATED INTRODUCTION TO COMPUTER SCIENCE, 8 Credits
Overview of the fundamental concepts of computer science. Introduction to problem solving, algorithm development, data types, and basic data structures. Introduction to analysis of algorithms and principles of software engineering. System development and computer programming using procedural/object-oriented paradigms. Offered via Ecampus only.
Prerequisite: MTH 112 with C or better or Math Placement - ALEKS with a score of 075
Available via Ecampus

CS 175, *COMMUNICATIONS SECURITY AND SOCIAL MOVEMENTS, 3 Credits
Equipping students with the theory and practice of communications security, this course explores how social movements can remain effective in the context of mass surveillance and state repression. Lec/rec. (Bacc Core Course)
Attributes: CPDP – Core, Perspective, Difference/Power/Discrimination

CS 195, WEBSITE DESIGN, 4 Credits
How to design and publish a static website using an existing publishing platform: Techniques and tools for designing and publishing on the World Wide Web; hypertext and HTML; site and page design; media integration; issues raised by Internet publishing.
Equivalent to: CS 295

CS 199, SPECIAL TOPICS/COMPUTER SCIENCE, 1-16 Credits
This course is repeatable for 16 credits.
Available via Ecampus

CS 201, COMPUTER PROGRAMMING FOR NON-CS MAJORS, 3 Credits
Covers a variety of fundamental topics in computer programming relevant to anyone who wants to write or work with computer code in their work or studies. Teaches basic computational thinking and programming skills which will allow students to solve a variety of real-world problems. In addition, students will learn more advanced topics such as how some basic algorithms work and can be written in computer code.
Prerequisite: MTH 111 with C- or better
Available via Ecampus
CS 225, DISCRETE STRUCTURES IN COMPUTER SCIENCE, 4 Credits
An introduction to the discrete mathematics of computer science, including logic, set and set operations, methods of proof, recursive definitions, combinatorics, and graph theory. (Note: Students may take either MTH 231 or CS 225, but cannot receive credit for both.)
Prerequisite: MTH 111 with C or better or Math Placement Test with a score of 24 or Math Placement - ALEKS with a score of 061 or MTH 112 (may be taken concurrently) with C or better
Available via Ecampus

CS 261, DATA STRUCTURES, 4 Credits
Abstract data types, dynamic arrays, linked lists, trees and graphs, binary search trees, hash tables, storage management, complexity analysis of data structures. Lec/rec.
Prerequisite: (CS 162 with C or better or CS 165 with C or better) and (CS 225 [C] or MTH 231 [C])
Equivalent to: EECS 261
Available via Ecampus

CS 262, PROGRAMMING PROJECTS IN C++, 4 Credits
Learning a second computer programming language. Elements of C ++. Object-oriented programming. Experience team work on a large programming project.
Prerequisite: CS 261 with C or better

CS 271, COMPUTER ARCHITECTURE AND ASSEMBLY LANGUAGE, 4 Credits
Introduction to functional organization and operation of digital computers. Coverage of assembly language; addressing, stacks, argument passing, arithmetic operations, decisions, macros, modularization, linkers and debuggers.
Prerequisite: CS 151 with C or better or CS 161 with C or better or CS 165 with C or better
Available via Ecampus

CS 290, WEB DEVELOPMENT, 4 Credits
How to design and implement a multi-tier application using web technologies: Creation of extensive custom client- and server-side code, consistent with achieving a high-quality software architecture.
Prerequisite: CS 162 with C or better or CS 165 with C or better
Equivalent to: CS 494
Available via Ecampus

CS 295, WEBSITE MANAGEMENT, 4 Credits
How to create and promote a dynamic website using existing frameworks/libraries: Designing, developing, publishing, maintaining, and marketing dynamic websites; web security and privacy issues; emerging web technologies; running a website marketing campaign.
Prerequisite: CS 195 with C or better
Recommended: Basic HTML and CSS

CS 299, SPECIAL TOPICS, 0-4 Credits
This course is repeatable for 99 credits.

CS 312, SYSTEM ADMINISTRATION, 4 Credits
Prerequisite: (CS 311 with C or better or CS 344 with C or better) and CS 372 [C]

CS 321, INTRODUCTION TO THEORY OF COMPUTATION, 3 Credits
Survey of models of computation including finite automata, formal grammars, and Turing machines.
Prerequisite: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: CS 321H
Available via Ecampus

CS 321H, INTRODUCTION TO THEORY OF COMPUTATION, 3 Credits
Survey of models of computation including finite automata, formal grammars, and Turing machines.
Attributes: HNRS – Honors Course Designator
Prerequisite: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: CS 321

CS 325, ANALYSIS OF ALGORITHMS, 4 Credits
Recurrence relations, combinatorics, recursive algorithms, proofs of correctness.
Prerequisite: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: CS 325H
Available via Ecampus

CS 325H, ANALYSIS OF ALGORITHMS, 4 Credits
Recurrence relations, combinatorics, recursive algorithms, proofs of correctness.
Attributes: HNRS – Honors Course Designator
Prerequisite: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: CS 325

CS 331, INTRODUCTION TO ARTIFICIAL INTELLIGENCE, 4 Credits
Fundamental concepts in artificial intelligence using the unifying theme of an intelligent agent. Topics include agent architectures, search, games, logic and reasoning, and Bayesian networks.
Prerequisite: CS 325 with C or better or CS 325H with C or better

CS 340, INTRODUCTION TO DATABASES, 4 Credits
Design and implementation of relational databases, including data modeling with ER or UML, diagrams, relational schema, SQL queries, relational algebra, user interfaces, and administration.
Prerequisite: CS 290 with C or better
Equivalent to: CS 275
Available via Ecampus
CS 344, OPERATING SYSTEMS I, 4 Credits
Introduction to operating systems using UNIX as the case study. System calls and utilities, fundamentals of processes and interprocess communication.
Prerequisite: CS 261 with C or better and (CS 271 [C] or ECE 271 [C])
Equivalent to: CS 311
Recommended: Experience programming in the C language
Available via Ecampus

CS 352, INTRODUCTION TO USABILITY ENGINEERING, 4 Credits
Basic principles of usability engineering methods for the design and evaluation of software systems. Includes the study of human-machine interactions, user interface characteristics and design strategies, software evaluation methods, and related guidelines and standards.
Prerequisite: CS 151 with C or better or CS 161 with C or better or CS 165 with C or better or CS 295 with C or better or ECE 151 with C or better
Equivalent to: CS 252
Available via Ecampus

CS 361, SOFTWARE ENGINEERING I, 4 Credits
Introduction to the 'front end' of the software engineering lifecycle; requirements analysis and specification; design techniques; project management.
Prerequisite: CS 261 with C or better
Available via Ecampus

CS 362, SOFTWARE ENGINEERING II, 4 Credits
Introduction to the 'back end' of the software engineering lifecycle implementation; verification and validation; debugging; maintenance.
Prerequisite: CS 261 with C or better
Recommended: Experience with object-oriented programming and data structures (eg. CS 161, CS 162, CS 361)
Available via Ecampus

CS 370, INTRODUCTION TO SECURITY, 4 Credits
Introductory course on computer security with the objective to introduce concepts and principles of computer systems security. Notions of security, basic cryptograhic primitives and their applications, basics of authentication and access control, basics of key-management, basics of malware and software security.
Prerequisite: CS 344 (may be taken concurrently) with C or better
Available via Ecampus

CS 372, INTRODUCTION TO COMPUTER NETWORKS, 4 Credits
Computer network principles, fundamental networking concepts, packet-switching and circuit switching, TCP/IP protocol layers, reliable data transfer, congestion control, flow control, packet forwarding and routing, MAC addressing, multiple access techniques. CROSSLISTED as CS 372/ECE 372.
Prerequisite: CS 261 with C or better and (ECE 271 [C] or CS 271 [C])
Equivalent to: ECE 372
Recommended: C programming and Unix familiarity.
Available via Ecampus

CS 373, DEFENSE AGAINST THE DARK ARTS, 4 Credits
Introduction to the current state of the art in anti-malware, computer forensics, and networking, messaging, and web security. Broad introduction to the field of computer security.
Prerequisite: CS 344 with C or better and CS 340 [C] and CS 372 [C]
Available via Ecampus

CS 381, PROGRAMMING LANGUAGE FUNDAMENTALS, 4 Credits
An introduction to the concepts found in a variety of programming languages. Programming languages as tools for problem solving. A brief introduction to languages from a number of different paradigms.
Prerequisite: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Available via Ecampus

CS 391, *SOCIAL AND ETHICAL ISSUES IN COMPUTER SCIENCE, 3 Credits
In-depth exploration of the social, psychological, political, and ethical issues surrounding the computer industry and the evolving information society. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
Equivalent to: CS 391H, CS 391H
Recommended: CS 101 or computer literacy
Available via Ecampus

CS 391H, *SOCIAL AND ETHICAL ISSUES IN COMPUTER SCIENCE, 3 Credits
In-depth exploration of the social, psychological, political, and ethical issues surrounding the computer industry and the evolving information society. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society; HNRS – Honors Course Designator
Equivalent to: CS 391
Recommended: CS 101 or computer literacy

CS 395, WEBSITE MULTIMEDIA, 4 Credits
How to create and deploy interactive digital multimedia through static websites: Technological, aesthetic, and pedagogical issues of communication using interactive multimedia and hypermedia; techniques for authoring interactive multimedia projects using a variety of digital media roots.
Prerequisite: CS 195 with C or better or (ART 120 with C or better and (CS 162 [C] or CS 165 [C])
CS 399, SPECIAL TOPICS, 0-4 Credits
This course is repeatable for 99 credits.

CS 401, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

CS 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

CS 405, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.
CS 406, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.
Available via Ecampus

CS 407, SEMINAR, 1-16 Credits
Graded P/N.
Equivalent to: CS 407H
This course is repeatable for 16 credits.

CS 407H, SEMINAR, 1-16 Credits
Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: CS 407
This course is repeatable for 16 credits.

CS 410, OCCUPATIONAL INTERNSHIP, 1-16 Credits
Graded P/N.
This course is repeatable for 16 credits.

CS 419, SELECTED TOPICS IN COMPUTER SCIENCE, 0-5 Credits
Topics of special and current interest not covered in other courses.
Equivalent to: CS 419H
This course is repeatable for 99 credits.
Available via Ecampus

CS 419H, SELECTED TOPICS IN COMPUTER SCIENCE, 1-5 Credits
Topics of special and current interest not covered in other courses.
Attributes: HNRS – Honors Course Designator
Equivalent to: CS 419
This course is repeatable for 99 credits.

CS 420, GRAPH THEORY WITH APPLICATIONS TO COMPUTER SCIENCE, 3 Credits
Directed and undirected graphs; paths, circuits, trees, coloring, planar graphs, partitioning; computer representation of graphs and graph algorithms; applications in software complexity metrics, program testing, and compiling.
Prerequisite: (CS 325 with C or better or CS 325H with C or better)

CS 427, CRYPTOGRAPHY, 4 Credits
Introduction to the theory and practice of modern cryptography. Fundamental primitives including pseudorandom generators, block ciphers, hash functions. Symmetric-key cryptography for privacy and authenticity. Public-key cryptography based on number-theoretic problems.
Prerequisite: CS 261 with C or better or MTH 355 with C or better
Available via Ecampus

CS 434, MACHINE LEARNING AND DATA MINING, 4 Credits
Introduction to machine learning and data mining algorithms (supervised learning, unsupervised learning, and reinforcement learning) tools that are widely employed in industrial and research settings.
Prerequisite: CS 325 with C or better or CS 325H with C or better

CS 440, DATABASE MANAGEMENT SYSTEMS, 4 Credits
Relational database design, normalization, file structures, disk storage, query processing and optimization, team development of database applications.
Prerequisite: CS 261 with C or better and CS 340 [C]

CS 444, OPERATING SYSTEMS II, 4 Credits
Explores principles of computer operating systems: concurrent processes, memory management, job scheduling, multiprocessing, file systems, performance evaluation, and networking.
Prerequisite: CS 344 with C or better and (CS 271 [C] or ECE 375 [C])
Equivalent to: CS 411

CS 446, NETWORKS IN COMPUTATIONAL BIOLOGY, 3 Credits
Prerequisite: CS 261 with C or better or BOT 476 with C or better
Recommended: Completion or concurrent enrollment in CS 325

CS 447, WIRELESS EMBEDDED SYSTEMS, 4 Credits
A hands-on introduction to programming wireless embedded systems (aka the 'Internet of Things'). Topics include sensors, actuators, state machines, scheduling, wireless communications, time synchronization, localization, fault tolerance, and security related to cyber-physical systems.
Prerequisite: CS 344 with C or better

CS 450, INTRODUCTION TO COMPUTER GRAPHICS, 4 Credits
Theoretical and practical treatment of 3D computer graphics using OpenGL: geometric modeling, transformations, lighting, texture mapping, shading, rendering, and animation.
Prerequisite: CS 261 with C or better

CS 453, SCIENTIFIC VISUALIZATION, 4 Credits
Applies 3D computer graphics methods to visually understand scientific and engineering data. Methods include hyperbolic projections; mapping scalar values to color spaces; data visualization using range sliders; scalar visualization (point clouds, cutting planes, contour plots, isosurfaces); vector visualization (arrow clouds, particle advection, streamlines); terrain visualization; Delauney triangulation; and volume visualization.
Prerequisite: CS 261 with C or better
Recommended: Prior experience with Unix or Windows, programming experience.
CS 457, COMPUTER GRAPHICS SHADERS, 4 Credits
Theoretical and practical treatment of computer graphics shaders, including both RenderMan and GPU shaders. Programming in both RenderMan and OpenGL shading languages.
Recommended: Previous graphics pipeline programming experience.

CS 458, INTRODUCTION TO INFORMATION VISUALIZATION, 4 Credits
Tools and techniques for designing, developing, and deploying interactive visualizations of abstract data sources. Discusses techniques based on principles from design, cognitive science, and perceptual psychology. Topics include 1D, 2D, 3D, multivariate representations, time-series, graphs and trees, text and documents, and interaction techniques.
Prerequisite: CS 361 with C or better

CS 461, SENIOR SOFTWARE ENGINEERING PROJECT I, 3 Credits
Utilize software engineering methodology in a team environment to develop a real-world application. Teams will be responsible for all phases of software development, including project planning, requirements analysis, design, coding, testing, configuration management, quality assurance, documentation, and delivery. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: CS 361 with C or better and CS 325 [C] and CS 362 [C]
Available via Ecampus

CS 462, SENIOR SOFTWARE ENGINEERING PROJECT II, 3 Credits
Utilize software engineering methodology in a team environment to develop a real-world application. Teams will be responsible for all phases of software development, including project planning, requirements analysis, design, coding, testing, configuration management, quality assurance, documentation, and delivery. Three-term sequence required.
( Writing Intensive Courses)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: CS 362 with C or better and CS 461 [C]

CS 463, SENIOR SOFTWARE ENGINEERING PROJECT, 2 Credits
Utilize software engineering methodology in a team environment to develop a real-world application. Teams will be responsible for all phases of software development, including project planning, requirements analysis, design, coding, testing, configuration management, quality assurance, documentation, and delivery. Three-term sequence required.
Prerequisite: CS 462 with C or better

CS 464, OPEN SOURCE SOFTWARE, 4 Credits
Provides a theoretical foundation of the history, key concepts, technologies, and practices associated with modern Free and Open Source Software (FOSS) projects, and gives students an opportunity to explore and make contributions to FOSS projects with some mentoring and guidance.
Prerequisite: CS 261 with C or better and CS 361 [C]
Available via Ecampus

CS 466, WEB-BASED START-UP PROJECT, 4 Credits
Real-world, hands-on learning in a high-tech web/mobile-based company environment. Research in the development of product ideas, hypotheses, and business models to create customer experiments. Prototyping and statistical analysis to develop, optimize, and evaluate solutions. Rapid iteration/refactoring based on customer input, web analytics, and user engagement metrics. Offered at OSU-Cascades only.
Corequisites: CS 461

CS 467, ONLINE CAPSTONE PROJECT, 4 Credits
Real-world team-based experience with the software engineering design and delivery cycle, including requirements analysis and specification, design techniques, and requirements and final project written documentation. For students in the online CS double-degree program only.
Prerequisite: CS 344 with C or better and CS 361 [C] and CS 362 [C]
Available via Ecampus

CS 468, INCLUSIVE DESIGN (HCI), 4 Credits
Inclusive design is designing software that works for a wide variety of differently abled customers. Teaches the skills needed to design inclusively without having to have a separate design for each differently abled customer.
Prerequisite: CS 352 with C or better
Recommended: CS 565 with a minimum grade of C

CS 472, COMPUTER ARCHITECTURE, 4 Credits
Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSLISTED as CS 472/ ECE 472 and CS 572/ECE 572.
Prerequisite: ECE 375 with C or better
Equivalent to: CS 470, ECE 472

CS 475, INTRODUCTION TO PARALLEL PROGRAMMING, 4 Credits
Theoretical and practical survey of parallel programming, including a discussion of parallel architectures, parallel programming paradigms, and parallel algorithms. Programming one or more parallel computers in a higher-level parallel language.
Prerequisite: CS 261 with C or better
Available via Ecampus
CS 476, ADVANCED COMPUTER NETWORKING, 4 Credits
Prerequisite: (CS 372 with C or better or ECE 372 with C or better) and (ECE 353 [C] or ST 314 [C] or ST 314H [C])
Equivalent to: ECE 476, ECECS 476

CS 477, INTRODUCTION TO DIGITAL FORENSICS, 4 Credits
Introduces concepts related to digital forensics, its role and importance, and tools and techniques for collecting and curating digital evidence. The course will also discuss the role of evidence in the justice system and some legal aspects as they pertain to digital forensics. It will introduce tools and techniques for computer and network forensics.
Prerequisite: CS 344 with C or better and CS 370 [C]
Available via Ecampus

CS 478, NETWORK SECURITY, 4 Credits
Basic concepts and techniques in network security, risks and vulnerabilities, applied cryptography and various network security protocols. Coverage of high-level concepts such as authentication, confidentiality, integrity, and availability applied to networking systems. Fundamental techniques including authentication protocols, group key establishment and management, trusted intermediaries, public key infrastructures, SSL/TLS, IPSec, firewalls and intrusion detection. Crosslisted as CS 478/ECE 478.
Prerequisite: CS 372 with C or better or ECE 372 with C or better
Equivalent to: ECE 478
Recommended: CS 370
Available via Ecampus

CS 480, TRANSLATORS, 4 Credits
Explores content on the subject of compilers; attribute grammars, syntax-directed translation, lex, yacc, LR(1) parsers, symbol tables, semantic analysis, and peep-hole optimization.
Prerequisite: CS 344 with C or better and CS 381 [C] and (CS 321 [C] or CS 321H [C])

CS 491, COMPUTER SCIENCE SKILLS FOR SIMULATION AND GAME PROGRAMMING, 4 Credits
Game and simulation development is very much a data and math-intensive activity. A certain number of actions must be produced, and producing them by hand is hard. This is a middleware CS course that fills in many of the missing pieces for those wanting to enter the simulation and game development worlds in a software tool-building capacity.
Prerequisite: CS 261 with C or better and (CS 225 [C] or MTH 231 [C]) and MTH 252 [C]

CS 492, MOBILE SOFTWARE DEVELOPMENT, 4 Credits
Introduction to concepts and techniques for developing mobile applications. Students will become familiar with modern mobile structure, implementation, development tools, and workflow.
Prerequisite: CS 344 with C or better
Available via Ecampus

CS 493, CLOUD APPLICATION DEVELOPMENT, 4 Credits
Covers developing RESTful cloud services, an approach based on representational state transfer technology, an architectural style and approach to communications used in modern cloud services development.
Prerequisite: CS 290 with C or better and CS 340 [C] and CS 372 [C]
Available via Ecampus

CS 495, INTERACTIVE MULTIMEDIA PROJECTS, 4 Credits
Students apply principles and procedures of digital art, design, communication, and software authoring while working on large integrated media projects.
Recommended: CS 395

CS 496, MOBILE AND CLOUD SOFTWARE DEVELOPMENT, 4 Credits
Introduction to the concepts and techniques for developing mobile and cloud applications.
Prerequisite: CS 344 with C or better or CS 311 with C or better
Recommended: Working knowledge of at least one operating system

CS 499, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

CS 501, RESEARCH, 1-16 Credits
Graded P/N.
This course is repeatable for 99 credits.

CS 503, COMPUTER SCIENCE MS THESIS, 1-16 Credits
Graded P/N.
This course is repeatable for 999 credits.

CS 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 20 credits.

CS 506, PROJECTS, 1-16 Credits
Graded P/N.
This course is repeatable for 99 credits.

CS 507, SEMINAR, 1-16 Credits
Graded P/N.
This course is repeatable for 16 credits.

CS 510, OCCUPATIONAL INTERNSHIP, 1-4 Credits
This course is repeatable for 99 credits.
Available via Ecampus
CS 511, PROGRAMMING AND DATA STRUCTURES, 4 Credits
Computer programming, problem solving, data structures, object-oriented programming, recursion, sorting, dynamic programming, asymptotic time complexity
Recommended: College algebra, plus the ability to navigate an operating system, manipulate files, and use a command line.
Available via Ecampus

CS 512, DATA SCIENCE TOOLS AND PROGRAMMING, 4 Credits
Accessing and distributing data in the cloud; relational and non-relational databases; map reduction; cloud data processing; load balancing; types of data-stores used in the cloud.
Recommended: CS 511 or an equivalent course or programming experience in in a high-level language like Python, Java or C++.
Available via Ecampus

CS 515, ALGORITHMS AND DATA STRUCTURES, 4 Credits
Greedy algorithms, divide and conquer, dynamic programming, network flow, data structures.
Recommended: Undergraduate course in algorithms

CS 516, THEORY OF COMPUTATION AND FORMAL LANGUAGES, 4 Credits

CS 517, THEORY OF COMPUTATION, 4 Credits
Turing machines, decidability, NP-completeness, complexity classes, randomized computation, relativization, circuit complexity, interactive proof systems, lower bounds, cryptography.

CS 519, SELECTED TOPICS IN COMPUTER SCIENCE, 0-5 Credits
Topics of special and current interest not covered in other courses. May not be offered every year.
This course is repeatable for 99 credits.
Available via Ecampus

CS 520, GRAPH THEORY WITH APPLICATIONS TO COMPUTER SCIENCE, 3 Credits
Directed and undirected graphs; paths, circuits, trees, coloring, planar graphs, partitioning; computer representation of graphs and graph algorithms; applications in software complexity metrics, program testing, and compiling.
Recommended: CS 325 and MTH 232

CS 523, ADVANCED ALGORITHMS, 4 Credits
Approximation algorithms, randomized and probabilistic algorithms, online algorithms.
Recommended: CS 515

CS 527, ERROR-CORRECTING CODES, 4 Credits
Hamming codes, linear codes, cyclic codes, BCH and Reed-Solomon codes. Introduction to Galois fields. Encoding and decoding algorithms. Burst error correcting codes, asymmetric and unidirectional codes. Applications of codes for computer systems.
Recommended: Discrete math and probability

CS 529, SELECTED TOPICS IN THEORETICAL COMPUTER SCIENCE, 1-5 Credits
Topics of interest in algorithms and theory of computation. Topics include approximation algorithms, planar graph algorithms, distributed algorithms, combinatorial optimization, computational geometry.
This course is repeatable for 99 credits.
Recommended: CS 515

CS 531, ARTIFICIAL INTELLIGENCE, 4 Credits

CS 533, INTELLIGENT AGENTS AND DECISION MAKING, 4 Credits
Recommended: CS 531

CS 534, MACHINE LEARNING, 4 Credits

CS 535, DEEP LEARNING, 4 Credits
Prerequisite: CS 534 with C or better or ROB 537 with C or better
CS 536, PROBABILISTIC GRAPHICAL MODELS, 4 Credits
Representation of probabilistic graphical models, both directed (Bayesian networks) and undirected (Markov networks). Exact and approximate inference techniques. Parameter and structure learning from data.
Recommended: Strong programming skills

CS 537, COMPUTER VISION I, 3 Credits
An introduction to low-level computer vision and visual geometry. Topics of interest include the following: detection of interest points and edges, matching points and edges, color models, projective geometry, camera calibration, epipolar geometry, homography, image stitching, and multitarget tracking.
Recommended: Undergraduate-level statistics, probability, calculus, linear algebra, good programming skills, machine learning or AI

CS 539, SELECTED TOPICS IN ARTIFICIAL INTELLIGENCE, 0-5 Credits
Advanced topics in artificial intelligence. Typical topics include machine learning for sequential and spatial data, knowledge representation and inference, probabilistic modeling of complex systems, data mining and information extraction.
This course is repeatable for 99 credits.

CS 540, DATABASE MANAGEMENT SYSTEMS, 4 Credits
Purpose of database systems, levels of data representation. Entity-relationship model. Relational systems: data definition, data manipulation, query language (SQL), relational calculus and algebra, data dependencies and normal forms. DBTG network model. Query optimization, recovery, concurrency control.
Recommended: CS 261

CS 544, OPERATING SYSTEMS II, 4 Credits
Principles of computer operating systems: concurrent processes, memory management, job scheduling, multiprocessing, file systems, performance evaluation, and networking. Lec/rec.
Equivalent to: CS 511
Recommended: (CS 311 or CS 344) and (CS 271 or ECE 375)

CS 546, NETWORKS IN COMPUTATIONAL BIOLOGY, 3 Credits
Recommended: Completion or concurrent enrollment in CS 325

CS 549, SELECTED TOPICS ON DATA SCIENCE & SYSTEMS, 0-5 Credits
Current topics in data science and systems, e.g. querying, inference, and learning over large datasets; reasoning and learning on graph, heterogeneous, and multi-modal data; data curation; knowledge representation; systems for large data exploration and analytics; distributed data systems; human-centered data science; fairness and responsibility in data science.
This course is repeatable for 99 credits.
Recommended: CS 540

CS 550, INTRODUCTION TO COMPUTER GRAPHICS, 4 Credits
Theoretical and practical treatment of 3D computer graphics using OpenGL: geometric modeling, transformations, viewing, lighting, texture mapping, shading, rendering, and animation.
Recommended: CS 261

CS 551, COMPUTER GRAPHICS, 4 Credits
3-D graphics hardware: Line and polygon scan conversion, modeling transformations, viewing transformations, matrix stacks, hierarchical models, perspective and orthographic projections, visible surface determination, illumination models, shading models, texture mapping, ray tracing.
Recommended: CS 450 or CS 550

CS 552, COMPUTER ANIMATION, 4 Credits
Traditional animation concepts: production pipeline, keyframing implementation, interpolation, point-mass dynamics, spring-mass systems, rigid body dynamics, forward and inverse kinematics, human motion control, motion capture.
Recommended: CS 551

CS 553, SCIENTIFIC VISUALIZATION, 4 Credits
Applies 3D computer graphics methods to visually understand scientific and engineering data. Methods include hyperbolic projections; mapping scalar values to color spaces; data visualization using range sliders; scalar visualization (point clouds, cutting planes, contour plots, isosurfaces); vector visualization (arrow clouds, particle advection, streamlines); terrain visualization; Delauney triangulation; and volume visualization.
Recommended: Prior experience with Unix or Windows, programming experience.

CS 554, GEOMETRIC MODELING IN COMPUTER GRAPHICS, 4 Credits
Advanced topics in computer graphics focusing on representation and processing of polygonal models and their application. Surface fundamentals; discrete differential geometry and topology; data structures for representing 3-D surfaces; surface subdivision and smoothing; mesh simplification and multi-resolution representation of 3-D surfaces; geometry compression; surface parameterization; geometry remeshing; topological simplification; implicit surfaces.
Recommended: CS 450
CS 557, COMPUTER GRAPHICS SHADERS, 4 Credits
Theoretical and practical treatment of computer graphics shaders, including both RenderMan and GPU shaders. Programming in both RenderMan and OpenGL shading languages.
Recommended: Previous graphics pipeline programming experience.

CS 559, SELECTED TOPICS IN COMPUTER GRAPHICS AND VISION, 0-5 Credits
Advanced topics in graphics, animation, and vision. Topics include distribution ray tracing, global-illumination, radiosity, image-based modeling and rendering, vision-assisted image and video editing, 3-D vision, 3-D virtual environments, 3-D interaction, control for physical simulation, motion graphs, computational geometry, etc. This course is repeatable for 99 credits.

CS 560, DATA-DRIVEN SOFTWARE ENGINEERING, 4 Credits
An overview of data-driven empirical research methods that can be used to understand the different aspects of software engineering.
Prerequisite: CS 561 with C or better

CS 561, SOFTWARE ENGINEERING METHODS, 4 Credits
Master software engineering methods and supporting tools in the context of agile processes. Teams will engage in all aspects of software development including design, testing, implementation, deployment and maintenance. 3 hours of lecture per week plus one-hour independent lab per week.
Recommended: CS 362

CS 562, SOFTWARE PROJECT MANAGEMENT, 4 Credits
Master software project management with an emphasis on timely, cost-effective delivery of high-quality systems. Learn about existing techniques and supporting tools, with a particular focus on coordination and project management. 3 hours of lecture per week plus one-hour independent lab per week.
Recommended: CS 561

CS 563, SOFTWARE MAINTENANCE AND EVOLUTION, 4 Credits
Contribute to the cutting-edge of software engineering. Learn about existing techniques and supporting tools, with a particular focus on maintenance and evolution. Identify opportunities to support software maintenance and evolution more effectively, by creating new knowledge and supporting systems through research and innovation. 3 hours of lecture per week plus one-hour independent lab per week.
Prerequisite: CS 561 with C or better

CS 564, FIELD STUDIES IN SE AND HCI, 4 Credits
Deals with the type of empirical study known as the ‘case’ study. These are studies that collect data from natural software development situations as they really occur in the field, in which the researcher does not manipulate or ‘control’ anything. The course is an end-to-end coverage of the process. Mainly focuses on case studies involving human software developers in the field. The student will conduct a field study as part of this course.

CS 565, HUMAN-COMPUTER INTERACTION, 4 Credits
Basic principles of Human-Computer Interaction (HCI) for the design and evaluation of software systems. Includes research methods for studying human-machine interactions and user interfaces, design strategies, software evaluation methods, and related guidelines and standards.

CS 567, LABORATORY STUDIES IN SE AND HCI, 4 Credits
Empirical lab studies of software development. Covers how to go about designing, preparing for, running, analyzing, and writing-for-publication lab experiments of programming situations involving human subjects. This is an end-to-end coverage of the entire process, and will put students in a position to conduct lab studies of their own with human subjects.

CS 568, INCLUSIVE DESIGN (HCL), 4 Credits
Inclusive design is designing software that works for a wide variety of differently abled customers. Teaches the skills needed to design inclusively without having to have a separate design for each differently abled customer.
Recommended: CS 352 [C] or CS 565 [C]

CS 569, SELECTED TOPICS IN SOFTWARE ENGINEERING, 0-5 Credits
Topics include new programming methodologies, productivity, software development, software complexity metrics.
This course is repeatable for 99 credits.
Recommended: CS 561

CS 570, HIGH PERFORMANCE COMPUTER ARCHITECTURE, 4 Credits
Advanced concepts in computer architecture. Performance improvement employing advanced pipelining and multiple instruction scheduling techniques. Issues in memory hierarchy and management. Crosslisted as CS 570/ECE 570.
Equivalent to: ECE 570
Recommended: ECE 472 or ECE 572
CS 572, COMPUTER ARCHITECTURE, 4 Credits
Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSTLISTED as CS 472/ECE 472 and CS 572/ECE 572.
Equivalent to: ECE 375
Recommended: ECE 375

CS 575, INTRODUCTION TO PARALLEL PROGRAMMING, 4 Credits
Theoretical and practical survey of parallel programming, including a discussion of parallel architecture, parallel programming paradigms, and parallel algorithms. Programming one or more parallel computers in a higher-level parallel language.
Available via Ecampus

CS 576, ADVANCED COMPUTER NETWORKING, 4 Credits
Equivalent to: ECE 576
Recommended: (CS 372 or ECE 372) and (ECE 353 or ST 314 or ST 314H)

CS 578, CYBER-SECURITY, 4 Credits
A broad overview of the field of computer and network security. Essential cryptographic mechanisms such as symmetric and public-key cryptography (e.g., encryption, signatures), network security and authentication protocols (e.g., Kerberos, TLS, IPSec), system security (e.g., access control, firewalls), advanced topics (e.g., searchable encryption, cloud security, secure computation). CROSSTLISTED as CS 578/ECE 578.
Equivalent to: ECE 578

CS 579, TOPICS IN COMPUTER ARCHITECTURE AND PARALLEL PROCESSING, 0-5 Credits
Current topics in advanced computer architecture and parallel processing.
This course is repeatable for 99 credits.
Recommended: CS 575 or CS 572 or ECE 572

CS 581, PROGRAMMING LANGUAGES I, 4 Credits
Graduate-level introduction to functional programming and programming language theory. Strongly typed functional programming in Haskell, abstract syntax and grammars, interpreters, denotational semantics, domain theory, and lambda calculus.

CS 582, PROGRAMMING LANGUAGES II, 4 Credits
Essentials of programming language theory for understanding and conducting programming language research. Dependently typed programming in Agda, Coq, or Idris; operational semantics; type systems; unification and type inference.
Prerequisite: CS 581 with C or better

CS 583, ADVANCED FUNCTIONAL PROGRAMMING, 4 Credits
Advanced functional programming concepts and strategies, with a focus on techniques useful for the design and implementation of programming languages. Includes higher-order abstract syntax, functors and monads, generalized algebraic data types, functional data structures, and graph reduction.
Prerequisite: CS 581 with C or better

CS 585, DOMAIN-SPECIFIC LANGUAGES, 4 Credits
Graduate-level introduction to the design and implementation of domain-specific languages (DSLs). Domain analysis; review and revision of language designs; binding constructs to support abstraction; definition of syntax and semantics of DSLs; prototype implementation of embedded DSL.
Prerequisite: CS 581 with C or better

CS 589, SELECTED TOPICS IN PROGRAMMING LANGUAGES, 1-5 Credits
An in-depth examination of a specific topic of interest in programming language design and implementation. Example topics include object-oriented programming, parallel programming, compiler optimization, programming language semantics.
This course is repeatable for 99 credits.

CS 599, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

CS 601, RESEARCH, 1-16 Credits
Graded P/N.
This course is repeatable for 99 credits.

CS 603, COMPUTER SCIENCE PHD THESIS, 1-16 Credits
This course is repeatable for 999 credits.

CS 605, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

CS 607, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.
CS 637, COMPUTER VISION II, 4 Credits
An introduction to recent advances in visual recognition, including object detection, semantic segmentation, multimodal parsing of images and text, image captioning, face recognition, and human activity recognition. The course covers common formulations of these problems, including energy minimization on graphical models, and supervised machine learning approaches to low- and high-level recognition tasks.
Prerequisite: CS 535 with B+ or better or CS 537 with B- or better
Recommended: CS 519

Electrical & Computer Engineering (ECE)

ECE 111, INTRODUCTION TO ECE: TOOLS, 3 Credits
Introduction to the electrical and computer engineering professional practice. Covers the foundations of engineering problem solving and other skills necessary for success. Students will be taught engineering practice through hands-on approaches. Recommended for electrical and computer engineering majors, and for those interested in engineering as a profession. Lec/lab. Has extra fees.
Recommended: Completion or concurrent enrollment in MTH 111

ECE 112, INTRODUCTION TO ECE: CONCEPTS, 3 Credits
Basic electrical and computer engineering concepts, problem solving and hands-on laboratory project. Topics include electronic circuit and device models, digital logic, circuit analysis, and simulation tools. Lec/lab. Has extra fees.
Prerequisite: MTH 111 with C or better or MTH 112 with C or better or MTH 251 with C or better or MTH 251H with C or better or Math Placement Test with a score of 23

ECE 199, SPECIAL STUDIES, 0-16 Credits
One-credit section. Graded P/N. This course is repeatable for 16 credits.

ECE 271, DIGITAL LOGIC DESIGN, 3 Credits
A first course in digital logic design. Data types and representations, Boolean algebra, state machines, simplification of switching expressions, and introductory computer arithmetic. Lec/rec.
Prerequisite: MTH 251 (may be taken concurrently) with C or better or MTH 251H (may be taken concurrently) with C or better or MTH 231 (may be taken concurrently) with C or better

ECE 272, DIGITAL LOGIC DESIGN LABORATORY, 1 Credit
This laboratory course accompanies ECE 271, Digital Logic Design. This also illustrates topics covered in the lectures of ECE 271 using computer-aided design, verification tools, and prototyping hardware.
Recommended: Completion or concurrent enrollment in ECE 271

ECE 322, ELECTRONICS I, 3 Credits
Fundamental device characteristics including diodes, MOSFETs and bipolar transistors; small- and large-signal characteristics and design of linear circuits.
Prerequisite: ENGR 203 with C or better
Equivalent to: ECE 322H

ECE 322H, ELECTRONICS I, 3 Credits
Fundamental device characteristics including diodes, MOSFETs and bipolar transistors; small- and large-signal characteristics and design of linear circuits.
Attributes: HNRS – Honors Course Designator
Prerequisite: ENGR 203 with C or better
Equivalent to: ECE 322

ECE 323, ELECTRONICS II, 3 Credits
Transient operation of MOSFETs and bipolar transistors; multistage amplifiers; frequency response; feedback and stability.
Prerequisite: ECE 322 with C or better

ECE 331, ELECTROMECHANICAL ENERGY CONVERSION, 4 Credits
Energy conversion principles for electric machines. Steady state characteristics of direct current, induction, and synchronous machines. Application of stepper and servo motors and synchronous generators.
Prerequisite: (ENGR 202 with C or better or ENGR 202H with C or better) and MTH 256 [C] and PH 213 [C]

ECE 332, LABORATORY ON ELECTROMECHANICAL ENERGY CONVERSION, 1 Credit
DC, PMAC, and induction machine testing, operation, and control.
Prerequisite: ENGR 202 with C or better or ENGR 202H with C or better
Corequisites: ECE 331

ECE 341, JUNIOR DESIGN I, 3 Credits
Introduction to system design and group projects. Design and fabrication of an electrical engineering project in a small group.
Prerequisite: CS 261 (may be taken concurrently) with C or better and ENGR 203 [C]

ECE 342, JUNIOR DESIGN II, 3 Credits
Introduction to system design and group projects. Design and fabrication of an electrical engineering project in a small group.
Prerequisite: ECE 341 with C or better

ECE 351, SIGNALS AND SYSTEMS I, 3 Credits
Analytical techniques for continuous-time and discrete-time signal, system, and circuit analysis. Lec.
Prerequisite: ENGR 203 with C or better and (MTH 256 [C] or MTH 256H [C])

ECE 352, SIGNALS AND SYSTEMS II, 3 Credits
Analytical techniques for continuous-time and discrete-time signal, system, and circuit analysis.
Prerequisite: ECE 351 with C or better and (MTH 306 [C] or MTH 306H [C])
ECE 353, INTRODUCTION TO PROBABILITY AND RANDOM SIGNALS, 3 Credits
Explores discrete and continuous probability concepts, single and multiple random variable distributions, expectation, introductory stochastic processes, correlation and power spectral density properties of random signals, random signals through linear filters.
Prerequisite: ECE 351 with C or better

ECE 372, INTRODUCTION TO COMPUTER NETWORKS, 4 Credits
Computer network principles, fundamental networking concepts, packet-switching and circuit switching, TCP/IP protocol layers, reliable data transfer, congestion control, flow control, packet forwarding and routing, MAC addressing, multiple access techniques. CROSSLISTED as CS 372/ECE 372.
Prerequisite: CS 261 with C or better and (ECE 371 [C] or CS 271 [C])
Equivalent to: CS 372
Recommended: C programming and Unix familiarity.

ECE 375, COMPUTER ORGANIZATION AND ASSEMBLY LANGUAGE PROGRAMMING, 4 Credits
Introduction to computer organization, how major components in a computer system function together in executing a program, and assembly language programming. Lec/lab.
Prerequisite: ECE 271 with C or better
Recommended: CS 261 or C/C++ programming

ECE 390, ELECTRIC AND MAGNETIC FIELDS, 4 Credits
Static and quasi-static electric and magnetic fields.
Prerequisite: (MTH 255 with C or better or MTH 255H with C or better) and ENGR 203 (may be taken concurrently) [C] and PH 213 [C]

ECE 391, TRANSMISSION LINES, 3 Credits
Transient and steady-state analysis of transmission line circuits with application to engineering problems.
Prerequisite: ECE 322 (may be taken concurrently) with C or better and ENGR 203 [C] and (MTH 254 [C] or MTH 254H [C]) and (MTH 256 [C] or MTH 256H [C])
Equivalent to: ECE 391X

ECE 399, SPECIAL TOPICS, 1-16 Credits
Course work to meet students’ needs in advanced or specialized areas and to introduce new, important topics in electrical and computer engineering at the undergraduate (junior/senior) level.
Equivalent to: ECE 399H
This course is repeatable for 16 credits.

ECE 401, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ECE 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

ECE 405, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

ECE 406, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ECE 410, INTERNSHIP, 1-16 Credits
This course is repeatable for 16 credits.

ECE 411, ENGINEERING MAGNETICS, 3 Credits
Application of magnetic materials in the design of magnetic devices. Properties of magnetic materials; engineering design of actuators, sensors and data storage devices. Introduction to spintronics.
Prerequisite: ECE 390 with C or better

ECE 413, SENSORS, 3 Credits
Overview of sensor technologies including materials, physics of operation, applications and system integration.
Prerequisite: ECE 323 with C or better and PH 213 [C] and (CH 201 [C] or CH 231 [C]) or (CH 121 [C] and CH 122 [C]) or (CH 231 [C] and CH 261 [C])

ECE 415, MATERIAL SCIENCE OF NANOTECHNOLOGY, 3 Credits
Introductory physical chemistry of solid surfaces, thermodynamics, and kinetics applied to synthesis of nanomaterials such as nanoparticles, nanowires, thin films, carbon nanotubes, fullerenes, graphene, etc. Characterization of nanomaterials, applications of nanomaterials, nanosynthesis techniques, integration of nanotechnology, and emerging nanotechnology topics.
Prerequisite: ECE 416 with C or better or ENGR 321 with C or better or ENGR 321H with C or better

ECE 416, ELECTRONIC MATERIALS AND DEVICES, 4 Credits
Semiconductor fundamentals and physical principles of pn junctions and Schottky barrier diodes.
Prerequisite: ENGR 201 with C or better and PH 213 [C] and (CH 201 [C] or CH 231 [C]) or (CH 121 [C] and CH 122 [C]) or (CH 231 [C] and CH 261 [C])
Equivalent to: ECE 317

ECE 417, BASIC SEMICONDUCTOR DEVICES, 4 Credits
Theory and physical principles of bipolar junction and field-effect transistors. Lec/rec.
Prerequisite: ECE 416 with C or better

ECE 418, SEMICONDUCTOR PROCESSING, 4 Credits
Theory and practice of basic semiconductor processing techniques. Introduction to process simulation. Lec/lab/rec.
Prerequisite: ECE 416 with C or better
ECE 422, CMOS INTEGRATED CIRCUITS I, 4 Credits
Analysis and design of analog integrated circuits in CMOS technology; current mirrors, gain stages, single-ended operational amplifier, frequency response, and compensation.
Prerequisite: ECE 322 with C or better and ECE 323 (may be taken concurrently) [C]

ECE 423, CMOS INTEGRATED CIRCUITS II, 4 Credits
Analysis and design of analog integrated circuits in CMOS technology; cascaded current mirrors, cascaded gain stages, single-ended and fully differential operational amplifier, common-mode feedback, noise, and distortion. Lec/lab.
Prerequisite: ECE 422 with C or better

ECE 431, POWER ELECTRONICS, 4 Credits
Fundamentals and applications of devices, circuits and controllers used in systems for electronic power processing. Lec/lab.
Prerequisite: ECE 322 with C or better and ECE 323 (may be taken concurrently) [C] and ECE 351 [C]

ECE 432, DYNAMICS OF ELECTROMECHANICAL ENERGY CONVERSION, 4 Credits
Generalized machine theory. Techniques for dynamic analysis of electromechanical machines including arbitrary reference frame theory. Lec/lab.
Prerequisite: ECE 331 with C or better and ENGR 203 [C]
Corequisites: ECE 431

ECE 433, POWER SYSTEM ANALYSIS, 4 Credits
Fundamentals and control of real and reactive power, steady-state load flow studies, unbalance, stability and transient system analysis.
Prerequisite: ECE 323 with C or better and ECE 352 [C] and (ENGR 202 [C] or ENGR 202H [C]) and MTH 254 [C] and MTH 306 [C]
Recommended: Three-phase power

ECE 437, SMART GRID, 3 Credits
Fundamentals of smart power grids. Technology advances in transmission and distribution systems, policy drivers, assets and demand management, and smart grid security.
Prerequisite: ECE 433 with C or better
Recommended: Background in power systems analysis equivalent to ECE 433

ECE 438, ELECTRIC AND HYBRID ELECTRIC VEHICLES, 4 Credits
Transportation electrification history, hybrid electric vehicle architecture, powertrain components and their modeling and control, vehicle system dynamics and controls.
Prerequisite: ECE 331 with C or better and ECE 431 [C]

ECE 441, ENGINEERING DESIGN PROJECT, 3 Credits
Exposes problem situations and issues in engineering design similar to those encountered in industry through an extended team design project. (Writing Intensive Course)
Attributes: CWIN – Core, Skills, WC
Prerequisite: ECE 441 with C or better

ECE 442, ENGINEERING DESIGN PROJECT, 3 Credits
Exposes problem situations and issues in engineering design similar to those encountered in industry through an extended team design project. (Writing Intensive Course)
Attributes: CWIN – Core, Skills, WC
Prerequisite: ECE 441 with C or better

ECE 443, ENGINEERING DESIGN PROJECT, 2 Credits
Exposes problem situations and issues in engineering design similar to those encountered in industry through an extended team design project. (Writing Intensive Course)
Attributes: CWIN – Core, Skills, WC
Prerequisite: ECE 442 with C or better

ECE 451, SYSTEMS DYNAMICS AND CONTROL, 4 Credits
Modeling and analysis of linear continuous systems in time and frequency domains. Fundamentals of single-input-single-output control system design. CROSSTLISTED as ECE 451/ME 430.
Prerequisite: (ME 317 with C or better or ME 317H with C or better or (ECE 351 with C or better and ECE 352 [C] and (ENGR 212 [C] or ENGR 212H [C])))
Equivalent to: ME 430, ME 430H
Available via Ecampus

ECE 461, INTRODUCTION TO ANALOG AND DIGITAL COMMUNICATIONS, 4 Credits
Fundamental concepts of analog and digital telecommunication systems: modeling, analysis, and design of analog amplitude and angle modulation systems; probabilistic performance assessment of modulated signals over noisy channels; introduction to baseband digital modulation techniques such as binary pulse amplitude modulation and pulse position modulation and their demodulation in the presence of random noise. Lec.
Prerequisite: ECE 351 with C or better and ECE 352 [C] and ECE 353 [C]

ECE 462, DIGITAL COMMUNICATIONS AND CHANNEL CODING, 4 Credits
Modeling, analysis, design of baseband and passband digital communications systems: geometric representation of signals; correlator receivers for M-ary digital communications systems; decision theory and its application to digital communication systems in additive white Gaussian noise environment; generation, transmission, and reception of passband digital modulated signals (BPSK, QPSK, FSK PAM); basics of information theory and channel encoding. Lec.
Prerequisite: ECE 461 with C or better and ECE 351 [C] and ECE 352 [C] and ECE 353 [C]
ECE 463, WIRELESS COMMUNICATIONS NETWORK, 4 Credits
Wireless networks: personal area (IEEE 802.15.4a), local area (IEEE 802.11), metropolitan area (IEEE 802.16), and mobile cellular networks (e.g., CDMA); physical-layer techniques for data modulation and multiple access; RF system engineering aspects of mobile cellular networks (e.g., system capability for voice and packet data traffics, RF coverage for a certain propagation environment.) Lec.
Prerequisite: ECE 351 with C or better and ECE 352 [C]
Recommended: Probability background and ECE 461

ECE 464, DIGITAL SIGNAL PROCESSING, 4 Credits
Analysis and design of discrete-time linear-time invariant systems for processing discrete-time signals: DT-LTI system properties, DT signal analysis using Discrete-Time Fourier Transform, Discrete Fourier Transform and z-Transform, frequency response and transfer function. Signal sampling and reconstruction, digital processing of continuous-time signals, FIR and IIR digital filter design, and filter structures.
Prerequisite: ECE 351 with C or better and ECE 352 [C]

ECE 468, DIGITAL IMAGE PROCESSING, 3 Credits
Introduction to digital image processing including fundamental concepts of visual perception, image sampling and quantization, image enhancement in spatial and frequency domains (through 2D Fourier transform), image restoration, and color image processing. Implementation of algorithms using Matlab Image Processing Toolbox.
Prerequisite: ECE 351 with C or better and ECE 352 [C]

ECE 471, ENERGY-EFFICIENT VLSI DESIGN, 4 Credits
Combinational and sequential logic design using CMOS transistors; analysis of power consumption and logic delay of digital logic; clock design including skew, jitter, and dynamic clock energy consumption; supply voltage and power supply noise sources; dynamic voltage frequency scaling (DVFS); sub-threshold logic design and effect on energy/robustness; custom digital integrated circuit design including transistor layouts and CAD entry; CMOS scaling and the effect on process variability and power consumption. Lec/lab.
Prerequisite: ECE 271 with C or better and ECE 322 [C] and ECE 323 (may be taken concurrently) [C]

ECE 472, COMPUTER ARCHITECTURE, 4 Credits
Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSLISTED as CS 472/ECE 472 and CS 572/ECE 572.
Prerequisite: ECE 375 with C or better
Equivalent to: CS 472

ECE 473, MICROCONTROLLER SYSTEM DESIGN, 4 Credits
Implementation of embedded computer systems focusing on the development of hardware and software for an embedded microcontroller system. Topics include internal microcontroller architecture, interfacing peripheral devices, mixed analog and digital systems, and hardware and software implementation of several systems using a microcontroller and peripherals. Lec/lab.
Prerequisite: ECE 322 with C or better and ECE 375 [C] and CS 261 [C]

ECE 474, VLSI SYSTEM DESIGN, 4 Credits
Introduction to custom and semi-custom digital integrated circuit design as used in VLSI systems. The use of CAD/CAE tools, design management, and design methodology are introduced.
Prerequisite: ECE 322 with C or better and ECE 375 [C]

ECE 476, ADVANCED COMPUTER NETWORKING, 4 Credits
Prerequisite: (CS 372 with C or better or ECE 372 with C or better) and (ECE 353 [C] or ST 314 [C] or ST 314H [C])
Equivalent to: CS 476, EECS 476

ECE 477, MULTIMEDIA SYSTEMS, 4 Credits
Design of multimedia systems used in information technology covering the hardware, software, applications, and networks. Components covered include multimedia representation, coding and compression techniques, wireless networks, networking for multimedia, and embedded system for multimedia. Lec.
Recommended: ECE 375

ECE 478, NETWORK SECURITY, 4 Credits
Basic concepts and techniques in network security, risks and vulnerabilities, applied cryptography and various network security protocols. Coverage of high-level concepts such as authentication, confidentiality, integrity, and availability applied to networking systems. Fundamental techniques including authentication protocols, group key establishment and management, trusted intermediaries, public key infrastructures, SSL/TLS, IPSec, firewalls and intrusion detection CROSSLISTED as CS 478/ECE 478.
Prerequisite: CS 372 with C or better or ECE 372 with C or better
Equivalent to: CS 478
Recommended: CS 370

ECE 482, OPTICAL ELECTRONIC SYSTEMS, 4 Credits
Photodetectors, laser theory, and laser systems. Lec/lab. CROSSLISTED as ECE 482/PH 482 and ECE 582/PH 582.
Equivalent to: PH 482
Recommended: ECE 391 or (PH 481 or PH 581)
ECE 483, GUIDED WAVE OPTICS, 4 Credits
Optical fibers, fiber mode structure and polarization effects, fiber interferometry, fiber sensors, optical communication systems. Lec/lab. CROSSLISTED as ECE 483/PH 483 and ECE 583/PH 583.
Prerequisite: ECE 391 (may be taken concurrently) with C or better or PH 481 (may be taken concurrently) with C or better
Equivalent to: PH 483

ECE 484, ANTENNAS AND PROPAGATION, 4 Credits
Introduction to antennas and radiowave propagation. Offered alternate years.
Prerequisite: (ECE 390 with C or better and ECE 391 [C])

ECE 485, MICROWAVE DESIGN TECHNIQUES, 4 Credits
Introduction to basic design techniques required for the design of high-frequency circuits and systems. Lec/Lab.
Prerequisite: ECE 390 with C or better and ECE 391 [C]

ECE 499, SPECIAL TOPICS, 0-16 Credits
Course work to meet students’ needs in advanced or specialized areas and to introduce new important topics in electrical and computer engineering at the undergraduate level.
This course is repeatable for 16 credits.

ECE 501, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ECE 503, ECE MS THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ECE 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

ECE 506, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ECE 507, SEMINAR, 1-16 Credits
Graded P/N.
This course is repeatable for 16 credits.

ECE 510, OCCUPATIONAL INTERNSHIP, 1-4 Credits
This course is repeatable for 99 credits.
Available via Ecampus

ECE 516, ELECTRONIC MATERIALS AND DEVICES, 4 Credits
Semiconductor fundamentals and physical principles of pn junctions and Schottky barrier diodes.
Equivalent to: ECE 317
Recommended: ENGR 201

ECE 517, BASIC SEMICONDUCTOR DEVICES, 4 Credits
Theory and physical principles of bipolar junction and field-effect transistors. Lec/rec.
Recommended: ECE 416

ECE 518, SEMICONDUCTOR PROCESSING, 4 Credits
Theory and practice of basic semiconductor processing techniques. Introduction to process simulation. Lec/lab/rec.
Recommended: ECE 416

ECE 520, ANALOG CMOS INTEGRATED CIRCUITS, 4 Credits
Principles and techniques of design of electronic circuits with focus on a design methodology for analog integrated circuits. Practical aspects of using CAD tools in analyzing and laying out circuits will be discussed.

ECE 521, ANALOG CIRCUIT SIMULATION, 4 Credits
Formulation/solution of circuit equations; sparse matrix techniques; DC, transient, sensitivity, noise and Fourier analyses; RF circuit simulation.
Recommended: ECE 423 or ECE 520

ECE 522, CMOS INTEGRATED CIRCUITS I, 4 Credits
Analysis and design of analog integrated circuits in CMOS technology; current mirrors, gain stages, single-ended operational amplifier, frequency response, and compensation.
Recommended: ECE 322 and completion or concurrent enrollment in ECE 323

ECE 523, CMOS INTEGRATED CIRCUITS II, 4 Credits
Analysis and design of analog integrated circuits in CMOS technology; cascaded current mirrors, cascaded gain stages, single-ended and fully differential operational amplifier, common-mode feedback, noise, and distortion. Lec/lab.
Recommended: ECE 422 or ECE 522

ECE 530, CONTEMPORARY ENERGY APPLICATIONS, 4 Credits
Contemporary energy issues and applications; fundamental physics of renewable energy sources (e.g. wind, wave, and solar), devices used to harvest energy from these sources, state-of-the-art renewable energy technology, power transmission, transformers, and energy storage.
Recommended: Matlab, basic circuit analysis with RLC components and diode

ECE 531, POWER ELECTRONICS, 4 Credits
Fundamentals and applications of devices, circuits and controllers used in systems for electronic power processing. Lec/lab.
Recommended: ECE 322 and ECE 351 and completion or concurrent enrollment in ECE 323
ECE 532, DYNAMICS OF ELECTROMECHANICAL ENERGY CONVERSION, 4 Credits
Generalized machine theory. Techniques for dynamic analysis of electromechanical machines including arbitrary reference frame theory. Lec/lab.
Corequisites: ECE 531
Recommended: ECE 331

ECE 533, POWER SYSTEM ANALYSIS, 4 Credits
Fundamentals and control of real and reactive power, steady-state load flow studies, unbalance, stability and transient system analysis.
Recommended: ECE 323 and ECE 352 and three-phase power

ECE 535, ADJUSTABLE SPEED DRIVES AND MOTION CONTROL, 3 Credits
Adjustable speed drives, associated power electronic converters, simulation and control. Lec.
Equivalent to: ECE 647
Recommended: ECE 530

ECE 536, POWER SYSTEM PROTECTION, 3 Credits
Recommended: ECE 433 or ECE 533

ECE 537, SMART GRID, 3 Credits
Fundamentals of smart power grids. Technology advances in transmission and distribution systems, policy drivers, assets and demand management, and smart grid security.
Recommended: Background in power systems analysis equivalent to ECE 433

ECE 538, ELECTRIC AND HYBRID ELECTRIC VEHICLES, 4 Credits
Transportation electrification history, hybrid electric vehicle architecture, powertrain components and their modeling and control, vehicle system dynamics and controls.
Equivalent to: ECE 534
Recommended: ECE 331 and ECE 431

ECE 550, LINEAR SYSTEMS, 4 Credits
Linear dynamic systems theory and modeling.
Recommended: ECE 351 and ECE 352

ECE 560, STOCHASTIC SIGNALS AND SYSTEMS, 4 Credits
Stochastic processes, correlation functions, spectral analysis applicable to communication and control systems.
Recommended: ECE 461 or ECE 561

ECE 561, INTRODUCTION TO ANALOG AND DIGITAL COMMUNICATIONS, 4 Credits
Fundamental concepts of analog and digital telecommunication systems: modeling, analysis, and design of analog amplitude and angle modulation systems; probabilistic performance assessment of modulated signals over noisy channels; introduction to baseband digital modulation techniques such as binary pulse amplitude modulation and pulse position modulation and their demodulation in the presence of random noise. Lec.
Recommended: ECE 351 and ECE 352 and ECE 353

ECE 562, DIGITAL COMMUNICATIONS AND CHANNEL CODING, 4 Credits
Modeling, analysis, design of baseband and passband digital communications systems: geometric representation of signals; correlator receivers for M-ary digital communications systems; decision theory and its application to digital communication systems in additive white Gaussian noise environment; generation, transmission, and reception of passband digital modulated signals (BPSK, QPSK, FSK PAM); basics of information theory and channel encoding. Lec.
Recommended: ECE 461 and ECE 351 and ECE 352 and ECE 353

ECE 563, WIRELESS COMMUNICATIONS NETWORK, 4 Credits
Wireless networks: personal area (IEEE 802.15.4a), local area (IEEE 802.11), metropolitan area (IEEE 802.16), and mobile cellular networks (e.g., CDMA); physical-layer techniques for data modulation and multiple access; RF system engineering aspects of mobile cellular networks (e.g., system capability for voice and packet data traffics, RF coverage for a certain propagation environment.) Lec.
Recommended: Probability background and ECE 461

ECE 564, DIGITAL SIGNAL PROCESSING, 4 Credits
Analysis and design of discrete-time linear-time invariant systems for processing discrete-time signals: DT-LTI system properties, DT signal analysis using Discrete-Time Fourier Transform, Discrete Fourier Transform and z-Transform, frequency response and transfer function. Signal sampling and reconstruction, digital processing of continuous-time signals, FIR and IIR digital filter design, and filter structures.
Recommended: ECE 351 and ECE 352

ECE 565, ESTIMATION, FILTERING, AND DETECTION, 4 Credits
Principles of estimation, linear filtering, and detection.
Recommended: ECE 353

ECE 566, INFORMATION THEORY, 4 Credits
Introduction to information theory: entropy, differential entropy, entropy rates, mutual information, data compression, channel capacity, source coding, channel coding, network information theory.
Recommended: ECE 353 and strong mathematical background
ECE 569, CONVEX OPTIMIZATION, 4 Credits
Introduces the fundamental concepts, theories of convex and nonconvex optimization, and the algorithmic solutions as well as applications to many research disciplines including signal processing, networking, communications, and machine learning. Emphasis will be on (i) convex analysis and optimality conditions, (ii) first-order large-scale algorithms (gradient, proximal gradient, ADMM, Frank-Wolfe, stochastic gradient, block coordinate descent), and (iii) convergence analysis. Recommended: Linear algebra and ECE 599 Matrix Analysis for Signal Processing

ECE 570, HIGH PERFORMANCE COMPUTER ARCHITECTURE, 4 Credits
Advanced concepts in computer architecture. Performance improvement employing advanced pipelining and multiple instruction scheduling techniques. Issues in memory hierarchy and management. CROSSLISTED as CS 570/ECE 570.
Equivalent to: CS 570
Recommended: ECE 472 or ECE 572

ECE 571, ENERGY-EFFICIENT VLSI DESIGN, 4 Credits
Combinational and sequential logic design using CMOS transistors; analysis of power consumption and logic delay of digital logic; clock design including skew, jitter, and dynamic clock energy consumption; supply voltage and power supply noise sources; dynamic voltage frequency and scaling (DVFS); sub-threshold logic design and effect on energy/robustness; custom digital integrated circuit design including transistor layouts and CAD entry; CMOS scaling and the effect on process variability and power consumption. Lec/lab.
Equivalent to: ECE 573
Recommended: ECE 271 and ECE 322 and completion or concurrent enrollment in ECE 323 (all with a minimum grade of C)

ECE 572, COMPUTER ARCHITECTURE, 4 Credits
Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSLISTED as CS 472/ECE 472 and CS 572/ECE 572.
Equivalent to: CS 572
Recommended: ECE 375

ECE 574, VLSI SYSTEM DESIGN, 4 Credits
Introduction to custom and semi-custom digital integrated circuit design as used in VLSI systems. The use of CAD/CAE tools, design management, and design methodology are introduced. Recommended: ECE 322 or ECE 375

ECE 576, ADVANCED COMPUTER NETWORKING, 4 Credits
Equivalent to: CS 576, ECE 566
Recommended: (CS 372 or ECE 372) and (ECE 353 or ST 314 or ST 314H)

ECE 577, MULTIMEDIA SYSTEMS, 4 Credits
Design of multimedia systems for information technology covering the hardware, software, applications, and networks. Components covered include multimedia representation, coding and compression techniques, wireless networks, networking for multimedia, and embedded system for multimedia. Lec.
Recommended: ECE 375

ECE 578, CYBER-SECURITY, 4 Credits
A broad overview of the field of computer and network security. Essential cryptographic mechanisms such as symmetric and public-key cryptography (e.g., encryption, signatures), network security and authentication protocols (e.g., Kerberos, TLS, IPSec), system security (e.g., access control, firewalls), advanced topics (e.g., searchable encryption, cloud security, secure computation). CROSSLISTED as CS 578/ECE 578.
Equivalent to: CS 578

ECE 580, NETWORK THEORY, 4 Credits
Linear graphs, multiport networks, and other topics in advanced network theory.

ECE 582, OPTICAL ELECTRONIC SYSTEMS, 4 Credits
Photodetectors, laser theory, and laser systems. Lec/lab. CROSSLISTED as ECE 482/PH 482 and ECE 582/PH 582.
Equivalent to: PH 582
Recommended: PH 481 or PH 581

ECE 583, GUIDED WAVE OPTICS, 4 Credits
Optical fibers, fiber mode structure and polarization effects, fiber interferometry, fiber sensors, optical communication systems. Lec/lab. CROSSLISTED as ECE 483/PH 483 and ECE 583/PH 583.
Equivalent to: PH 583
Recommended: Completion or concurrent enrollment in (ECE 391 or PH 481 or PH 581)

ECE 584, ANTENNAS AND PROPAGATION, 4 Credits
Introduction to antennas and radiowave propagation. Offered alternate years.
ECE 585, MICROWAVE DESIGN TECHNIQUES, 4 Credits
Introduction to basic design techniques required for the design of high-frequency circuits and systems. Lec/Lab.

ECE 590, ANALYTICAL TECHNIQUES IN ELECTROMAGNETIC FIELDS, 4 Credits
Basic analytical techniques required to solve meaningful field problems in engineering.

ECE 591, ADVANCED ELECTROMAGNETICS, 3 Credits
Advanced techniques for analyzing problems in electromagnetics, primarily numerical. Offered alternate years.
Recommended: ECE 590

ECE 593, RF MICROWAVE CIRCUIT DESIGN, 3 Credits
Active/passive RF and microwave circuit design with emphasis to wireless systems.
Recommended: ECE 390 and ECE 391

ECE 599, SPECIAL TOPICS, 0-16 Credits
Course work to meet students' needs in advanced or specialized areas and to introduce new important topics in electrical and computer engineering at the graduate level.
This course is repeatable for 99 credits.

ECE 601, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ECE 603, ECE PhD THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ECE 605, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

ECE 606, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ECE 607, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

ECE 611, ELECTRONIC MATERIALS PROCESSING, 3 Credits
Technology, theory, and analysis of processing methods used in integration circuit fabrication. Offered alternate years. CROSSTHETED as CHE 611/ECE 611.
Equivalent to: CHE 611, ECE 511

ECE 612, PROCESS INTEGRATION, 3 Credits
Process integration, simulation, and statistical quality control issues related to integrated circuit fabrication. Offered alternate years.
CROSSTHETED as CHE 612/ECE 612.
Equivalent to: CHE 612, ECE 512
Recommended: ECE 611 or CHE 611

ECE 613, ELECTRONIC MATERIALS AND CHARACTERIZATION, 3 Credits
Physics and chemistry of electronic materials and methods of materials characterization. Offered alternate years. CROSSTHETED as CHE 613/ECE 613.
Equivalent to: CHE 613, ECE 513

ECE 614, SEMICONDUCTORS, 3 Credits
Essential aspects of semiconductor physics relevant for an advanced understanding of semiconductor materials and devices. Offered alternate years.
Equivalent to: ECE 514
Recommended: Exposure to quantum mechanics and solid state physics.

ECE 615, SEMICONDUCTOR DEVICES I, 3 Credits
Advanced treatment of two-terminal semiconductor electronic devices. Offered alternate years.
Equivalent to: ECE 515
Recommended: ECE 614

ECE 616, SEMICONDUCTOR DEVICES II, 3 Credits
Advanced treatment of three-terminal semiconductor electronic devices. Offered alternate years.
Equivalent to: ECE 516
Recommended: ECE 615

ECE 617, THIN FILM TRANSISTORS, 4 Credits
Thin-film electronics typically necessitate semiconducting materials lacking long-range order (disordered semiconductors), and hence provide a range of challenges and opportunities for device engineers. Provides a comprehensive review of the device physics and materials science of thin film electronics – in particular thin-film transistors. Provides students with the theoretical and practical knowledge to be successful in the development and study of thin film transistors, in both academic and industrial environments.
Recommended: ECE 390, ECE 416/ECE516, ECE 417/ECE 517, ECE 614

ECE 619, SELECTED TOPICS IN SOLID STATE, 3 Credits
Special courses taught on various topics in solid state as interests and demands vary.
This course is repeatable for 99 credits.

ECE 621, RADIO FREQUENCY IC DESIGN, 3 Credits
Radio frequency (RF) circuits. Principles, analysis, and design of bipolar and MOS RF IC building blocks: low noise amplifiers, mixers, oscillators, frequency synthesizers.
Recommended: (ECE 422 or ECE 522) and (ECE 423 or ECE 523) or ECE 520

ECE 626, ANALOG CMOS CIRCUIT DESIGN, 3 Credits
Switched-capacitor circuit design, on-chip filters, data converters. Practical aspects of analog CMOS IC design.
**ECE 627, OVERSAMPLED DELTA-SIGMA DATA CONVERTERS, 3 Credits**

Noise-shaping theory in first, second, and higher-order modulators. Design, simulation, and realization in hardware of converters using this popular architecture.

**ECE 629, SELECTED TOPICS IN MICROELECTRONICS, 3 Credits**

Course work to meet student's needs in advanced or specialized areas and to introduce the newest important results in microelectronics.

**ECE 659, SELECTED TOPICS IN SYSTEMS AND CONTROL, 3 Credits**

Course work to meet students' needs in advanced or specialized areas and to introduce the newest important results in systems and control. *This course is repeatable for 18 credits.*

**ECE 669, SELECTED TOPICS IN COMMUNICATIONS AND SIGNAL PROCESSING, 3 Credits**

Course work to meet students' needs in advanced or specialized areas and to introduce the newest important results in signal processing. *This course is repeatable for 18 credits.*

**ECE 679, SELECTED TOPICS IN COMPUTER ENGINEERING, 1-16 Credits**

Topics to be presented at various times include information storage and retrieval, computer architecture, fault-tolerant computing, asynchronous sequential circuits, automata, data transmission, coding theory. *This course is repeatable for 99 credits.*

**ECE 699, SPECIAL TOPICS, 3 Credits**

Advanced studies in field and wave theories and special devices. Topic examples are microwave and acoustic devices, advanced lasers and masers, electron beam interactions with traveling waves, MHD device dynamics. *This course is repeatable for 99 credits.*

**Engineering Science (ENGR)**

**ENGR 003, UNDERGRADUATE RESEARCH, 0 Credits**

Engage in research activities appropriate to the discipline; and through the research experience, acquire skills, techniques, and knowledge relevant to the field of study. In consultation with a faculty mentor, engage in research activity, and make and execute a plan for a project.

**ENGR 101, DESIGN OF COFFEE, 2 Credits**

Roast coffee beans and brew and taste coffee while using engineering design to create the perfect cup of coffee using the least amount of electricity. Lec/rec. *Available via Ecampus*

**ENGR 111, ENGINEERING ORIENTATION I, 3 Credits**

Engineering as a profession, historical development, ethics, curricula and engineering careers. Introduction to problem analysis and solution, data collection, accuracy and variability. Lec/rec. *Equivalent to: ENGR 111H*

**ENGR 112, INTRODUCTION TO ENGINEERING COMPUTING, 3 Credits**

Systematic approaches to engineering problem solving using computers. Logical analysis, flow charting, input/output design, introductory computer programming and use of engineering software. Lec/lab/rec. *Equivalent to: ENGR 112H, ENGR 112H*

**ENGR 112H, INTRODUCTION TO ENGINEERING COMPUTING, 3 Credits**

Systematic approaches to engineering problem solving using computers. Logical analysis, flow charting, input/output design, introductory computer programming and use of engineering software. Lec/lab/rec. *Attributes: HNRS – Honors Course Designator*

**ENGR 199, SPECIAL TOPICS, 0-16 Credits**

Graded P/N. *Equivalent to: ENGR 199H*

**ENGR 201, ELECTRICAL FUNDAMENTALS I, 3 Credits**

Analysis of linear circuits. Circuit laws and theorems. DC responses of circuits. Operational amplifier characteristics and applications. Lec/lab. *Prerequisite: (MTH 251 with C or better or MTH 251H with C or better) and (MTH 252 [C] or MTH 252H [C])*

**ENGR 201H, ELECTRICAL FUNDAMENTALS I, 3 Credits**

Analysis of linear circuits. Circuit laws and theorems. DC responses of circuits. Operational amplifier characteristics and applications. Lec/lab. *Attributes: HNRS – Honors Course Designator*

**ENGR 202, ELECTRICAL FUNDAMENTALS II, 3 Credits**

Analysis of linear circuits. Circuit laws and theorems. DC responses of circuits. Operational amplifier characteristics and applications. Lec/lab. *Prerequisite: (MTH 251 with C or better or MTH 251H with C or better) and (MTH 252 [C] or MTH 252H [C])*

**ENGR 201H, ELECTRICAL FUNDAMENTALS I, 3 Credits**

Analysis of linear circuits. Circuit laws and theorems. DC responses of circuits. Operational amplifier characteristics and applications. Lec/lab. *Attributes: HNRS – Honors Course Designator*

**ENGR 202, ELECTRICAL FUNDAMENTALS II, 3 Credits**

Sinusoidal steady-state analysis and phasors. Application of circuit analysis to solve single-phase and three-phase circuits including power, mutual inductance, transformers and passive filters. Lec/lab. *Prerequisite: ENGR 201 with C or better or ENGR 201H with C or better*
ENGR 203, ELECTRICAL FUNDAMENTALS III, 3 Credits
Laplace transforms, Fourier series, Bode plots, and their application to circuit analysis.
Prerequisite: (ENGR 201 with C or better or ENGR 201H with C or better) and (ENGR 202 [C] or ENGR 202H [C]) and (MTH 256 [C] or MTH 256H [C])

ENGR 211, STATICS, 3 Credits
Analysis of forces induced in structures and machines by various types of loading. Lec/rec.
Prerequisite: MTH 252 with C or better or MTH 252H with C or better
Equivalent to: ENGR 211H
Available via Ecampus

ENGR 211H, STATICS, 3 Credits
Analysis of forces induced in structures and machines by various types of loading. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisite: MTH 252 with C or better or MTH 252H with C or better
Equivalent to: ENGR 211

ENGR 212, DYNAMICS, 3 Credits
Kinematics, Newton's laws of motion, and work-energy and impulse-momentum relationships applied to engineering systems. Lec/rec.
Prerequisite: (ENGR 211 with C or better or ENGR 211H with C or better) and (PH 211 [C] or PH 211H [C])
Equivalent to: ENGR 212H
Available via Ecampus

ENGR 212H, DYNAMICS, 3 Credits
Kinematics, Newton's laws of motion, and work-energy and impulse-momentum relationships applied to engineering systems. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisite: (ENGR 211 with C or better or ENGR 211H with C or better) and (PH 211 [C] or PH 211H [C])
Equivalent to: ENGR 212

ENGR 213, STRENGTH OF MATERIALS, 3 Credits
Properties of structural materials; analysis of stress and deformation in axially loaded members, circular shafts, and beams, and in statically indeterminate systems containing these components. Lec/rec.
Prerequisite: ENGR 211 with C or better or ENGR 211H with C or better
Equivalent to: ENGR 213H
Available via Ecampus

ENGR 213H, STRENGTH OF MATERIALS, 3 Credits
Properties of structural materials; analysis of stress and deformation in axially loaded members, circular shafts, and beams, and in statically indeterminate systems containing these components. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisite: ENGR 211 with C or better or ENGR 211H with C or better
Equivalent to: ENGR 213

ENGR 221, THE SCIENCE, ENGINEERING AND SOCIAL IMPACT OF NANOTECHNOLOGY, 3 Credits
Nanotechnology is an emerging engineering field that manipulates atoms and molecules to fabricate new materials and tiny devices. Properties of nanostructured materials, manufacturing methods, characterization methods, and impact on health and safety. Benefits and concerns about nanotechnology will be assessed. Lec/rec. CROSSLISTED as ENGR 221/ MATS 221.
Equivalent to: MATS 221
Recommended: One year of college science.

ENGR 248, ENGINEERING GRAPHICS AND 3-D MODELING, 3 Credits
Introduction to graphical communication theory, including freehand sketching techniques, geometric construction, multi-view, pictorial, sectional and auxiliary view representation and dimensioning techniques. Practical application of theoretical concepts using solid modeling software to capture design intent and generate engineering drawings. Lec/Lab.
Available via Ecampus

ENGR 299, SPECIAL TOPICS, 0-16 Credits
Equivalent to: ENGR 299H
This course is repeatable for 16 credits.

ENGR 299H, SPECIAL TOPICS, 0-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: ENGR 299
This course is repeatable for 16 credits.

ENGR 350, *SUSTAINABLE ENGINEERING, 3 Credits
Examination of technological innovations and alternatives required to maintain human quality of life and environmental sustainability. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
Equivalent to: ENGR 350H
Available via Ecampus

ENGR 350H, *SUSTAINABLE ENGINEERING, 3 Credits
Examination of technological innovations and alternatives required to maintain human quality of life and environmental sustainability. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society; HNRS – Honors Course Designator
Equivalent to: ENGR 350
ENGR 352, *CREATIVE COLLABORATION: DESIGNING AND BUILDING, 3 Credits
Working in multi-disciplinary teams, design, implement, and document a piece of public art work or science museum display. Projects may be made of any media, but must demonstrate creativity both in the engineering used to create them and the technology and society message they convey. CROSSLISTED as ART 352/ENGR 352. (Bacc Core Course)
Attributes: CPLA – Core, Pers, Lit and Arts
Equivalent to: ART 352

ENGR 363, *ENERGY MATTERS, 3 Credits
Establishes a basic energy vocabulary, applies the fundamental concepts of identifying energy use and determining efficiency, and studies the implications of energy decisions in the context of traditional, alternative, and sustainable energy resources. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
Equivalent to: ENGR 363H
Recommended: MTH 112 or higher

ENGR 363H, *ENERGY MATTERS, 3 Credits
Establishes a basic energy vocabulary, applies the fundamental concepts of identifying energy and determining efficiency, and studies the implications of energy decisions in the context of traditional, alternative, and sustainable energy resources. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society; HNRS – Honors Course Designator
Equivalent to: ENGR 363
Recommended: MTH 112 or higher

ENGR 390, ENGINEERING ECONOMY, 3 Credits
Time value of money; economic study techniques, depreciation, taxes, retirement, and replacement of engineering facilities.
Available via Ecampus

ENGR 391, ENGINEERING ECONOMICS AND PROJECT MANAGEMENT, 3 Credits
Critical issues in the management of engineering and high-technology projects are discussed. Economic, time, and performance parameters of engineering projects are analyzed from the organizational and resource perspectives. Network optimization and simulation concepts are introduced. Fundamental engineering economics concepts are introduced and applied to planning and managing projects.
Equivalent to: ENGR 391H
Available via Ecampus

ENGR 391H, ENGINEERING ECONOMICS AND PROJECT MANAGEMENT, 3 Credits
Critical issues in the management of engineering and high-technology projects are discussed. Economic, time, and performance parameters of engineering projects are analyzed from the organizational and resource perspectives. Network optimization and simulation concepts are introduced. Fundamental engineering economics concepts are introduced and applied to planning and managing projects.
Attributes: HNRS – Honors Course Designator
Equivalent to: ENGR 391

ENGR 399, SPECIAL TOPICS, 1-16 Credits
Equivalent to: ENGR 399H
This course is repeatable for 16 credits.
Available via Ecampus

ENGR 399H, SPECIAL TOPICS, 1-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: ENGR 399
This course is repeatable for 16 credits.

ENGR 407, SEMINAR, 1-16 Credits
Graded P/N.
Equivalent to: ENGR 407H
This course is repeatable for 16 credits.

ENGR 407H, SEMINAR, 1-16 Credits
Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: ENGR 407
This course is repeatable for 16 credits.

ENGR 415, ^ENGINEERING CAPSTONE DESIGN I, 4 Credits
Utilizes engineering methodologies in a team environment to develop real-world solutions to an engineering problem. Develops all phases of system development, including project planning, requirements analysis, design, testing, configuration management, quality assurance, documentation, and delivery. First course/term of a two term design project.
Attributes: CWIC – Core, Skills, WIC

ENGR 416, ^ENGINEERING CAPSTONE DESIGN II, 4 Credits
Utilizes engineering methodologies in a team environment to develop real-world solutions to an engineering problem. Teams will be responsible for all phases of system development, including project planning, requirements analysis, design, testing, configuration management, quality assurance, documentation, and delivery. Second course/term of a two term design project.
Attributes: CWIC – Core, Skills, WIC
Prerequisite: ENGR 415 with C- or better

ENGR 450, PROFESSIONAL PREPARATION FOR BEGINNING LEVEL ENGINEERS, 1 Credit
Practical training on professional skills essential for a career as a practicing engineer. Covers development of networking and interviewing skills, preparation of a resume, job search strategies and guidance on future professional development.

ENGR 499, SPECIAL TOPICS, 1-16 Credits
Equivalent to: ENGR 499H
This course is repeatable for 16 credits.
ENGR 499H, SPECIAL TOPICS, 1-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: ENGR 499
This course is repeatable for 16 credits.

ENGR 520, MENG INTRODUCTION TO PORTFOLIO, 1 Credit
Explores OSU resources, Graduate School, and College of Engineering requirements to prepare for work on an MEng final portfolio. Engages in writing skills necessary to complete the final portfolio. Investigates communication styles, Imposter Syndrome, understanding and coping mechanisms, and professional ethics as they relate to an MEng final portfolio.

ENGR 521, MENG PORTFOLIO COMPLETION, 1 Credit
Demonstrate how graduate learning outcomes have been met. Formulate clear and reasonable professional goals and articulate how the program has helped prepare for achievement of those goals. Create a final portfolio document summarizing core knowledge and its integration with other fields.
Prerequisite: ENGR 520 with C or better

ENGR 531, APPLIED IMAGING AND IMAGE PROCESSING, 3 Credits
Explore image formats, storage issues, characteristics and significance of histograms; define and explain image artifacts such as random and periodic noise. Implement different image processing operations such as filters, registration, and mathematical algorithms to enhance an image and facilitate subsequent segmentation such as histogram thresholding, cluster analysis, watershed analysis, etc. Make quantitative measurements from images, such as length, area, orientation, connectivity, anisotropy, and perimeter of objects, as well as porosities, surface areas and curvatures. Apply advanced image analysis via skeletonization, morphological/ topological analysis, surface generation/ triangulation etc.
This course is repeatable for 3 credits.
Recommended: Introductory preparation in mathematical analysis, vectors, matrices, probability, statistics, linear systems, and computer programming

ENGR 550, PROFESSIONAL PREPARATION FOR ENGINEERS, 1 Credit
Practical training on professional skills essential for a career as a practicing engineer. Covers development of networking and interviewing skills, preparation of a resume and related online media, and guidance on future professional development. As this is a graduate-level course, it will include guidance on how students can develop and present themselves in ways that differentiate their abilities from those of more junior engineers.
Available via Ecampus

ENGR 555, FOUNDATIONS OF ENGINEERING EDUCATION RESEARCH AND PRACTICE, 3 Credits
An examination as to why engineering education is practiced and researched the way that it is through reading, discussion and writing. The focus of the course will be on written and verbal interactions informed by careful reading of assigned texts.

ENGR 599, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

Environmental Engineering (ENVE)
ENVE 199, SPECIAL TOPICS, 1-16 Credits
Equivalent to: ENVE 299H
This course is repeatable for 16 credits.

ENVE 299H, SPECIAL TOPICS, 0-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: ENVE 299
This course is repeatable for 16 credits.

ENVE 321, ENVIRONMENTAL ENGINEERING FUNDAMENTALS, 4 Credits
Application of engineering principles to the analysis of environmental problems. Topics include water, wastewater, solid wastes, and air pollution.
Prerequisite: MTH 256 with C or better or MTH 256H with C or better

ENVE 322, FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING, 4 Credits
Application of engineering principles to the analysis of environmental problems. Topics include water, wastewater, solid wastes, and air pollution.
Prerequisite: ((CH 222 with C or better or CH 232 with C or better or CH 232H with C or better or CH 225H with C or better) and (MTH 256 [C] or MTH 256H [C]))

ENVE 401, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 405, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.
ENVE 406, SPECIAL PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 407, SEMINAR, 1-16 Credits
Equivalent to: ENVE 407H
This course is repeatable for 16 credits.

ENVE 407H, SEMINAR, 1-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: ENVE 407
This course is repeatable for 16 credits.

ENVE 410, OCCUPATIONAL INTERNSHIP, 1-12 Credits
This course is repeatable for 12 credits.

ENVE 415, ENVIRONMENTAL ENGINEERING LABORATORY, 3 Credits
Theoretical and empirical analysis of several unit operations, use of formal work processes, safety, teamwork, oral and written communication, and personal accountability. Lec/lab/rec.
Prerequisite: CBEE 414 with C or better
Equivalent to: CHE 415

ENVE 421, DRINKING WATER TREATMENT PROCESSES, 4 Credits
Characterization and treatment of drinking water sources including engineering principles for the selection and design of treatment processes. Lec/rec/lab.
Prerequisite: ENVE 322 with C or better

ENVE 422, WASTEWATER TREATMENT PROCESSES, 4 Credits
Characterization and treatment of municipal and industrial wastewaters including engineering principles for the selection and design of treatment processes. Lec/rec.
Prerequisite: ENVE 421 with C or better

ENVE 425, AIR POLLUTION CONTROL, 3 Credits
Study of air pollution sources, transport, and control, including engineering, chemical, meteorological, social, and economic aspects. Lec/rec.
Prerequisite: ENVE 321 with C or better or ENVE 322 with C or better

ENVE 431, FATE AND TRANSPORT OF CHEMICALS IN ENVIRONMENTAL SYSTEMS, 4 Credits
Fundamentals of organic chemistry and engineering principles applied to the movement and fate of xenobiotic compounds. Lec/lab/rec.
Prerequisite: ((CH 123 with C or better or CH 223 with C or better or CH 226H with C or better or CH 233 with C or better) and (CH 440 [C] or CHE 331 [C] or CHE 331H [C]) and (ENVE 321 [C] or ENVE 322 [C] and ENVE 421 [C])

ENVE 456, SUSTAINABLE WATER RESOURCES DEVELOPMENT, 3 Credits
Sustainable water resources engineering principles, assessing the impact of engineering practices. Use of engineering analyses and sustainable principles to design projects and minimize their environmental impact.

ENVE 457, BIOREACTORS, 3 Credits
Design and analysis of bioreactors using suspension and immobilized microbial cultures.
Prerequisite: CHE 333 with C or better and ENVE 322 [C]

ENVE 490, ENVIRONMENTAL ENGINEERING DESIGN, 4 Credits
Open-ended design of environmental processes including development of process flow diagrams, control strategies, process simulators, and financial analysis of processes. Lec/rec.
Prerequisite: ENVE 421 with C or better and ENVE 422 [C]

ENVE 499, SPECIAL TOPICS IN ENVIRONMENTAL ENGINEERING, 1-4 Credits
A critical examination of topics selected by the instructor from among topics not covered in other environmental engineering courses.
This course is repeatable for 4 credits.

ENVE 501, RESEARCH AND SCHOLARSHIP, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 503, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ENVE 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 506, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 507, SEMINAR, 1-16 Credits
One-credit seminar. Graded P/N.
This course is repeatable for 16 credits.

ENVE 510, INTERNSHIP, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 521, DRINKING WATER TREATMENT PROCESSES, 4 Credits
Characterization and treatment of drinking water sources including engineering principles for the selection and design of treatment processes. Lec/rec/lab.
Recommended: ENVE 322
ENVE 522, WASTEWATER TREATMENT PROCESSES, 4 Credits
Charactrization and treatment of municipal and industrial wastewaters including engineering principles for the selection and design of treatment processes. Lec/rec.
Recommended: ENVE 421

ENVE 525, AIR POLLUTION CONTROL, 3 Credits
Study of air pollution sources, transport, and control, including engineering, chemical, meteorological, social, and economic aspects. Lec/rec.
Recommended: ENVE 321 or ENVE 322

ENVE 531, FATE AND TRANSPORT OF CHEMICALS IN ENVIRONMENTAL SYSTEMS, 4 Credits
Fundamentals of organic chemistry and engineering principles applied to the movement and fate of xenobiotic compounds. Lec/lab/rec.
Recommended: (CH 123 or CH 223 or CH 226H or CH 233) and (CH 440 or CHE 331 or CHE 331H) and (ENVE 321 or ENVE 322) and ENVE 421

ENVE 532, AQUATIC CHEMISTRY: NATURAL AND ENGINEERED SYSTEMS, 4 Credits
Low temperature thermodynamic and selective kinetic treatments primarily of the inorganic chemistry groups, but also organic ligands and surface active groups, of natural and engineered waters; thermodynamic principles and computational techniques for prediction of equilibrium speciation; comparison of predictions to observations; computer laboratory. Lec/rec.
Equivalent to: OC 532
Recommended: One year of college-level chemistry (CH 221 and CH 222 and CH 223) or(CH 231 or CH 231H) and (CH 232 or CH 232H) and (CH 233 or CH 233H); a minimum of one year organic or physical chemistry; and concurrent enrollment in ENVE 536 and/or OC 652

ENVE 535, PHYSICAL AND CHEMICAL TREATMENT PROCESSES, 4 Credits
Fundamental principles of physical and chemical processes relevant for the treatment of contaminants in environmental matrices (e.g. water, air and soil).
Prerequisite: ENVE 532 with C or better
Equivalent to: ENVE 538

ENVE 541, MICROBIAL PROCESSES IN ENVIRONMENTAL SYSTEMS, 4 Credits
Energetics kinetics and stoichiometry of microbial transformations of organic and inorganic compounds. Mathematical models of biodegradation.

ENVE 545, MICROBIAL METHODS IN ENVIRONMENTAL ENGINEERING, 3 Credits
Covers the principles of microbiological methods pertinent to environmental engineers with an emphasis on applications in drinking water treatment, wastewater treatment, and soil remediation. The course is targeted at engineering students that do not have much experience with culture-based and molecular-based techniques.
Prerequisite: ENVE 541 with C+ or better

ENVE 554, GROUNDWATER REMEDIATION, 4 Credits

ENVE 556, SUSTAINABLE WATER RESOURCES DEVELOPMENT, 3 Credits
Sustainable water resources engineering principles, assessing the impact of engineering practices. Use of engineering analyses and sustainable principles to design projects and minimize their environmental impact.

ENVE 599, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

ENVE 601, RESEARCH AND SCHOLARSHIP, 1-16 Credits
This course is repeatable for 16 credits.

ENVE 603, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ENVE 699, SELECTED TOPICS IN ENVIRONMENTAL ENGINEERING, 1-4 Credits
A critical examination of topics selected by the instructors from among topics not covered in other environmental engineering courses.
Equivalent to: ENVE 611
This course is repeatable for 8 credits.

Science of Engineering (ESC)
ESC 111, INTRODUCTION TO ENGINEERING, 3 Credits
Describes different fields of engineering; Performs calculations and synthesize results; Develops critical thinking skills and apply to engineering problems; Applies engineering specific technical and soft skills.
Equivalent to: MIME 101
ESC 340, INTRO TO EXPERIMENTATION, 4 Credits
Theory and application of instrumentation and measurement techniques are covered. Course topics include fundamentals of sampling theory, error and uncertainty analysis, signal conditioning, sensor fundamentals, and data analysis. Laboratory exercises provide experience utilizing data acquisition hardware and software, as well as a variety of sensors for measuring parameters from mechanical and electrical engineering systems.
Prerequisite: CS 162 with C or better and ENGR 202 [C] and PH 213 [C] and ST 314 [C]

ESC 350, ENGINEERING MATERIALS, 4 Credits
An introduction to materials and their structures and properties. The physical and chemical phenomena responsible for the electrical, mechanical, and thermal behavior of solids will be studied.
Prerequisite: PH 213 with C or better and CH 232 [C]

ESC 401, RESEARCH, 1-16 Credits
Equivalent to: ESE 401
This course is repeatable for 4 credits.

ESC 497, *MIME CAPSTONE DESIGN, 4 Credits
Product design; selection and replacement of major tools, processes, and equipment; paperwork controls; subsystem revision; system or plant revision; selection and training of personnel; long-run policies and strategy. CROSSLISTED as ESC 497/ESE 497. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: (ENGR 390 with C or better or BA 360 with C or better) and ME 312 [C] and (ME 331 [C] or ME 331H [C]) and ESE 355 [C] and ESE 360 [C] and (ST 314 [C] or ST 314H [C]) and WR 327 [C]
Equivalent to: ESE 497, MIME 497

ESC 498, *MIME CAPSTONE DESIGN, 4 Credits
Product design; selection and replacement of major tools, processes, and equipment; paperwork controls; subsystem revision; system or plant revision; selection and training of personnel; long-run policies and strategy. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: ESE 497 with C or better or IE 497 with C or better or ME 497 with C or better or MIME 497 with C or better
Equivalent to: ESE 498, IE 498, ME 498

ESC 499, SPECIAL TOPICS, 4 Credits
This course is repeatable for 16 credits.

Energy Systems Engineering (ESE)

ESE 330, MODELING AND ANALYSIS OF DYNAMIC SYSTEMS, 4 Credits
Presents basic concepts of dynamic behavior, and the analytical and computational techniques for predicting and assessing dynamic behavior. Modeling a basic system, compound system, dynamic stability, and natural behavior to continuing and abrupt inputs are presented.
Prerequisite: ENGR 202 with C or better and ENGR 212 [C] and MTH 256 [C] and MTH 306 [C]

ESE 355, ENERGY REGULATION, 4 Credits
Introductory course to the policies and laws governing energy generation and transmission in the United States with a focus on electricity. History of regulations give context to understand current regulation and potential future policies. Laws regulating the use of alternative energy resources covered in a practical setting. Offered at OSU-Cascades only.
Prerequisite: BA 360 (may be taken concurrently) with C or better or ENGR 390 (may be taken concurrently) with C or better

ESE 360, ENERGY CONSUMPTION ANALYSIS, 4 Credits
Analysis of energy use in transportation, residential and industrial sectors to understand how new technologies improve energy efficiency. Tradeoff techniques applied to decide between less efficient, less expensive systems versus more efficient, more expensive systems. International energy consumption compared, and energy losses evaluated for heating, cooling and electronic systems. Offered at OSU-Cascades only.
Prerequisite: (BA 360 (may be taken concurrently) with C or better or ENGR 390 (may be taken concurrently) with C or better)

ESE 401, RESEARCH, 1-16 Credits
Equivalent to: ESC 401
This course is repeatable for 4 credits.

ESE 430, FEEDBACK CONTROL SYSTEMS, 4 Credits
Modeling and analysis of linear, continuous-time systems in the time and frequency domains. Fundamentals of single-input-single-output control system design using both time-domain and frequency-domain techniques.
Prerequisite: ESE 330 with C or better

ESE 450, ENERGY GENERATION SYSTEMS, 4 Credits
Survey of technical fundamentals and operational principles of conventional and renewable energy conversion systems to understand the environmental and sustainable issues for energy systems currently in use or may be used in the future to power our industrial society. Offered at OSU-Cascades only.
Prerequisite: ME 312 with C or better
ESE 470, ENERGY DISTRIBUTION SYSTEMS, 4 Credits
Detailed coverage of the electrical energy distribution system, its operation, control and design. Design considerations and impacts to meet emerging and evolving customer needs. Broader understanding of natural gas and oil pipeline distribution for these infrastructure commodities. Offered at OSU-Cascades only.
Prerequisite: ENGR 202 with C or better and ME 311 [C]

ESE 471, ENERGY STORAGE SYSTEMS, 4 Credits
Coverage of energy storage techniques involving electrochemical, mechanical and emerging options. Integration of the energy storage media, its effects on the bulk power system, and design tradeoffs to understand environmental impacts, cost, reliabilities, and efficiencies for commercialization of bulk energy storage. Offered at OSU-Cascades only.
Prerequisite: ENGR 202 with C or better and ME 312 [C]

ESE 497, *MIME CAPSTONE DESIGN, 4 Credits
Product design; selection and replacement of major tools, processes, and equipment; paperwork controls; subsystem revision; system or plant revision; selection and training of personnel; long-run policies and strategy. CROSSLISTED as ESC 497/ESE 497. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: ENGR 390 with C or better or BA 360 with C or better) and IE 425 [C] and (ME 312 [C] or ME 312H [C]) and (ME 331 [C] or ME 331H [C]) and ESE 355 [C] and ESE 360 [C] and (ST 314 [C] or ST 314H [C]) and WR 327 [C]
Equivalent to: IE 497, ME 497, MIME 497

ESE 498, *MIME CAPSTONE DESIGN, 4 Credits
Product design; selection and replacement of major tools, processes, and equipment; paperwork controls; subsystem revision; system or plant revision; selection and training of personnel; long-run policies and strategy. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: ESE 497 with C or better or IE 497 with C or better or ME 497 with C or better or MIME 497 with C or better
Equivalent to: ESC 498, IE 498, ME 498

ESE 499, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.

Humanitarian Engineering Science & Technology (HEST)
HEST 199, SPECIAL TOPICS, 1-6 Credits
This course is repeatable for 9 credits.

HEST 201, INNOVATION FOR SOCIAL IMPACT, 3 Credits
Introduces methods for designing solutions to address needs of low-resource or other vulnerable peoples using tools from engineering and social sciences, and investigates techniques to bring ideas to market sustainably through social entrepreneurship. Multidisciplinary teams will step through the design process, including detailed needs assessment and customer discovery, critique and application of theoretical frameworks, exploration of the diffusion process and relevant system/institutions, prototyping, plans for technical and user experience testing, and considering implementation. CROSSLISTED as ANTH 201/HEST 201.
Equivalent to: ANTH 201

HEST 241, HOUSEHOLD ENERGY IN GUATEMALA: BACKGROUND, 1 Credit
An introduction to the technical, social, environmental, and economic issues surrounding energy needs for households in developing countries and the technologies and policies needed to help address them. Students are introduced to concepts about global development, needs assessment and co-design, qualitative and quantitative evaluation, and local socioeconomic conditions. This course is preparation for the 10-day Summer HEST 242 faculty-led study abroad course in Guatemala. Students from any major are invited to participate in this multidisciplinary course series.

HEST 242, HOUSEHOLD ENERGY IN GUATEMALA: APPLICATIONS, 3 Credits
Through immersion in rural communities during this 10-day interdisciplinary study abroad course, students will gain a deeper understanding of household energy needs in developing countries, as well as the social, environmental, technical, and economic issues surrounding technologies and polices to help meet these needs. The outcomes produced by a variety of household technologies such as biomass cookstoves will be evaluated through qualitative and quantitative data gathering, including experiments, observations, and surveys, giving students the chance to practice their research and cross-cultural communication skills under a variety of circumstances.
Recommended: HEST 241

HEST 299, SPECIAL TOPICS, 1-6 Credits
This course is repeatable for 9 credits.

HEST 310, *INTRO TO COMMUNITY ENGAGEMENT AND COMMUNITY-BASED DESIGN, 3 Credits
Includes study of civic problems and issues, design-thinking concepts and application to co-design of engineering, science and technology-based solutions with social impact, and development of dispositions for effective community engagement through field study and service-learning. Recommended course for student wanting to complete a HEST internship. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
**HEST 320, *ENGINEERING FOR GLOBAL HEALTH SOLUTIONS, 3 Credits**

An introduction to the critical processes and drivers involved in the development of engineering solutions to address global health problems. Topics include world health challenges, accessing and interpreting health and economic data, basic healthcare systems around the world, the importance of ethical guidelines in ensuring the protection of human subjects, the process of cost effectiveness assessment of a technology, and the timescale and hurdles to adoption of a technology. (Bacc Core Course)

**Attributes:** CSST – Core, Synthesis, Science/Technology/Society

**HEST 399, SPECIAL TOPICS, 1-6 Credits**

*This course is repeatable for 9 credits.*

**HEST 411, ENGINEERING DESIGN FOR EMERGENCY & LOW-RESOURCE ENVIRONMENTS, 3 Credits**

Introduces the challenges of engineering in emergency and low-resource environments, concepts of appropriate technologies and response, and engineering design of discrete services and technologies such as water systems, environmental health systems and infrastructure. **Recommended:** Completion of an undergraduate engineering fluid mechanics course

**HEST 412, *MULTIDISCIPLINARY CASE STUDIES IN HUMANITARIAN ENGINEERING, SCIENCE AND TECHNOLOGY, 3 Credits**

Introduces students to multidisciplinary methods and perspectives applied to case studies in humanitarian engineering, science and technology. Applications to real world issues with global implications at the interface of humanity and nature are addressed from a systems perspective using a case study approach. **Available via Ecampus**

**HEST 415, UAV ENGINEERING, 4 Credits**

Develop a strong foundation in Unmanned Aerial Vehicles (UAV) systems technologies. Engineering evaluation of UAV systems, subcomponents, aircraft missions, operations and Federal Aviation Administration (FAA) requirements. Apply actual UAV models and subsystems to a real-world project on UAV deployment for humanitarian and environmental missions. Write a technical report as a team-project, developing and demonstrating critical thinking and engineering reporting skills in the subject. **CROSSTLISTED as AAE 415/HEST 415.**

**Prerequisite:** ME 316 with C or better and ME 317 [C] and ME 331 [C] and ME 373 [C]

**Equivalent to:** AAE 415

**HEST 499, SPECIAL TOPICS, 1-6 Credits**

*This course is repeatable for 9 credits.*

**HEST 511, ENGINEERING DESIGN FOR EMERGENCY & LOW-RESOURCE ENVIRONMENTS, 3 Credits**

Introduces the challenges of engineering in emergency and low-resource environments, concepts of appropriate technologies and response, and engineering design of discrete services and technologies such as water systems, environmental health systems and infrastructure. **Recommended:** Completion of an undergraduate engineering fluid mechanics course

**HEST 512, MULTIDISCIPLINARY CASE STUDIES IN HUMANITARIAN ENGINEERING, SCIENCE AND TECHNOLOGY, 3 Credits**

Introduces students to multidisciplinary methods and perspectives applied to case studies in humanitarian engineering, science and technology. Applications to real world issues with global implications at the interface of humanity and nature are addressed from a systems perspective using a case study approach. **Available via Ecampus**

**HEST 541, HOUSEHOLD ENERGY IN GUATEMALA: BACKGROUND, 1 Credit**

An introduction to the technical, social, environmental, and economic issues surrounding energy needs for households in developing countries and the technologies and policies needed to help address them. Students are introduced to concepts about global development, needs assessment and co-design, qualitative and quantitative evaluation, and local socioeconomic conditions. This course is preparation for the 10-day Summer HEST 542 faculty-led study abroad course in Guatemala. Students from any major are invited to participate in this multidisciplinary course series.

**HEST 542, HOUSEHOLD ENERGY IN GUATEMALA: APPLICATIONS, 3 Credits**

Through immersion in rural communities during this 10-day interdisciplinary study abroad course, students will gain a deeper understanding of household energy needs in developing countries, as well as the social, environmental, technical, and economic issues surrounding technologies and polices to help meet these needs. The outcomes produced by a variety of household technologies such as biomass cookstoves will be evaluated through qualitative and quantitative data gathering, including experiments, observations, and surveys, giving students the chance to practice their research and cross-cultural communication skills under a variety of circumstances. **Recommended:** HEST 541

**HEST 599, SPECIAL TOPICS, 1-6 Credits**

*This course is repeatable for 9 credits.*
**Industrial & Manufacturing Engineering (IE)**

**IE 112, SPREADSHEET SKILLS FOR INDUSTRIAL & MANUFACTURING ENGINEERS, 1 Credit**

Basic spreadsheet functionality needed to create spreadsheet applications for common industrial and manufacturing engineering information processing tasks, including simple databases, statistical analysis, quality control, forecasting, production planning and control, and operations analysis and improvement. Topics include creating spreadsheets, formatting, data types, formulas, charts, user-defined functions, and pivot tables.

**IE 199, SPECIAL TOPICS, 1-16 Credits**

Special topics in industrial engineering. 
*This course is repeatable for 16 credits.*

**IE 212, COMPUTATIONAL METHODS FOR INDUSTRIAL ENGINEERING, 4 Credits**

**Prerequisite:** ENGR 112 with C or better and IE 112 (may be taken concurrently) [C] 
**Recommended:** Algebra, calculus, differentiation and integration

**IE 255, INTRODUCTORY QUANTITATIVE ANALYSIS OF INDUSTRIAL AND MANUFACTURING SYSTEMS, 3 Credits**

An introduction to basic analysis concepts that will be utilized in subsequent industrial and manufacturing engineering courses. Emphasis will be placed on fundamental concepts such as data collection, commonly applied quantitative analysis methods, and how these are utilized to support decisions in different industrial and manufacturing system applications. Examples include resource utilization calculations, equipment fraction equations, queuing models, basic statistical inference procedures, and probability models used in discrete event simulation. 
**Prerequisite:** MTH 252 with C or better

**IE 285, INTRODUCTION TO INDUSTRIAL AND MANUFACTURING ENGINEERING, 3 Credits**

Introduction to selected topics in industrial and manufacturing engineering, including history and philosophy, product design and manufacturing cycle, integrate role of engineering and business, and multi-objective nature of organizations. Surveys of selected design problems in resource allocation, operations and quality management, and production engineering. CROSSLISTED as IE 285/MFGE 285. 
**Prerequisite:** IE 112 (may be taken concurrently) with C or better or FOR 112 (may be taken concurrently) with C or better 
**Equivalent to:** MFGE 285

**IE 299, SPECIAL TOPICS, 1-16 Credits**

Special topics in industrial engineering. 
*This course is repeatable for 16 credits.*

**IE 355, STATISTICAL QUALITY CONTROL, 4 Credits**

Control of quality through the use of statistical analysis; typical control techniques and underlying theory. Development of reliability models and procedures for product assurance. Lec/lab. 
**Prerequisite:** IE 255 with C or better or ST 314 with C or better 
**Equivalent to:** IE 351

**IE 356, EXPERIMENTAL DESIGN FOR INDUSTRIAL PROCESSES, 4 Credits**

Systematic analysis of processes through the use of statistical analysis, methods, and procedures. Application of statistical techniques including use of classic process analysis techniques, regression and design of experiments. Lec/rec.  
**Prerequisite:** IE 255 with C or better or ST 314 with C or better 
**Equivalent to:** IE 352

**IE 366, WORK SYSTEMS ENGINEERING, 4 Credits**

Principles and techniques of work measurement, methods engineering, workplace design, work sampling, and predetermined time systems. Basic human factors engineering and ergonomics principles applied to workplace design. The work systems engineering process. Lec/lab/rec. 
**Prerequisite:** IE 255 with C or better or ST 314 with C or better) and PH 212 [C] and PH 213 [C]  
**Equivalent to:** IE 341

**IE 367, PRODUCTION PLANNING AND CONTROL, 4 Credits**

Forecasting techniques, inventory analysis, master production scheduling, material and capacity requirements, planning and scheduling methods. 
**Prerequisite:** IE 255 with C or better or ST 314 with C or better 
**Equivalent to:** IE 362

**IE 368, FACILITY DESIGN AND OPERATIONS MANAGEMENT, 4 Credits**

Design and analysis of industrial facilities including just-in-time systems, queuing, material handling systems, material flow analysis, line balancing, systematic layout planning, design of warehouse facilities, and facilities location. 
**Prerequisite:** ENGR 248 with C or better and (IE 255 [C] or ST 314 [C])  
**Equivalent to:** IE 365

**IE 380, *THE RESPONSIBLE ENGINEER, 3 Credits**

The idea of responsibility and the ethical responsibilities of the engineer. Introduction to value, ethics, and ethical systems. Engineering as value creation and the ethical ramifications of engineering. Codes of engineering ethics. Recognizing and addressing ethical dilemmas in engineering. Examination of the individual, social, and environmental effects of engineering and technology. (Baccalaureate Core Course) 
**Attributes:** CSST – Core, Synthesis, Science/Technology/Society

**IE 399, SPECIAL TOPICS, 1-16 Credits**

Special topics in industrial engineering. 
*This course is repeatable for 16 credits.*
IE 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

IE 405, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

IE 406, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

IE 407, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

IE 410, INTERNSHIP, 1-16 Credits
This course is repeatable for 16 credits.

IE 411, VISUAL PROGRAMMING FOR INDUSTRIAL APPLICATIONS, 4 Credits
Object-oriented modeling, Unified Modeling Language, software development concepts, file and database connectivity, and visual programming skills (Microsoft Visual Basic) for use in developing industrial applications, such as process monitoring and supply chain management.
Prerequisite: IE 212 with C or better
Equivalent to: IE 414

IE 412, INFORMATION SYSTEMS ENGINEERING, 4 Credits
Framework for enterprise information systems. Engineering and scientific systems. Requirements definition, enhanced entity relationship modeling, logical modeling, structured query language, relational model, referential integrity. Lec/lab.
Prerequisite: IE 212 with C or better

IE 415, SIMULATION AND DECISION SUPPORT SYSTEMS, 4 Credits
Analysis of operations and production systems through the application of computer simulation modeling techniques. Fundamentals of computer simulation including random number generation, input/output data analysis, model validation and verification. Lec/lab.
Prerequisite: IE 112 with C or better and (IE 255 [C] or ST 314 [C])

IE 418, TELECOMMUNICATION CONCEPTS, 3 Credits
Telecommunication concepts for industrial applications. OSI reference model, local area networks, wide area networks, internet architecture. Taught fall in even years.
Prerequisite: IE 212 with C or better
Recommended: Previous programming experience

IE 419, WIRELESS NETWORKS, 3 Credits
RF fundamentals, ISO 802.11 standards, spread spectrum technology, narrow band technology, direct sequence and frequency hopping transmission schemes, electromagnetic interference, design of indoor wireless networks.
Prerequisite: IE 418 with C or better

IE 425, INDUSTRIAL SYSTEMS OPTIMIZATION, 4 Credits
A first course in operations research. Topics include mathematical programming formulations and solutions, the simplex method, network optimization, introduction to metaheuristics, and linear programming under uncertainty.
Prerequisite: (IE 255 with C or better or ST 314 with C or better) and (MTH 306 [C] or MTH 341 [C])
Equivalent to: IE 421, IE 422

IE 426, STOCHASTIC MODELS OF INDUSTRIAL SYSTEMS, 4 Credits
The application of probabilistic and stochastic modeling methodologies to analyze the performance of production and service systems. Major topics include probability models for space planning, Poisson arrival processes, discrete and continuous time Markov chain models of machine cycle times, and queuing models applied to various industrial systems. Other applications of these tools to model inventories, process behavior, and equipment reliability is illustrated.
Prerequisite: (IE 255 with C or better or ST 314 with C or better) and IE 425 [C]

IE 470, MANAGEMENT SYSTEMS ENGINEERING, 4 Credits
Improvement of organizational performance through the design and implementation of systems that integrate personnel, technological, environmental, and organizational variables. Topics include performance assessment and measurement as well as improvement methodologies.
Prerequisite: ENGR 390 with C or better and IE 355 [C] and IE 366 [C] and IE 367 [C] and IE 368 [C]
Equivalent to: IE 474

IE 471, PROJECT MANAGEMENT IN ENGINEERING, 3 Credits
Critical issues in the management of engineering and high-technology projects are discussed. Time, cost, and performance parameters are analyzed from the organizational, people, and resource perspectives. Network optimization and simulation concepts are introduced. Resource-constrained project scheduling case discussions and a term project are included.
Prerequisite: ENGR 390 with C or better and IE 355 [C] and IE 366 [C] and IE 367 [C] and IE 368 [C]

IE 475, ADVANCED MANUFACTURING COSTING TECHNIQUES, 3 Credits
Costing techniques applicable in advanced manufacturing enterprises: activity-based costing, economic value added, Japanese cost management techniques, life cycle costing, throughput accounting, cost of quality, and financial versus operational performance measures. Emphasis on linkages to such advanced manufacturing systems as cellular manufacturing, flexible manufacturing, JIT, Lean, and ERP.
Prerequisite: ENGR 390 with C or better and IE 355 [C] and IE 366 [C] and IE 367 [C] and IE 368 [C]
Equivalent to: IE 495
IE 499, SPECIAL TOPICS, 1-5 Credits
Recent advances in industrial engineering pertaining to the theory and application of system studies. Analysis and design of natural resource systems; evaluation; detection extraction; processing and marketing systems; advanced design of production systems with reference to social, economic, and regional planning; human engineering studies of man-machine systems; applications of operations research techniques. Nonsequence course. Not offered every term.
This course is repeatable for 99 credits.

IE 503, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

IE 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

IE 506, PROJECTS, 1-16 Credits
Graded P/N.
This course is repeatable for 16 credits.

IE 507, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

IE 511, VISUAL PROGRAMMING FOR INDUSTRIAL APPLICATIONS, 4 Credits
Object-oriented modeling, Unified Modeling Language, software development concepts, file and database connectivity, and visual programming skills (Microsoft Visual Basic) for use in developing industrial applications, such as process monitoring and supply chain management.
Equivalent to: IE 514
Recommended: IE 212

IE 512, INFORMATION SYSTEMS ENGINEERING, 4 Credits
Framework for enterprise information systems. Engineering and scientific systems. Requirements definition, enhanced entity relationship modeling, logical modeling, structured query language, relational model, referential integrity. Lec/lab.

IE 515, SIMULATION AND DECISION SUPPORT SYSTEMS, 4 Credits
Analysis of operations and production systems through the application of computer simulation modeling techniques. Fundamentals of computer simulation including random number generation, input/output data analysis, model validation and verification. Lec/lab.
Recommended: ST 314

IE 518, TELECOMMUNICATION CONCEPTS, 3 Credits
Telecommunication concepts for industrial applications. OSI reference model, local area networks, wide area networks, internet architecture. Taught fall in even years.
Recommended: IE 212 and previous programming experience.

IE 519, WIRELESS NETWORKS, 3 Credits
RF fundamentals, ISO 802.11 standards, spread spectrum technology, narrow band technology, direct sequence and frequency hopping transmission schemes, electromagnetic interference, design of indoor wireless networks.
Prerequisite: IE 518 with C or better

IE 521, INDUSTRIAL SYSTEMS OPTIMIZATION I, 3 Credits
Techniques for analysis and solution of problems in industrial and management systems. Emphasis on application of linear and integer programming and extensions.
Equivalent to: IE 525
Recommended: MTH 341

IE 522, INDUSTRIAL SYSTEMS OPTIMIZATION II, 3 Credits
Techniques for analysis and solution of problems in industrial and management systems. Emphasis on applications of dynamic programming. Markovian processes, and questions as applied to industrial problems.
Recommended: ST 314

IE 523, INTEGER PROGRAMMING, 3 Credits
Classic models and algorithms for discrete optimization. Includes intuition and theory about computational strategies for solution of integer programming and combinatorial optimization problems.
Prerequisite: IE 521 with C or better

IE 533, HUMAN ANALYTICS AND BEHAVIORAL OPERATIONS, 3 Credits
Introduces several quantitative applications related to determining workforce size, skill-sets, and multi-functionality in service and manufacturing systems based on measurable quality and productivity performance, at the intersection of human factors engineering and production planning. Modeling and solving problems in a context of the speed and accuracy trade-off. Models include learning, forgetting, teamwork, fatigue, procrastination, and individual difference measures.
Recommended: Introductory math programming

IE 542, DESIGN OF HUMAN FACTORS / ERGONOMICS EXPERIMENTS, 4 Credits
Designed to provide graduate students with introductions to a broad range of methods appropriate for studying humans, tasks, environments and their interaction along with various topics in the area of Human Factors/Ergonomics. Reading/discussion format.
Recommended: Graduate level statistics course

IE 545, HUMAN FACTORS ENGINEERING, 4 Credits
Analysis and design of work systems considering human characteristics, capabilities and limitations. Analysis and design of displays, controls, tools, and workstations. Human performance analysis. Human factors research methods.
Equivalent to: IE 541
IE 546, HUMAN-MACHINE SYSTEMS ENGINEERING, 3 Credits
Development of safe, high performance human-machine systems. System/function/task analysis, function allocation, design, mockups and rapid prototyping, human factors test and evaluation. Critical examination of the human-factors and domain-specific literature to identify human factors problems, and knowledge and methods to address those problems.
Equivalent to: IE 542
Recommended: IE 545

IE 548, COGNITIVE ENGINEERING, 3 Credits
Theories and models of human sensory, cognitive, and motor performance pertaining to the operation of complex systems. Applications to human-machine systems engineering. Research topics and methods related to cognitive engineering.
Recommended: IE 545

IE 552, DESIGN OF INDUSTRIAL EXPERIMENTS, 3 Credits
A first course in design of experiments with an emphasis on applications and fundamental data analysis methods. Basic statistical inference, analysis of variance, blocking, general factorial designs, and two-level factorial designs are covered.
Recommended: ST 314

IE 553, DESIGN OF INDUSTRIAL EXPERIMENTS II, 3 Credits
This second course in design of experiments is a continuation of IE 552. The same textbook is used. Topics covered include two-level fractional factorial designs, regression models, response surface methods, rules for expected sum of squares and expected mean squares, a summary of the 'no-name' approach to DOE, and analysis of experiments with unbalanced data (time permitting).
Prerequisite: IE 552 with C or better

IE 563, ADVANCED PRODUCTION PLANNING AND CONTROL, 3 Credits
Recommended: IE 521 and ST 314

IE 564, DESIGN AND SCHEDULING OF CELLULAR MANUFACTURING SYSTEMS, 3 Credits
Recommended: Computer experience

IE 570, MANAGEMENT SYSTEMS ENGINEERING, 4 Credits
Improvement of organizational performance through the design and implementation of systems that integrate personnel, technological, environmental, and organizational variables. Topics include performance assessment and measurement as well as improvement methodologies.
Equivalent to: IE 574

IE 571, PROJECT MANAGEMENT IN ENGINEERING, 3 Credits
Critical issues in the management of engineering and high-technology projects are discussed. Time, cost, and performance parameters are analyzed from the organizational, people, and resource perspectives. Network optimization and simulation concepts are introduced. Resource-constrained project scheduling case discussions and a term project are included.
Available via Ecampus

IE 575, SYSTEMS THINKING THEORY AND PRACTICE, 4 Credits
An introduction to systems science theory and practice. Systems science theory is explored through the fundamentals of systems thinking theory, and theory of knowledge. Systems science practice is explored through system dynamics modeling techniques for simulating socio-technical systems, structures, and processes.

IE 581, OPERATIONS MANAGEMENT, 4 Credits
Critical and current issues on the implementation of operations management strategies for the engineering manager. Includes aspects of operations in an engineering management environment such as work systems design, forecasting, strategy, facilities location and design, management of quality and resources planning and management.
Prerequisite: IE 582 with B or better
Recommended: IE 571
Available via Ecampus

IE 582, INTRODUCTION TO MANAGEMENT FOR ENGINEERS AND SCIENTISTS, 4 Credits
An introduction to concepts, tools, and practices necessary for a broad understanding of the roles of engineering and technical managers. A mix of research results, case studies, and experiential learning is used to bolster theories of management, with focus on technical organizations.
Available via Ecampus

IE 583, ADVANCED ENGINEERING ECONOMICS ANALYSIS, 4 Credits
Examines the economics dimension of engineering management, from costing techniques to financial analysis. Topics include industrial cost analysis and estimation, economic planning, forecasting, and budgeting, and financial analysis for engineering and engineering management.
Prerequisite: IE 582 with B or better
Recommended: Basic courses in engineering economic analysis (ENGR 390)
Available via Ecampus
IE 584, SYSTEMS ENGINEERING, 4 Credits
An overview of systems engineering within engineering management practice. Principles of systems engineering are explored through traditional and contemporary hard and soft systems of engineering techniques and practices, and through future developments in the field.
Prerequisite: IE 582 with B- or better
Recommended: IE 581 and IE 583 and IE 586 and IE 587
Available via Ecampus

IE 585, LEGAL ASPECT OF ENGINEERING MANAGEMENT, 3 Credits
A survey of legal topics relevant to engineers, including basic of legal system, labor law, intellectual property, torts, and contracts. This is an introductory course, emphasizes on legal principles that can provide engineers with the ability to recognize legal issues that are likely to arise in the engineering profession and engineering management. Note: This is an introductory class and will in no way make a student a lawyer. Students are advised to seek legal representation if he/she encounters a legal issue.
Prerequisite: IE 582 with B or better
Recommended: IE 581 and IE 583 and (IE 586 or CCE 552)
Available via Ecampus

IE 586, PROJECT RISK MANAGEMENT, 4 Credits
An introduction to the concept of project risk in producing constructed engineering projects. Course content includes project baselining, risk definition and identification, risk assessment and management techniques, risk control, risk response, and risk management. CROSSLISTED as CCE 552/IE 586.
Equivalent to: CCE 552
Available via Ecampus

IE 587, MANAGEMENT OF INFORMATION SYSTEMS, 4 Credits
An introduction to the management of information systems and their strategic importance in business. Topics covered include global e-business and collaboration, databases and information management, basics of telecommunication and wireless technology, security vulnerabilities of information systems, basics of business intelligence and business analytics, knowledge management and enhanced decision making.
Prerequisite: IE 582 with B or better
Available via Ecampus

IE 588, MANAGEMENT OF NEW PRODUCT DEVELOPMENT, 4 Credits
Introduces the new product development (NPD) process with the objective of understanding the underlying structure in NPD and exploring the methods to manage NPD processes by applying them to case studies and term project. The NPD process is investigated through its five key phases: (1) Opportunity identification/selection, (2) Concept generation, (3) Concept/project evaluation, (4) Development, and (5) Launch.
Prerequisite: IE 581 with B or better and IE 582 [B] and IE 583 [B]
Recommended: IE 584
Available via Ecampus

IE 589, PROFESSIONAL RESPONSIBILITY AND ETHICS, 3 Credits
An in-depth exploration of professional engineering ethics. Course content includes conceptual theoretical basis of ethics, ethics among professional organizations, ethical consideration of design, critical analysis of ethical situations, ethics in the workplace, and ethical considerations regarding the broader environment. CROSSLISTED as CCE 554/IE 589.
Equivalent to: CCE 554
Available via Ecampus

IE 590, STRATEGIC PLANNING IN ENGINEERING ORGANIZATIONS, 4 Credits
Provides an overview the strategic planning process from a variety engineering perspective. Variety engineering is explored via key management control theory concepts and through applying students’ work experience.
Prerequisite: IE 581 with B or better and IE 582 [B] and IE 583 [B]
Available via Ecampus

IE 591, STATISTICAL CONCEPTS FOR ENGINEERING MANAGERS, 4 Credits
Provides a first review of basic probability and statistical inference concepts and methods relevant for engineering managers. This is followed by a presentation of frequently utilized statistical methods in industry. These include process control, regression analysis, and experimental design. For each method, the fundamental ideas will be covered, and simple examples will be presented to provide engineering managers with the background needed to initiate and manage applications of these methods in industry. The course will end with an overview of process optimization, and robust parameter design.
Prerequisite: IE 582 with B or better
Available via Ecampus

IE 594, RESEARCH METHODS IN ENGINEERING, 3 Credits
Introduction to research methodologies including surveys, interviews, quasi-experimentation, and case studies. Methods for research design, and collection and analysis of data.
Equivalent to: IE 574

IE 599, SPECIAL TOPICS, 1-5 Credits
Recent advances in industrial engineering pertaining to the theory and application of system studies. Analysis and design of natural resource systems; evaluation; detection extraction; processing and marketing systems; advanced design of production systems with reference to social, economic, and regional planning; human engineering studies of man-machine systems; applications of operations research techniques. Nonsequence course. Not offered every term.
Equivalent to: IE 592
This course is repeatable for 99 credits.
Available via Ecampus

IE 603, THESIS, 1-16 Credits
This course is repeatable for 99 credits.

IE 605, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.
IE 606, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

IE 607, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

Materials Science (MATS)

MATS 221, THE SCIENCE, ENGINEERING AND SOCIAL IMPACT OF NANOTECHNOLOGY, 3 Credits
Nanotechnology is an emerging engineering field that manipulates atoms and molecules to fabricate new materials and tiny devices. Properties of nanostructured materials, manufacturing methods, characterization methods, and impact on health and safety. Benefits and concerns about nanotechnology will be assessed. Lec/rec. CROSSLISTED as ENG 221/ MATS 221.
Equivalent to: ENGR 221
Recommended: One year of college science.

MATS 321, INTRODUCTION TO MATERIALS SCIENCE, 4 Credits
Crystal structure, microstructure, and physical properties of metals, ceramics, polymers, composites, and amorphous materials. Also includes elementary mechanical behavior and phase equilibria.
Prerequisite: CH 202 with C or better or CH 222 with C or better or CH 232 with C or better or CH 232H with C or better or CH 224H with C or better
Equivalent to: ENGR 321, ENGR 321H, MATS 321H
Available via Ecampus

MATS 321H, INTRODUCTION TO MATERIALS SCIENCE, 4 Credits
Crystal structure, microstructure, and physical properties of metals, ceramics, polymers, composites, and amorphous materials. Also includes elementary mechanical behavior and phase equilibria.
Attributes: HNRS – Honors Course Designator
Prerequisite: CH 202 with C or better or CH 222 with C or better or CH 232 with C or better or CH 232H with C or better or CH 224H with C or better
Equivalent to: ENGR 321, ENGR 321H, MATS 321

MATS 322, MECHANICAL PROPERTIES OF MATERIALS, 3 Credits
Mechanical behavior of materials, relating laboratory test results to material structure, and elements of mechanical analysis.
Prerequisite: (ENGR 213 with C or better or ENGR 213H with C or better) and (ENGR 321 [C] or ENGR 321H [C] or MATS 321 [C])
Equivalent to: ENGR 322

MATS 413, THERMODYNAMICS AND PHASE EQUILIBRIA OF MATERIALS, 4 Credits
Explores the statistical interpretation of entropy, heat capacity, enthalpy of condensed phases, solution thermodynamics, liquid-solid and solid-solid phase equilibria. Considers the principles of thermodynamics governing phase stability with a focus on liquid-solid and solid-solid equilibria, and phase stability in two-component systems. Examines the relationship of Gibbs free energy to phase stability.
Prerequisite: MATS 321 with C or better and (ME 311 [C] or NSE 311 [C] or CHE 311 [C])

MATS 441, PHYSICAL METALLURGY, 3 Credits
Introduction to properties of metals and alloys including solidification, diffusion, solid solutions, intermediate phases, annealing, heat treatment and phase transformation with a focus on ferrous and non-ferrous metal systems. Identifies relationships between material composition, structure, and properties resulting from synthesis, processing or service. Explores the knowledge of ferrous and non-ferrous alloy systems and their significant metallurgical properties and applications.
Prerequisite: MATS 321 with C or better

MATS 445, WELDING METALLURGY, 4 Credits
Theory-based course focused on the metallurgy of welds. Topics covered include welding/joining processes, heat input, diffusion, solidification, phase transformation, materials compatibility and welding defects. This is NOT a practical welding class.
Prerequisite: (MATS 321 with C or better or ENGR 321 with C or better or ENGR 321H with C or better) or MATS 570 with C or better

MATS 455, EXPERIMENTAL TECHNIQUES IN MATERIAL SCIENCE, 4 Credits
Materials processing, characterization, computational and data analysis techniques in materials science. Focus on processing-structure-property relationships. Lec/lab.
Prerequisite: (ENGR 321 with C or better or ENGR 321H with C or better)
Equivalent to: ME 455
This course is repeatable for 8 credits.
Recommended: ME 570

MATS 478, THIN FILM MATERIALS CHARACTERIZATION AND PROPERTIES, 4 Credits
Processing of thin films and characterization of the microstructure; diffusion and solid state reactions; mechanical, magnetic and electronic properties of thin films.
Prerequisite: (ME 311 with C or better or ME 311H with C or better) and (ENGR 321 [C] or ENGR 321H [C] or MATS 321 [C]) and (ENGR 322 [C] or MATS 322 [C])
Equivalent to: ME 478

MATS 499, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.
MATS 545, WELDING METALLURGY, 4 Credits
Theory-based course focused on the metallurgy of welds. Topics covered include welding/joining processes, heat input, diffusion, solidification, phase transformation, materials compatibility and welding defects. This is NOT a practical welding class.
Recommended: (MATS 321 or ENGR 321 or ENGR 321H) or MATS 570

MATS 555, EXPERIMENTAL TECHNIQUES IN MATERIAL SCIENCE, 4 Credits
Materials processing, characterization, computational and data analysis techniques in materials science. Focus on processing-structure-property relationships. Lec/lab.
Prerequisite: ME 570 with C or better
Equivalent to: ME 555
This course is repeatable for 8 credits.
Recommended: ENGR 321 or ENGR 321H

MATS 570, STRUCTURE-PROPERTY RELATIONS IN MATERIALS, 4 Credits
Equivalent to: ME 570

MATS 571, ELECTRONIC PROPERTIES OF MATERIALS, 4 Credits
Equivalent to: ME 571
Recommended: CH 545 or ME 570

MATS 578, THIN FILM MATERIALS CHARACTERIZATION AND PROPERTIES, 4 Credits
Processing of thin films and characterization of the microstructure; diffusion and solid state reactions; mechanical, magnetic and electronic properties of thin films.
Equivalent to: ME 578

MATS 581, THERMODYNAMICS OF SOLIDS, 4 Credits
Equivalent to: ME 581

MATS 582, RATE PROCESSES IN MATERIALS, 3 Credits
Diffusion in solids, including vacancy and interstitial and short-circuit diffusion. Phase transformations including classic nucleation and growth theory. Applications to materials development.
Prerequisite: MATS 581 with C or better or ME 581 with C or better
Equivalent to: ME 582

MATS 584, ADVANCED FRACTURE OF MATERIALS, 4 Credits
Fracture mechanics will be used as a basis for predicting failure of materials, understanding failure mechanisms, and identifying causes of failure. Course will include discussion of recent journal articles, experimental demonstrations, and analysis of real fracture data.
Equivalent to: ME 584
Recommended: ENGR 322

MATS 587, DISLOCATIONS, DEFORMATION, AND CREEP, 4 Credits
The effects of point, line, and planar defects on plastic deformation and creep behavior in solids will be discussed with emphasis on the role of dislocations and vacancies.
Equivalent to: ME 587
Recommended: ENGR 322

MATS 588, COMPUTATIONAL METHODS IN MATERIALS SCIENCE, 4 Credits
A broad introduction to important materials science simulation methods. These include molecular dynamics, density functional theory, and Monte Carlo methods. Learning is through a mixture of lecture and hands-on lab projects in which students use computational methods to explore and reinforce fundamental concepts in materials science. Lec/lab.
Equivalent to: ME 588
Recommended: Experience with Matlab or Mathematica or an equivalent numerical and programming environment.

MATS 599, SPECIAL TOPICS, 1-16 Credits
This course is repeatable for 16 credits.

MATS 659, PRINCIPLES OF TRANSMISSION ELECTRON MICROSCOPY, 4 Credits
This lecture-only course covers basic principles of transmission electron microscopy (TEM) including instrument components, electron optics, electron diffraction, and the origins and interpretation of image contrast. Spectroscopic techniques are covered, but diffraction and imaging techniques are emphasized. Coverage of experimental techniques will focus on those useful for addressing problems in materials science.
Recommended: MATS 570 and (CH 616 or MATS 555)
MATS 671, ELECTRONIC PROPERTIES OF OXIDES, 3 Credits
Band theory of solids applied to metal oxide materials. Includes metallic oxides, non-stoichiometric semiconductors and associated defect chemistry, high temperature superconductors, electrostatics, linear dielectrics, non-linear dielectrics, piezoelectrics, and the optical properties of oxides.
Equivalent to: ME 671
Recommended: MATS 571 or PH 575

Mechanical Engineering (ME)
ME 206, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ME 250, INTRODUCTION TO MANUFACTURING PROCESSES, 1 Credit
Use of measuring and layout tools, interpretation of blueprints and drawings, identification of engineering materials. Operation of machine tools, including calculation of machining parameters. Operation of gas and MIG welding equipment. Lec/lab. Graded P/N.
Prerequisite: ENGR 248 with C or better and (PH 211 [C] or PH 211H [C])

ME 299, SPECIAL TOPICS, 1-16 Credits
Graded P/N.
Equivalent to: ME 299H
This course is repeatable for 16 credits.

ME 299H, SPECIAL STUDIES, 1-16 Credits
Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: ME 299
This course is repeatable for 16 credits.

ME 306, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ME 311, INTRODUCTION TO THERMAL-FLUID SCIENCES, 4 Credits
Basic concepts of fluid mechanics, thermodynamics and heat transfer are introduced. Conservation of mass, energy, moment and the second law of thermodynamics are included. CROSSLISTED as ME 311/NSE 311.
Prerequisite: (ENGR 212 with C or better or ENGR 212H with C or better) and (MTH 256 [C] or MTH 256H [C])
Equivalent to: ENGR 311, ENGR 311H, ME 311H, NE 311, NE 311H, NSE 311, NSE 311H

ME 311H, INTRODUCTION TO THERMAL-FLUID SCIENCES, 4 Credits
Basic concepts of fluid mechanics, thermodynamics and heat transfer are introduced. Conservation of mass, energy, moment and the second law of thermodynamics are included. CROSSLISTED as ME 311/NSE 311.
Attributes: HNRS – Honors Course Designator
Prerequisite: (ENGR 212 with C or better or ENGR 212H with C or better) and (MTH 256 [C] or MTH 256H [C])
Equivalent to: ENGR 311, ENGR 311H, ME 311, NE 311, NE 311H, NSE 311, NSE 311H

ME 312, THERMODYNAMICS, 4 Credits
Analyzes exergy destruction, machine and cycle processes, law of corresponding states, non-reactive gas mixtures, reactive mixtures, thermodynamics of compressible fluid flow. CROSSLISTED as ME 312/NSE 312.
Prerequisite: ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better
Equivalent to: ENGR 312, ME 312H, NE 312, NE 312H, NSE 312, NSE 312H

ME 312H, THERMODYNAMICS, 4 Credits
Analyzes exergy destruction, machine and cycle processes, law of corresponding states, non-reactive gas mixtures, reactive mixtures, thermodynamics of compressible fluid flow. CROSSLISTED as ME 312/NSE 312.
Attributes: HNRS – Honors Course Designator
Prerequisite: ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better
Equivalent to: ENGR 312, ME 312, ME 312H, NE 312, NSE 312, NSE 312H

ME 316, MECHANICS OF MATERIALS, 3 Credits
Determination of stresses, deflections, and stability of deformable bodies with an introduction to finite element analysis.
Prerequisite: (ENGR 213 with C or better or ENGR 213H with C or better) and (MTH 256 [C] or MTH 256H [C])

ME 317, INTERMEDIATE DYNAMICS, 4 Credits
Continues the study of kinematics and kinetics of particles and rigid bodies, with applications to mechanical systems of current interest to engineers.
Prerequisite: (ENGR 212 with C or better or ENGR 212H with C or better) and (MTH 256 [C] or MTH 256H [C]) and (ENGR 112 [C] or CS 161 [C] or CBEE 102 [C] or NSE 115 [C])
Equivalent to: ME 317H

ME 317H, INTERMEDIATE DYNAMICS, 4 Credits
Continues the study of kinematics and kinetics of particles and rigid bodies, with applications to mechanical systems of current interest to engineers.
Attributes: HNRS – Honors Course Designator
Prerequisite: (ENGR 212 with C or better or ENGR 212H with C or better) and (MTH 256 [C] or MTH 256H [C]) and (ENGR 112 [C] or CS 161 [C] or CBEE 102 [C] or NSE 115 [C])
Equivalent to: ME 317
ME 331, INTRODUCTORY FLUID MECHANICS, 4 Credits
Introduces the concepts and applications of fluid mechanics and dimensional analysis with an emphasis on fluid behavior, internal and external flows, analysis of engineering applications of incompressible pipe systems, and external aerodynamics. CROSSTLISTED as ME 331/NSE 331.
Prerequisite: ENGR 311 with C or better or ENGR 311H with C or better or ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better
Equivalent to: ENGR 331, ENGR 331H, ME 331H, NSE 331, NSE 331H

ME 331H, INTRODUCTORY FLUID MECHANICS, 4 Credits
Introduces the concepts and applications of fluid mechanics and dimensional analysis with an emphasis on fluid behavior, internal and external flows, analysis of engineering applications of incompressible pipe systems, and external aerodynamics. CROSSTLISTED as ME 331/NSE 331.
Attributes: HNRS – Honors Course Designator
Prerequisite: ENGR 311 with C or better or ENGR 311H with C or better or ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better
Equivalent to: ENGR 331, ENGR 331H, ME 331H, NSE 331, NSE 331H

ME 332, HEAT TRANSFER, 4 Credits
Analyzes conductive, convective and radiative energy transfer using control volume and differential analysis and prediction of transport properties. CROSSTLISTED as ME 332/NSE 332.
Prerequisite: ME 331 with C or better or ME 331H with C or better or NSE 331 with C or better or NSE 331H with C or better or NE 311 with C or better or NE 311H with C or better or ME 311 with C or better or ME 311H with C or better
Equivalent to: ME 332H, NE 332, NE 332H, NSE 332, NSE 332H

ME 332H, HEAT TRANSFER, 4 Credits
Analyzes conductive, convective and radiative energy transfer using control volume and differential analysis and prediction of transport properties. CROSSTLISTED as ME 332/NSE 332.
Attributes: HNRS – Honors Course Designator
Prerequisite: ME 331 with C or better or ME 331H with C or better or NSE 331 with C or better or NSE 331H with C or better or NE 311 with C or better or NE 311H with C or better or ME 311 with C or better or ME 311H with C or better
Equivalent to: ME 332, NE 332, NE 332H, NSE 332, NSE 332H

ME 335, INTRODUCTION TO INSTRUMENTATION AND MEASUREMENT SYSTEMS, 4 Credits
Illustrates the function, operation, and application of common mechanical engineering instruments, measurement principles, and statistical analysis. Demonstrates elements of measurement systems, including transduction, signal conditioning, and data recording. Examines function and operation of digital data acquisition systems.
Prerequisite: ENGR 202 with C or better or ENGR 202H with C or better and (ENG 212 [C] or ENGR 212H [C]) and (ENG 213 [C] or ENGR 213H [C])
Equivalent to: ME 451

ME 373, MECHANICAL ENGINEERING METHODS, 4 Credits
Analytical and numerical methods for solving representative mechanical engineering problems. Lec/rec.
Prerequisite: ENGR 112 with C or better or ENGR 112H with C or better and (MTH 256 [C] or MTH 256H [C]) and MTH 341 [C]
Equivalent to: ME 373H

ME 373H, MECHANICAL ENGINEERING METHODS, 4 Credits
Analytical and numerical methods for solving representative mechanical engineering problems. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisite: ENGR 112 with C or better or ENGR 112H with C or better and (MTH 256 [C] or MTH 256H [C]) and MTH 341 [C]
Equivalent to: ME 373

ME 382, INTRODUCTION TO DESIGN, 4 Credits
Organization, planning, economics, and the use of creativity and optimization in solving mechanical design problems. Case studies and/or industrial design problems. Lec/lab.
Prerequisite: ENGR 248 with C or better and ME 250 (may be taken concurrently) [C] and ENGR 212 [C] and ENGR 213 [C]
Equivalent to: ME 382H

ME 382H, INTRODUCTION TO DESIGN, 4 Credits
Organization, planning, economics, and the use of creativity and optimization in solving mechanical design problems. Case studies and/or industrial design problems. Lec/lab.
Attributes: HNRS – Honors Course Designator
Prerequisite: ENGR 248 with C or better and ME 250 (may be taken concurrently) [C] and (PH 211 [C] or PH 211H [C])
Equivalent to: ME 382

ME 383, MECHANICAL COMPONENT DESIGN, 4 Credits
Failure analysis and design of machine components. Lec/lab.
Prerequisite: ME 316 with C or better and ME 250 (may be taken concurrently) [C] and (ENG 212 [C] or ENGR 212H [C]) and (ENG 213 [C] or ENGR 213H [C])
Equivalent to: ME 383H
ME 383H, MECHANICAL COMPONENT DESIGN, 4 Credits
Failure analysis and design of machine components. Lec/lab.
Attributes: HNRS – Honors Course Designator
Prerequisite: ME 316 with C or better and ME 250 (may be taken concurrently) [C] and (ENGR 212 [C] or ENGR 212H [C]) and ENGR 213 [C]
Equivalent to: ME 383

ME 401, RESEARCH, 1-16 Credits
This course is repeatable for 9 credits.

ME 403, THESIS, 1-16 Credits
This course is repeatable for 16 credits.

ME 405, READING AND CONFERENCE, 1-16 Credits
Equivalent to: ME 405H
This course is repeatable for 9 credits.

ME 405H, READING AND CONFERENCE, 1-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: ME 405
This course is repeatable for 9 credits.

ME 406, PROJECTS, 1-16 Credits
This course is repeatable for 15 credits.

ME 407, SEMINAR, 1-16 Credits
Equivalent to: ME 407H
This course is repeatable for 2 credits.

ME 410, INTERNSHIP, 1-16 Credits
Credits may not apply toward BS degree in Mechanical Engineering. Graded P/N.
This course is repeatable for 16 credits.

ME 411, AEROSPACE APPLICATIONS IN MECHANICAL ENGINEERING, 4 Credits
Provides students with the fundamentals of mechanical engineering applications to aerospace. Topics covered include an overview of modern aircraft and spacecraft analysis, with an emphasis on performance, stability, structures, materials, FAA and FAR standards and current professional practices in the conceptual design of aerospace vehicles. Student projects will integrate course topics.
Prerequisite: (ME 316 with C or better and (ME 317 [C] or ME 317H [C]) and (ME 331 [C] or ME 331H [C]) and (ME 373 [C] or ME 373H [C]))

ME 412, DESIGN OF MECHANISMS, 4 Credits
Analysis and study of the function, classification, position, velocity, and acceleration of multi-element mechanical linkages and mechanisms. Synthesis of mechanisms for specified multiple point paths, quick return, dwell, and straight-line motion. The lecture will instruct students in the kinematic analysis and synthesis of mechanisms through the use of theory and software packages. The laboratory will familiarize students with a modern mechanism design and animation software package. Lec/lab.
Prerequisite: (ME 317 with C or better or ME 317H with C or better) and ME 383 [C]

ME 420, APPLIED STRESS ANALYSIS, 4 Credits
Elasticity theory, failure theories, energy methods, finite element analysis.
Prerequisite: ME 316 with C or better

ME 422, MECHANICAL VIBRATIONS, 4 Credits
Dynamic response of single and multiple degree-of-freedom systems.
Prerequisite: ME 317 with C or better or ME 317H with C or better
Equivalent to: ME 422H

ME 422H, MECHANICAL VIBRATIONS, 4 Credits
Dynamic response of single and multiple degree-of-freedom systems.
Attributes: HNRS – Honors Course Designator
Prerequisite: ME 317 with C or better or ME 317H with C or better
Equivalent to: ME 422

ME 424, FINITE ELEMENT MODELING OF MECHANICAL ENGINEERING SYSTEMS, 3 Credits
Application of modern finite element code in the analysis of complex mechanical engineering systems. Extensive use of engineering workstations. Lec/lab.
Prerequisite: ME 420 with C or better or ME 520 with C or better

ME 430, SYSTEMS DYNAMICS AND CONTROL, 4 Credits
Modeling and analysis of linear continuous systems in time and frequency domains. Fundamentals of single-input-single-output control system design. CROSSTLISTED as ECE 451/ME 430.
Prerequisite: (ME 317 with C or better or ME 317H with C or better or (ECE 351 with C or better and ECE 352 [C] and (ENGR 212 [C] or ENGR 212H [C]))
Equivalent to: ECE 451, ME 430H
Available via Ecampus
ME 430H, SYSTEMS DYNAMICS AND CONTROL, 4 Credits
Modeling and analysis of linear continuous systems in time and frequency domains. Fundamentals of single-input-single-output control system design. Crosslisted as ECE 451/ME 430.
Attributes: HNRS – Honors Course Designator
Prerequisite: (ME 317 with C or better or ME 317H with C or better or (ECE 351 with C or better and ECE 352 [C] and (ENGR 212 [C] or ENGR 212H [C])))
Equivalent to: ECE 451, ME 430

ME 443, RENEWABLE ENERGY: THERMAL FLUID SYSTEMS, 4 Credits
Evaluates several thermal/fluid power conversion strategies that deal with both thermal and fluid energy sources in terms of basic conversion technology, resource potential and developmental challenges. There are four modules, each targeting a particular renewable energy system in thermal and fluid sciences.
Prerequisite: (ME 311 with C or better or ME 311H with C or better or NE 311 with C or better or NE 331 [C] or NE 331H [C] or NE 331 [C] or NE 331H [C]) and (ME 332 [C] or ME 332H [C] or NE 332 [C] or NE 332H [C])

ME 444, THERMAL SYSTEMS DESIGN AND ANALYSIS, 4 Credits
Integration of the concepts, laws, and methodologies from fluid mechanics, heat transfer, and thermodynamics, into a set of practical tools for thermal energy systems design and analysis.
Prerequisite: (ME 332 with C or better or ME 332H with C or better or NSE 332 with C or better or NSE 332H with C or better and (ME 312 (may be taken concurrently) [C] or ME 312H (may be taken concurrently) [C] or NSE 332 (may be taken concurrently) [C] or NSE 332H (may be taken concurrently) [C])

ME 445, INTRODUCTION TO COMBUSTION, 4 Credits
Study of combustion science based on the background of chemistry, thermodynamics, fluid mechanics, heat and mass transfer. Stoichiometry, energetics of chemical reactions, flame temperature, equilibrium product analyses, chemical kinetics, and chain reactions.
Prerequisite: (ME 312 with C or better or ME 312H with C or better) and (ME 332 [C] or ME 332H [C])

ME 450, APPLIED HEAT TRANSFER, 4 Credits
An intermediate heat transfer course seeking to lay a foundation for determining the heating and cooling characteristics with a variety of modern and classical processes. Included is design of multi-component heat transfer systems. Lecture, 110 minutes twice per week.
Prerequisite: ME 332 with C or better or ME 332H with C or better

ME 452, THERMAL AND FLUIDS SCIENCES LABORATORY, 4 Credits
Course emphasis is on experiments related to thermodynamics, heat transfer, and fluid mechanics. Proper experimental methods, data and uncertainty analysis related to thermal and fluids measurements are discussed.
Prerequisite: (ME 311 with C or better or ME 311H with C or better) and (ME 331 [C] or ME 331H [C] and (ME 332 [C] or ME 332H [C])
Equivalent to: ME 452

ME 452H, THERMAL AND FLUIDS SCIENCES LABORATORY, 4 Credits
Course emphasis is on experiments related to thermodynamics, heat transfer, and fluid mechanics. Proper experimental methods, data and uncertainty analysis related to thermal and fluids measurements are discussed.
Attributes: HNRS – Honors Course Designator
Prerequisite: (ME 311 with C or better or ME 311H with C or better) and (ME 331 [C] or ME 331H [C] and (ME 332 [C] or ME 332H [C])
Equivalent to: ME 452

ME 453, STRUCTURE AND MECHANICS LABORATORY, 4 Credits
Techniques for measurement of structural response and material properties. Proper use of rosette strain gauges, load cells, and displacement transducers. Full-field strain measurement using photoelasticity and digital image correlation. Proper implementation of material testing standards. Characterization of anisotropic composite materials.
Prerequisite: ME 451 with C or better

ME 460, INTERMEDIATE FLUID MECHANICS, 4 Credits
Ideal fluid flow including potential flow theory. Introduction to compressible flow. Viscous flow and boundary layer theory. Introduction to turbulence.
Prerequisite: ME 331 with C or better or ME 331H with C or better

ME 461, GAS DYNAMICS, 4 Credits
Studies one-dimensional isentropic flow, nozzles, diffusers, normal and oblique shocks, compressible flow with friction and heating, and an introduction to propulsion systems.
Prerequisite: (ME 312 with C or better or ME 312H with C or better) and (ME 331 [C] or ME 331H [C])

ME 480, MATERIALS SELECTION, 3 Credits
Selecting materials for engineering applications. The major families of materials, their properties, and how their properties are controlled; case studies and design projects emphasizing materials selection.
Prerequisite: MATS 322 with C or better or ENGR 322 with C or better
ME 484, FRACTURE OF MATERIALS, 3 Credits
Fracture mechanics and fatigue mechanisms: mechanisms of ductile and brittle fracture. Environmentally induced fracture and fatigue. Considerations in design of engineering materials and structures will be discussed.
Prerequisite: MATS 322 with C or better or ENGR 322 with C or better

ME 499, SPECIAL TOPICS, 0-16 Credits
Equivalent to: ME 499H
This course is repeatable for 16 credits.

ME 499H, SPECIAL TOPICS, 0-16 Credits
Attributes: HNRS – Honors Course Designator
Equivalent to: ME 499
This course is repeatable for 16 credits.

ME 501, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ME 502, INDEPENDENT STUDIES, 1-16 Credits
This course is repeatable for 16 credits.

ME 503, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ME 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

ME 506, PROJECTS, 1-16 Credits
Graded P/N.
This course is repeatable for 16 credits.

ME 507, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

ME 508, THERMAL FLUID SCIENCE SEMINAR, 1 Credit
Student participation seminar experience for 1 course credit. Students will present and listen to seminars concerning ongoing research within the thermal fluid sciences.

ME 509, MATERIALS SCIENCE SEMINAR, 1 Credit
Student participation seminar experience for one credit; students will listen to seminars concerning ongoing research activities within materials science. Students will also have the opportunity to present their own research results periodically. Graded P/N.
Equivalent to: MATS 509

ME 511, PRECISION MACHINE DESIGN, 3 Credits
Tolerance analysis and application in design/manufacturing practice, principles of machine design and computational analysis of errors in machine design, sensor mounting and sensor calibration, machine level error budget with geometric and thermal errors, structural design of joints and supports, deterministic damping, exact constraint design for flexures and couplings, bearing systems design, motion and power system design for machine tools. CROSSLISTED as ME 511/MFGE 511.
Equivalent to: MFGE 511
Recommended: An understanding of mechanical component design and solid mechanics.

ME 512, DESIGN OF MECHANISMS, 4 Credits
Analysis and study of the function, classification, position, velocity, and acceleration of multi-element mechanical linkages and mechanisms. Synthesis of mechanisms for specified multiple point paths, quick return, dwell, and straight-line motion. The lecture will instruct students in the kinematic analysis and synthesis of mechanisms through the use of theory and software packages. The laboratory will familiarize students with a modern mechanism design and animation software package. Lec/lab.
Recommended: (ME 317 or ME 317H) and ME 383

ME 513, BIO-INSPIRED DESIGN, 4 Credits
Intersection of design and biology that seeks to systematically mine biological knowledge to solve design problems. Investigates inspiration from nature from three different types: visual, conceptual, and computational. Includes design rules, heuristics, principles or patterns to solve engineering problems. Algorithmic bio-inspiration emulates natural algorithms for control or optimization problems.

ME 515, RISK AND RELIABILITY ANALYSIS IN ENGINEERING DESIGN, 4 Credits
Fundamentals of risk, uncertainty, and reliability. Methods to analyze and quantify the risk of failures, and the reliability of complex systems, including fault tree analysis, reliability block diagrams, probabilistic risk assessment. Introduction to research methods for risk and reliability analysis during the early design stages.

ME 516, MODELING AND ANALYSIS OF COMPLEX SYSTEMS, 4 Credits
Introduction to challenges and considerations when designing complex systems. Fundamentals of systems engineering and methods used in practice. Models and tools used to enable the use of models for trade studies during the design of complex systems. Model-based design environments and methodologies. Introduction to decision support tools in design.

ME 517, OPTIMIZATION IN DESIGN, 4 Credits
Optimization methods as applied to engineering design, theory and application of nonlinear optimization techniques for multivariate unconstrained and constrained problems. Model boundedness and sensitivity.
ME 519, SELECTED TOPICS IN DESIGN, 3-4 Credits
Topics in mechanical design selected from the following: design processes, quality engineering, design for assembly, statistical machine design, the Taguchi method, and parametric design. This course is repeatable for 32 credits.

ME 520, APPLIED STRESS ANALYSIS, 4 Credits
Elasticity theory, failure theories, energy methods, finite element analysis. Recommended: ME 316

ME 521, LINEAR ELASTICITY, 4 Credits
A general introduction to the theory of elasticity. The solution of 2-D problems using the Airy stress function in rectangular and polar coordinates. The solution of 3-D problems using the Galerkin vector, the Papkovich-Neuber solution, and complex variable methods. Applications to asymptotic fields at discontinuities, contact and crack problems, and thermoelasticity. Recommended: ME 316

ME 522, MECHANICAL VIBRATIONS, 4 Credits
Dynamic response of single and multiple degree-of-freedom systems. Recommended: ME 317

ME 523, ADVANCED STRESS ANALYSIS, 4 Credits
An introduction to the mechanics of nonlinear elastic, plastic, and viscoelastic material behavior including large deformations. Recommended: ME 316

ME 524, FINITE ELEMENT MODELING OF MECHANICAL ENGINEERING SYSTEMS, 3 Credits
Application of modern finite element code in the analysis of complex mechanical engineering systems. Extensive use of engineering workstations. Lec/lab. Prerequisite: ME 520 with C or better

ME 526, NUMERICAL METHODS FOR ENGINEERING ANALYSIS, 3 Credits
Numerical solutions of linear equations, difference equations, ordinary and partial differential equations. CROSSLISTED as ME 526/NSE 526. Equivalent to: NE 526, NSE 526 Recommended: Programming experience and previous exposure to numerical methods

ME 529, SELECTED TOPICS IN SOLID MECHANICS, 3-4 Credits
Advanced topics in solid mechanics emphasizing research applications of current interest. This course is repeatable for 32 credits.

ME 531, LINEAR MULTIVARIABLE CONTROL SYSTEMS I, 4 Credits
Theoretical design of control systems for systems modeled by linear multivariable differential equations. Topics covered include controllability, observability, state feedback control, pole placement, output feedback, estimator design, and control designs that include both estimators and regulators.

ME 532, LINEAR MULTIVARIABLE CONTROL SYSTEMS II, 4 Credits
Focuses on designing control systems where the device to be controlled is an uncertain system, yet can be described by a set of linear differential equations. Lec. Prerequisite: ME 531 with C or better

ME 533, NONLINEAR DYNAMIC ANALYSIS, 4 Credits
Course focuses on understanding the behavior of nonlinear dynamic systems of interest to mechanical engineers. Lec. Recommended: ME 317

ME 534, NONLINEAR MULTIVARIABLE CONTROL SYSTEMS, 4 Credits
Focuses on designing control systems when the device to be controlled is mathematically described by a nonlinear set of differential equations. Lec. Prerequisite: ME 533 with C or better

ME 539, SELECTED TOPICS IN DYNAMICS, 1-16 Credits
Advanced topics in dynamics emphasizing research applications of current interest. This course is repeatable for 30 credits.

ME 540, INTERMEDIATE THERMODYNAMICS, 4 Credits
Students are expected to master classical thermodynamics by way of solving extended problems using software tools. Statistical thermodynamics concepts are also introduced and exercised. Recommended: ME 312

ME 541, LIQUID-VAPOR PHASE CHANGE AND HEAT TRANSFER, 4 Credits
Advanced treatment of underlying physics and engineering modeling approaches for heat transfer associated with vapor/liquid phase change processes. Topics include thermodynamics and mechanical aspects of phase change processes, pool boiling, filmwise and dropwise condensation, internal convective boiling and condensation, and other emerging areas in phase change heat transfer.
ME 543, RENEWABLE ENERGY: THERMAL FLUID SYSTEMS, 4 Credits
Evaluates several thermal/fluid power conversion strategies that deal with both thermal and fluid energy sources in terms of basic conversion technology, resource potential and developmental challenges. There are four modules, each targeting a particular renewable energy system in thermal and fluid sciences.
Recommended: (ME 311 or ME 311H or NE 311 or NE 311H) and (ME 331 or ME 331H or ME 331 or ME 331H) and (ME 332 or ME 332H or NE 332 or NE 332H)

ME 544, ADVANCED POWER GENERATION SYSTEMS, 4 Credits
Thermal mechanical evaluation of modern power generation technologies, including fossil and nuclear Rankine cycle power plants, gas turbines, cogeneration power plants, distributed power generation and fuel cells. Lec/rec.
Recommended: ME 312 and (ME 331 or ME 331H)

ME 545, INTRODUCTION TO COMBUSTION, 4 Credits
Study of combustion science based on the background of chemistry, thermodynamics, fluid mechanics, heat and mass transfer. Stoichiometry, energetics of chemical reactions, flame temperature, equilibrium product analyses, chemical kinetics, and chain reactions.
Recommended: ME 312 and (ME 332 or ME 332H)

ME 546, CONVECTION HEAT TRANSFER, 3 Credits
An advanced treatment of forced and natural convection heat transfer processes emphasizing underlying physical phenomena. Current topical literature will be considered; analytical and numerical problem solving is included.
Recommended: (ME 332 or ME 332H) and ME 373

ME 547, CONDUCTIVE HEAT TRANSFER, 3 Credits
Analytical and numerical solutions to steady state and transient conduction problems.
Recommended: (ME 332 or ME 332H) and ME 373

ME 548, RADIATION HEAT TRANSFER, 3 Credits
Analytical and numerical methods of solution of thermal radiation problems.
Recommended: (ME 332 or ME 332H) and ME 373

ME 549, SELECTED TOPICS IN HEAT TRANSFER, 3 Credits
Topics in heat transfer including advanced problems in conduction, radiation, and convection. Additional examination of heat transfer in multiphase systems, inverse problems, combined modes, equipment design, solution techniques and other topics of current interest considered, including extensive use of current literature. Not all topics covered each year.
This course is repeatable for 9 credits.

ME 550, APPLIED HEAT TRANSFER, 4 Credits
An intermediate heat transfer course seeking to lay a foundation for determining the heating and cooling characteristics with a variety of modern and classical processes. Included is design of multi-component heat transfer systems. Lecture, 110 minutes twice per week.
Recommended: ME 332 or ME 332H

ME 552, MEASUREMENTS IN FLUID MECHANICS AND HEAT TRANSFER, 4 Credits
Course emphasis is on measurement techniques and data analysis methods related to fluid mechanics and heat transfer. Proper experimental methods, data and uncertainty analyses related to thermal and fluids measurements are discussed. Local and spatial mapping of fluid and thermal fields are highlighted.
Recommended: (ME 331 or ME 331H) and (ME 332 or ME 332H) and ME 451.

ME 553, STRUCTURE AND MECHANICS LABORATORY, 4 Credits
Techniques for measurement of structural response and material properties. Proper use of rosette strain gauges, load cells, and displacement transducers. Full-field strain measurement using photoelasticity and digital image correlation. Proper implementation of material testing standards. Characterization of anisotropic composite materials.
Recommended: ME 451

ME 560, INTERMEDIATE FLUID MECHANICS, 4 Credits
Ideal fluid flow including potential flow theory. Introduction to compressible flow. Viscous flow and boundary layer theory. Introduction to turbulence.
Recommended: ME 331

ME 561, GAS DYNAMICS, 4 Credits
Studies one-dimensional isentropic flow, nozzles, diffusers, normal and oblique shocks, compressible flow with friction and heating, and an introduction to propulsion systems.
Recommended: ME 312 and (ME 331 or ME 331H)

ME 564, TURBULENCE MODELING, 3 Credits
An introductory course on theory of different turbulence modeling techniques such as Reynolds Averaged Navier Stokes (RANS), Large Eddy Simulation (LES), and Direct Numerical Simulation (DNS) applied to a range of turbulent flows including free shear flows, boundary layers, and internal flows.
Prerequisite: ME 560 with C or better and (ME 565 [C] or ME 566 [C])

ME 565, INCOMPRESSIBLE FLUID MECHANICS, 3 Credits
Generalized fluid mechanics; kinematics; methods of description, geometry of the vector field, dynamics of nonviscous fluids, potential motion, two-dimensional potential flow with vorticity.
ME 566, VISCOSOUS FLOW, 3 Credits
Boundary layer, stability, transition prediction methods, computational methods in fluid mechanics, recent developments.

ME 567, ENGINEERING APPLICATIONS OF COMPUTATIONAL FLUID DYNAMICS, 4 Credits
Basic concepts of computational fluid dynamics, a technique used for solving fully three-dimensional fluid flow problems with no exact solution, will be discussed and applied to general engineering applications using commercially available software. Lec.
Recommended: ME 312 and (ME 331 or ME 331H)

ME 568, TURBULENT FLOW DYNAMICS, 4 Credits
An introductory course of the basic physics of turbulent flows, coverage will include statistical methods and physical interpretation of a range of flows including boundary layer flows, internal flows, and environmental flows.
Prerequisite: ME 560 with C or better
Recommended: A first course in fluid mechanics such as ME 331

ME 569, SELECTED TOPICS IN FLUID MECHANICS, 2-4 Credits
Topics in fluid mechanics emphasizing research applications of current interest.
This course is repeatable for 32 credits.

ME 580, MATERIALS SELECTION, 3 Credits
Selecting materials for engineering applications. The major families of materials, their properties, and how their properties are controlled; case studies and design projects emphasizing materials selection. Lec/lab.
Equivalent to: MATS 580
Recommended: MATS 322 or ENGR 322

ME 583, COMPOSITE MATERIALS, 3 Credits
Explores fibers and matrices, mechanics of composites, reinforcement and failure mechanisms, properties and applications.
Recommended: ME 420 and ME 483 with a minimum grade of C

ME 585, FATIGUE OF MATERIALS, 4 Credits
Analyzes the failure of materials by fatigue including how fatigue behavior is characterized, how fatigue failure is predicted, the physical mechanisms responsible for fatigue failure of various materials, and how such behavior is related to the atomic structure and microstructure of the material.
Prerequisite: ME 570 with C or better or MATS 570 with C or better

ME 589, SELECTED TOPICS IN MATERIALS, 3 Credits
Topics in materials science to correspond to areas of graduate research. Topics will be chosen from the following list: optical materials, dielectrics, oxidation and corrosion, ceramics, thermophysical properties, polymers and viscoelasticity, coatings and thin films. Lec/rec.
This course is repeatable for 32 credits.

ME 596, SELECTED TOPICS IN THERMODYNAMICS, 3 Credits
Topics in thermodynamics including advanced problems in classical thermodynamics and statistical thermodynamics of current interest. Topics will likely be considered, including extensive use of literature. Not all topics covered each year.
This course is repeatable for 32 credits.

ME 597, PRECISION MOTION GENERATION, 4 Credits
Introduces fundamental knowledge in mechatronic systems used in manufacturing equipment such as CNC machine tools, and their computer numerical controls. Students will be exposed to sensors and actuators utilized in machine tools, industrial robots and for process automation. Fundamental knowledge to model and identify dynamics of motion delivery systems, design and analysis of accurate position control algorithms for precision motion generation will be covered. Digital motion control design will be introduced. Motion planning and real-time path interpolation algorithms will be covered. Students will be able to design NC systems for 2D motion platforms.
Recommended: ME 430

ME 599, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 32 credits.

ME 601, RESEARCH, 1-16 Credits
This course is repeatable for 16 credits.

ME 603, THESIS, 1-16 Credits
This course is repeatable for 999 credits.

ME 605, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.

ME 606, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.

ME 607, SEMINAR, 1-16 Credits
This course is repeatable for 16 credits.

ME 611, MODERN PRODUCT DESIGN, 4 Credits
Modern product development, design and prototyping are covered. Product development and prototyping is examined from a research standpoint in this course. Customer outcomes gathering, functional modeling, product architecture, modern techniques for concept generation and selection are explored. Also covered are recently developed theories and techniques for prototyping. The topics’ place in the overall design process is shown through a product development and prototyping project.
ME 613, SUSTAINABLE PRODUCT DESIGN, 4 Credits
Graduate students will work in multidisciplinary design teams to develop innovative and environmentally friendly products. Combining the principles of integrated product development and sustainable design thinking, students will (a) advance their knowledge of the design process by creating a patent-quality new product, (b) learn and employ environmentally-minded design theory and methods, including various software packages and online tools, and (c) further enhance teamworking skills by working collaboratively in a professional design team. Sustainable Product Development is conducted as a collaborative design experience, in that lectures, discussion, and team working time will be integrated into class sessions.

ME 615, DESIGN UNDER UNCERTAINTY, 4 Credits
Tackles the problem of decision making in engineering design. The fundamental challenge faced in making decisions in engineering designs is that they are almost exclusively decisions made under uncertainty. Sources of uncertainty could result from engineering models, experiments conducted, or lack of knowledge of future events. The course will cover three basic topics 1) how do we quantify uncertainty, 2) how do we account for the uncertainty in decision making, and 3) how do we make design selection decisions about products or systems we design.
Prerequisite: ME 517 with C or better

ME 617, DESIGN AUTOMATION, 4 Credits
Design automation is the field of study whereby advanced numerical methods are used to automate difficult or tedious design decisions. Typically, such methods are based on numerical optimization and artificial intelligence. They work in tandem with other engineering digital tools like computer-aided design, computer-aided manufacturing, and finite-element analysis. This course builds upon a fundamental understanding of optimization to introduce students to a range of different techniques that may be used to support engineering decision-making. This includes heuristic methods, AI tree-search, discrete and stochastic algorithms. The course concludes with discussion of recent innovations in multi-objective, multi-disciplinary and robust optimization.
Prerequisite: ME 517 with C or better

ME 667, COMPUTATIONAL FLUID DYNAMICS, 3 Credits
Application of modern computational techniques to solve a wide variety of fluid dynamics problems including both potential and viscous flow with requirements for computer code development.
Prerequisite: (ME 560 with C or better or ME 565 with C or better or ME 566 with C or better) and (ME 526 [C] or ME 575 [C])

Manufacturing Engineering (MFGE)

MFGE 241, INTRODUCTION TO MECHATRONICS, 3 Credits
Explores the fundamentals of mechatronics: electronic circuits, tools, and basic sensors/actuators commonly used in the manufacturing process monitoring. Examines the operation and use of these instruments and tools for mechatronics design and prototyping. Examines the fundamentals of five types of sensors: distance, movement, proximity, stress/strain, and temperature, with a focus on the mathematical modeling of the sensors when they are embedded in a mechanical system. Apply basic programming in LabVIEW software to support the operation of data sampling through a data acquisition card. Integrate mechanical design with electronics controlled by a computer in an open loop fashion in the lab.
Prerequisite: ENGR 202 with C or better

MFGE 285, INTRODUCTION TO INDUSTRIAL AND MANUFACTURING ENGINEERING, 3 Credits
Introduction to selected topics in industrial and manufacturing engineering, including history and philosophy, product design and manufacturing cycle, integrate role of engineering and business, and multi-objective nature of organizations. Surveys of selected design problems in resource allocation, operations and quality management, and production engineering. CROSSLISTED as IE 285/MFGE 285.
Prerequisite: IE 112 (may be taken concurrently) with C or better or FOR 112 (may be taken concurrently) with C or better
Equivalent to: IE 285

MFGE 336, PRODUCTION ENGINEERING, 4 Credits
Provides a general understanding of the production engineering function within industry and the means by which to achieve tight tolerances through machining. Geometric dimensioning and tolerancing, fixture and gage design, and fundamentals of metal cutting mechanics are introduced, and their interactions are explored. Lec/lab.
Prerequisite: (ENGR 213 with C or better or ENGR 213H with C or better) and ENGR 248 [C] and (ENGR 321 [C] or ENGR 321H [C] or MATS 321 [C] or MATS 321H [C]) and ME 250 [C]
Equivalent to: IE 336

MFGE 337, MATERIALS AND MANUFACTURING PROCESSES, 4 Credits
Introduces mechanical manufacturing methods by which materials are economically shaped into valuable products. The overall goal is to develop an understanding of how the functionality, shape, materials, cost and sustainability of a product influence manufacturing process selection and design. Lec/lab.
Prerequisite: (ENGR 321 with C or better or ENGR 321H with C or better or MATS 321 with C or better or MATS 321H with C or better) and ME 250 [C] and MFGE 336 [C]
Equivalent to: IE 337
MFGE 341, LOGICAL CONTROL FOR MECHATRONICS SYSTEMS, 4 Credits
Explore embedded software and hardware infrastructures used in mechatronics systems. Examine binary number and Boolean algebra using AND, OR, and XOR operators in microcontroller-controlled systems, and flip-flops and other basic components that realize binary control functions. Explore the working principles of AVR microcontroller systems, including the internal structure of clock timers, memory space, and IO addresses. Implement basic microcontroller operations using Assembly language. Demonstrate functions such as open loop control and wired/wireless communication in labs by programming a commercial microcontroller platform with assembly language.
Prerequisite: MFGE 241 with C or better

MFGE 413, COMPUTER AIDED DESIGN AND MANUFACTURING, 4 Credits
Introduces students to the application of computer aided engineering tools across the extended product design and manufacturing cycle. Students become familiar with new product development and working in a sustaining engineering environment with an emphasis on using computer-aided design (CAD) and computer-aided manufacturing (CAM) tools to gain competitive advantage.
Prerequisite: ENGR 248 with C or better and (IE 366 [C] or ME 382 [C] or ME 382H [C])
Equivalent to: ME 413

MFGE 436, LEAN MANUFACTURING SYSTEMS ENGINEERING, 4 Credits
The planning, evaluation, deployment, and integration of lean manufacturing theory and methods. Examines manufacturing processes/equipment and systems, e.g., planning/control, product design, supply chain resource management. Lec/lab.
Prerequisite: ENGR 390 with C or better or ENGR 391 with C or better
Equivalent to: IE 436

MFGE 437, COMPUTER CONTROL OF MANUFACTURING PROCESSES, 4 Credits
Introduces fundamental knowledge in the automation of manufacturing systems and processes. Automated manufacturing system design and operations—computer numerical control (CNC) technology; NC part programming; sensors and actuators, their modeling and dynamic simulation; feedback motion delivery systems design and tuning; programmable logic controls (PLC) for industrial control systems, and path planning for numerical controlled (NC) machinery. Lec/lab.
Prerequisite: (ME 317 with C or better or ME 317H with C or better or MFGE 336 with C or better) and (ENGR 212 [C] or ENGR 212H [C])
Equivalent to: IE 437

MFGE 438, COMPOSITES MANUFACTURING, 4 Credits
Introduction to fiber-reinforced composite materials and their applications. Topics include matrices and reinforcement; open and closed molding processes; filament winding, quality testing, damage assessment; basics of factory operations and sustainability of composites. Students will complete laboratory projects using fiber-reinforced laminates. Lec/lab.
Prerequisite: ENGR 213 with C or better or ENGR 213H with C or better

MFGE 441, DIGITAL CONTROL OF MECHATRONICS SYSTEMS, 4 Credits
Explores modeling and control of mechatronics systems. Review Laplace and Fourier transforms and then examine Industrial Proportional (P), Derivative (D), Integral (I)-based, PD, P-PI, PID, lead-lag and pole placement feedback control strategies, and their design principles based on time and frequency domain performance metrics. Explores the frequency domain loop-shaping control design approach, and reference command generation and feedforward control for motion control. Examines digital control and real-time implementation of feedback control laws on real-time micro-processor systems. Implement and test feedback control algorithms on a servo motor setup in the labs.
Prerequisite: MFGE 441 with C or better

MFGE 499, SPECIAL TOPICS, 0-5 Credits
This course is repeatable for 99 credits.

MFGE 507, SEMINAR, 1-16 Credits
Graded P/N.
This course is repeatable for 16 credits.

MFGE 511, PRECISION MACHINE DESIGN, 3 Credits
Tolerance analysis and application in design/manufacturing practice, principles of machine design and computational analysis of errors in machine design, sensor mounting and sensor calibration, machine level error budget with geometric and thermal errors, structural design of joints and supports, deterministic damping, exact constraint design for flexures and couplings, bearing systems design, motion and power system design for machine tools. CROSST/LISTED as ME 511/MFGE 511.
Equivalent to: ME 511
Recommended: An understanding of mechanical component design and solid mechanics.

MFGE 531, MICROMANUFACTURING, 4 Credits
Introduction to microsystem platforms, scaling laws and size effects in micromanufacturing techniques with an emphasis on microchannel arrays, microchannel lamination and micro-scale characterization. Lec/lab.
Equivalent to: IE 531
MFGE 535, INDUSTRIAL SUSTAINABILITY ANALYSIS, 3 Credits
Students are exposed to the role of business and engineering in the design and implementation of sustainable industrial systems. Drivers, metrics, and analysis concepts, methods, and tools are introduced. Students incorporate business and engineering considerations in making product, manufacturing process, and supply chain design considerations.

MFGE 536, LEAN MANUFACTURING SYSTEMS ENGINEERING, 4 Credits
The planning, evaluation, deployment, and integration of lean manufacturing theory and methods. Examines manufacturing processes/equipment and systems, e.g., planning/control, product design, supply chain resource management. Lec/lab. Equivalent to: IE 536
Available via Ecampus

MFGE 538, COMPOSITES MANUFACTURING, 4 Credits
Introduction to fiber-reinforced composite materials and their applications. Topics include matrices and reinforcement; open and closed molding processes; filament winding, quality, testing, damage assessment; basics of factory operations and sustainability of composites. Students will complete laboratory projects using fiber-reinforced laminates. Lec/lab. Recommended: (ENGR 213 or ENGR 213H)

MFGE 551, ADDITIVE MANUFACTURING, 3 Credits
Introduces basic principles and process physics for additive manufacturing as compared with subtractive manufacturing. Various processes in AM (extrusion, jetting, photopolymerization, powder bed fusion, direct energy deposition and sheet lamination) and laser AM are discussed. Materials selection in AM (metals, polymers, ceramics and composites), powder metallurgy and metallurgical phenomena in additive manufacturing will be covered.

MFGE 599, SPECIAL TOPICS, 0-5 Credits
This course is repeatable for 99 credits.

Mechanical/Industrial/Manufacturing Engineering (MIME)

MIME 101, INTRODUCTION TO MIME, 3 Credits
Provides students with an overview of mechanical, industrial, manufacturing, and energy systems engineering careers and an introduction to technical areas of study. Skills necessary for success in both the academic curriculum and in the engineering profession will also be emphasized, including communication and ethics. Lec/rec. Equivalent to: ME 101, MIME 101H

MIME 101H, INTRODUCTION TO MIME, 3 Credits
Provides students with an overview of mechanical, industrial, manufacturing, and energy systems engineering careers and an introduction to technical areas of study. Skills necessary for success in both the academic curriculum and in the engineering profession will also be emphasized, including communication and ethics. Lec/rec.
Attributes: HNRS – Honors Course Designator
Equivalent to: MIME 101

MIME 199, SPECIAL TOPICS, 0-4 Credits
Equivalent to: MIME 101

MIME 299, SPECIAL TOPICS, 0-4 Credits
This course is repeatable for 4 credits.

MIME 399, SPECIAL TOPICS, 0-4 Credits
Special topics in mechanical, industrial, and manufacturing engineering. This course is repeatable for 16 credits.

MIME 497, MIME CAPSTONE DESIGN, 4 Credits
Integrates engineering knowledge and experience by applying skills to work on real-world engineering project. Involves product design; selection and replacement of major tools, processes, and equipment; paperwork controls; subsystem revision; system or plant revision; selection and training of personnel; and long-run policies and strategy. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: (IE 355 with C or better and IE 356 [C] and IE 366 [C] and IE 367 [C] and IE 368 [C] and WR 327 [C]) or (MATS 322 [C] and ENGR 390 [C] and ME 250 [C] and (ME 312 [C] or ME 312H [C]) and (ME 317 [C] or ME 317H [C]) and (ME 382 [C] or ME 382H [C]) and (ME 383 [C] or ME 383H [C]) and (ST 314 [C] or ST 314H [C]) and WR 327 [C])
Equivalent to: ESE 497, IE 497, ME 497

MIME 498, MIME CAPSTONE DESIGN, 4 Credits
Product design; selection and replacement of major tools, processes, and equipment; paperwork controls; subsystem revision; system or plant revision; selection and training of personnel; long-run policies and strategy. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: MIME 497 with C or better or ESE 497 with C or better
Equivalent to: ESE 498, IE 498, ME 498

MIME 504, WRITING AND CONFERENCE/EXPLORATION, 1-9 Credits
Students will be allowed to register for a variable number of MIME 504 credits to bring their registration up to full-time status (9 credits). Graded P/N. Equivalent to: IE 504, ME 504, ROB 504
This course is repeatable for 15 credits.
MIME 507, SEMINAR/NEW STUDENT ORIENTATION, 1 Credit

Nuclear Science & Engineering (NSE)

NSE 114, INTRO TO NUCLEAR ENGINEERING AND RADIATION HEALTH PHYSICS I, 3 Credits
Introduction to the nuclear engineering and radiation health physics fields; problem-solving techniques; careers in the nuclear industry; nuclear history; elementary nuclear and reactor physics; basic nuclear fission and fusion theory; reactor types; nuclear safety; nuclear fuel cycle; and radiation protection. Equivalent to: NE 114, RHP 114

NSE 115, INTRO TO NUCLEAR ENGINEERING AND RADIATION HEALTH PHYSICS II, 3 Credits
Introduction to the nuclear engineering and radiation health physics fields; problem-solving techniques; careers in the nuclear industry; nuclear history; elementary nuclear and reactor physics; basic nuclear fission and fusion theory; reactor types; nuclear safety; nuclear fuel cycle; and radiation protection. Equivalent to: NE 115, RHP 115

NSE 233, MATHEMATICAL METHODS FOR NSE, 3 Credits
Development and application of analytical and numerical methods with applications to problems in the NE/RHP field. Major topics will include solution of ODEs and systems of ODEs, root finding techniques and numerical integration and differentiation. Major applications will include solution of the Bateman Equations and solution of the diffusion equation. Prerequisite: MTH 256 with C or better or MTH 256H with C or better Equivalent to: NE 233, RHP 233

NSE 234, NUCLEAR AND RADIATION PHYSICS I, 3 Credits
Relativistic dynamics; basic nuclear physics; basic quantum mechanics; radioactivity; electromagnetic waves; interaction of ionizing radiation with matter; cross sections; basic atomic structure. Prerequisite: MTH 251 with C or better or MTH 251H with C or better Equivalent to: NE 234, RHP 234

NSE 235, NUCLEAR AND RADIATION PHYSICS II, 3 Credits
Radioactivity; radioactive decay modes; decay kinetics, interaction of neutrons with matter; nuclear reactions; fission and fusion basics; cross sections. Prerequisite: (NSE 234 with C or better or NE 234 with C or better or RHP 234 with C or better) and (MTH 252 [C] or MTH 252H [C]) Equivalent to: NE 235, RHP 235

NSE 236, NUCLEAR RADIATION DETECTION AND INSTRUMENTATION, 4 Credits
Principles and mechanisms underlying nuclear radiation detection and measurements; operation of nuclear electronic laboratory instrumentation; application of gas-filled, scintillation and semiconductor laboratory detectors for measurement of alpha, beta, gamma, and neutron radiation; experimental investigation of interactions of radiation with matter. Lec/lab. Prerequisite: NSE 235 with C or better or NE 235 with C or better or RHP 235 with C or better Equivalent to: NE 236, RHP 236

NSE 311, INTRODUCTION TO THERMAL-FLUID SCIENCES, 4 Credits
Basic concepts of fluid mechanics, thermodynamics and heat transfer are introduced. Conservation of mass, energy, moment and the second law of thermodynamics are included. CROSSLISTED as ME 311/NSE 311. Prerequisite: (ENG 212 with C or better or ENGR 212H with C or better) and (MTH 256 [C]) Equivalent to: ME 311, ME 311H, NE 311, NE 311H, NSE 311H

NSE 311H, INTRODUCTION TO THERMAL-FLUID SCIENCES, 4 Credits
Basic concepts of fluid mechanics, thermodynamics and heat transfer are introduced. Conservation of mass, energy, moment and the second law of thermodynamics are included. CROSSLISTED as ME 311/NSE 311. Attributes: HNRS – Honors Course Designator Prerequisite: (ENG 212 with C or better or ENGR 212H with C or better) and (MTH 256 [C] or MTH 256H [C]) Equivalent to: ME 311, ME 311H, NE 311H, NSE 311

NSE 312, THERMODYNAMICS, 4 Credits
Analyzes exergy destruction, machine and cycle processes, law of corresponding states, non-reactive gas mixtures, reactive mixtures, thermodynamics of compressible fluid flow. CROSSLISTED as ME 312/NSE 312. Prerequisite: ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better Equivalent to: ENGR 312, ME 312, ME 312H, NE 312, NE 312H, NSE 312H

NSE 312H, THERMODYNAMICS, 4 Credits
Analyzes exergy destruction, machine and cycle processes, law of corresponding states, non-reactive gas mixtures, reactive mixtures, thermodynamics of compressible fluid flow. CROSSLISTED as ME 312/NSE 312. Attributes: HNRS – Honors Course Designator Prerequisite: ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better Equivalent to: ENGR 312, ME 312, ME 312H, NE 312, NE 312H, NSE 312

NSE 319, *SOCIETAL ASPECTS OF NUCLEAR TECHNOLOGY, 3 Credits
Description and discussion of nuclear-related issues as they impact society. (Bacc Core Course) Attributes: CSST – Core, Synthesis, Science/Technology/Society Equivalent to: NE 319
NSE 331, INTRODUCTORY FLUID MECHANICS, 4 Credits
Introduces the concepts and applications of fluid mechanics and dimensional analysis with an emphasis on fluid behavior, internal and external flows, analysis of engineering applications of incompressible pipe systems, and external aerodynamics. CROSSLISTED as ME 331/NSE 331.

Prerequisite: ENGR 311 with C or better or ENGR 311H with C or better or ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better

Equivalent to: ENGR 331, ENGR 331H, ME 331, ME 331H, NSE 331, NSE 331H

NSE 331H, INTRODUCTORY FLUID MECHANICS, 4 Credits
Introduces the concepts and applications of fluid mechanics and dimensional analysis with an emphasis on fluid behavior, internal and external flows, analysis of engineering applications of incompressible pipe systems, and external aerodynamics. CROSSLISTED as ME 331/NSE 331.

Attributes: HNRS – Honors Course Designator

Prerequisite: ENGR 311 with C or better or ENGR 311H with C or better or ME 311 with C or better or ME 311H with C or better or NSE 311 with C or better or NSE 311H with C or better or NE 311 with C or better or NE 311H with C or better

Equivalent to: ENGR 331, ENGR 331H, ME 331, ME 331H, NSE 331, NSE 331H

NSE 332, HEAT TRANSFER, 4 Credits
Analyzes conductive, convective and radiative energy transfer using control volume and differential analysis and prediction of transport properties. CROSSLISTED as ME 332/NSE 332.

Prerequisite: ME 331 with C or better or ME 331H with C or better or NSE 331 with C or better or NSE 331H with C or better or ME 331H with C or better or NE 331 with C or better or NE 331H with C or better

Equivalent to: ME 332, ME 332H, ME 332, ME 332H, NSE 332H, NSE 332

NSE 332H, HEAT TRANSFER, 4 Credits
Analyzes conductive, convective and radiative energy transfer using control volume and differential analysis and prediction of transport properties. CROSSLISTED as ME 332/NSE 332.

Attributes: HNRS – Honors Course Designator

Prerequisite: ME 331 with C or better or ME 331H with C or better or NSE 331 with C or better or NSE 331H with C or better or ME 331H with C or better or NE 331 with C or better or NE 331H with C or better

Equivalent to: ME 332, ME 332H, ME 332, ME 332H, NSE 332H, NSE 332

NSE 401, RESEARCH, 1-16 Credits
Graded P/N.

Equivalent to: NE 401

This course is repeatable for 99 credits.

NSE 403, THESIS/DISSERTATION, 1-16 Credits
Equivalent to: NE 403

This course is repeatable for 16 credits.

NSE 405, READING AND CONFERENCE, 1-16 Credits
Equivalent to: NE 405

This course is repeatable for 16 credits.

NSE 406, PROJECTS, 1-16 Credits
Equivalent to: NE 406

This course is repeatable for 16 credits.

NSE 407, SEMINAR, 1 Credit
Graded P/N.

Equivalent to: RHP 407

This course is repeatable for 16 credits.

NSE 410, INTERNSHIP, 1-12 Credits
Supervised technical work experience at approved organizations. Graded P/N.

Equivalent to: RHP 410

This course is repeatable for 12 credits.

NSE 415, NUCLEAR RULES AND REGULATIONS, 2 Credits
An introduction to the key nuclear regulatory agencies; major nuclear legislation; current radiation protection standards and organizations responsible for their implementation. Offered alternate years.

Prerequisite: NSE 236 with C or better

Equivalent to: NE 415, RHP 415

Recommended: NSE 481 or NE 481 or RHP 481

NSE 429, SELECTED TOPICS IN NUCLEAR ENGINEERING, 1-3 Credits
Topics associated with nuclear engineering not covered in other undergraduate courses; topics may vary from year to year.

Equivalent to: NE 429

This course is repeatable for 45 credits.

NSE 435, RADIATION SHIELDING AND EXTERNAL DOSIMETRY, 4 Credits
Theoretical principles of shielding for neutron and gamma radiation; external dosimetry fundamentals for neutrons, photons, and charged particles; applications to problems of practical interest; analytical, numerical, and computer solutions emphasized.

Prerequisite: (NSE 234 with C or better or NE 234 with C or better or RHP 234 with C or better) and (NSE 235 [C] or NE 235 [C] or RHP 235 [C]) and (NSE 481 [C] or NE 481 [C] or RHP 481 [C])

Equivalent to: NE 435

NSE 440, NUCLEAR FUEL CYCLE AND WASTE MANAGEMENT, 4 Credits
Mining, milling, conversion, enrichment, fuel fabrication, reprocessing, and waste management of nuclear fuel, including disposal of low- and high-level radioactive waste.

Prerequisite: NSE 235 with C or better or NE 235 with C or better or RHP 235 with C or better

Equivalent to: NE 440
NSE 450, PRINCIPLES OF NUCLEAR MEDICINE, 3 Credits
Basic principles of nuclear medicine; detectors; radiopharmaceutical; dosimetry; imaging procedures.

NSE 451, NEUTRONIC ANALYSIS I, 3 Credits
Physical models of neutronic systems; nuclear physics; steady state and transient neutronic system behavior; introductory neutron transport theory, one speed diffusion theory; numerical methods; fast and thermal spectrum calculations; multigroup methods; transmutation and burnup; reactor fuel management; reactivity control; perturbation theory; neutronic laboratory sessions.
Prerequisite: (MTH 256 with C or better or MTH 256H with C or better) and (NSE 235 [C] or NE 235 [C] or RHP 235 [C]) and (NSE 333 [C] or NE 333 [C] or RHP 333 [C])
Equivalent to: NE 451

NSE 452, NEUTRONIC ANALYSIS II, 3 Credits
Physical models of neutronic systems; nuclear physics; steady state and transient neutronic system behavior; introductory neutron transport theory, one speed diffusion theory; numerical methods; fast and thermal spectrum calculations; multigroup methods; transmutation and burnup; reactor fuel management; reactivity control; perturbation theory; neutronic laboratory sessions. Lec/lab.
Prerequisite: NSE 451 with C or better or NE 451 with C or better
Equivalent to: NE 452

NSE 455, REACTOR OPERATOR TRAINING I, 3 Credits
The Oregon State University TRIGA reactor Operator Training I class is one of a two-course series. Students interested in participating in this course are expected to enroll in both the NSE 455/NSE 555 and NSE 456/NSE 556 classes taught during spring and summer terms. Students successfully completing the NSE 455/NSE 555 and NSE 456/NSE 556 series will culminate their course work with the opportunity to take a certification test proctored by the Nuclear Regulatory Commission.
Prerequisite: (NSE 236 with C or better or NE 236 with C or better or RHP 236 with C or better) and (MTH 256 [C] or MTH 256H [C])
Equivalent to: NE 455

NSE 456, REACTOR OPERATOR TRAINING II, 4 Credits
The Oregon State University TRIGA reactor Operator Training II class is one of a two-course series. Students interested in participating in this course must have already taken and successfully passed NSE 455/NSE 555. Students successfully completing NSE 455/NSE 555 will culminate their course work with the opportunity to take a certification test proctored by the Nuclear Regulatory Commission.
Prerequisite: NSE 455 with C or better or NE 455 with C or better
Equivalent to: NE 456

NSE 457, NUCLEAR REACTOR LABORATORY, 2 Credits
Experimental investigation of the principles of nuclear reactor operation. Use of the OSU TRIGA Reactor and other laboratory facilities. Preparation and presentation of laboratory reports. Lec/lab.
Prerequisite: (NSE 451 with C or better or NE 451 with C or better or NSE 551 with C or better or NE 551 with C or better) and (NSE 452 [C] or NE 452 [C] or NSE 552 [C] or NE 552 [C])
Equivalent to: NE 457

NSE 459, REFLECTIVE LEARNING EXPERIENCE, 3 Credits
Part II of a two-part series aimed at developing the student's ability to utilize fundamental nuclear and radiation protection skills to transform concepts into practical designs. Design projects involve the integration of neutronics, thermal hydraulics, safety and risk analysis, power production, materials, radiation protection, economic optimization, statistics and other skills. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: NSE 481 with C or better
Equivalent to: NE 473

NSE 467, NUCLEAR REACTOR THERMAL HYDRAULICS, 4 Credits
Hydrodynamics and conductive, convective and radiative heat transfer in nuclear reactor systems. Core heat removal design; critical heat flux, hot spot factors, single- and two-phase flow behavior. Advanced thermal hydraulic computer codes.
Prerequisite: ME 332 with C or better or ME 332H with C or better or NSE 332 with C or better or NSE 332H with C or better or NE 332 with C or better or NE 332H with C or better
Equivalent to: NE 467

NSE 473, NUCLEAR REACTOR SYSTEMS ANALYSIS, 3 Credits
Analysis of nuclear light water reactor (pressurized water reactor and boiling water reactor) design and operation, including the nuclear steam supply system, engineered safety features and balance of plant systems; regulatory design requirements; industry standards; plant engineering and instrumentation drawings. Advanced reactor system designs.
Prerequisite: NSE 452 with C or better or NE 452 with C or better
Equivalent to: NE 473

NSE 474, ^NUCLEAR SYSTEMS DESIGN I, 4 Credits
Part I of a two-part series aimed at developing the student's ability to utilize fundamental nuclear and radiation protection skills to transform concepts into practical designs. Design projects involve the integration of neutronics, thermal hydraulics, safety and risk analysis, power production, materials, radiation protection, economic optimization, statistics and other skills. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: NSE 481 with C or better
Equivalent to: NE 474, RHP 474

NSE 475, ^NUCLEAR SYSTEMS DESIGN II, 4 Credits
Part II of a two-part series aimed at developing the student's ability to utilize fundamental nuclear and radiation protection skills to transform concepts into practical designs. Design projects involve the integration of neutronics, thermal hydraulics, safety and risk analysis, power production, materials, radiation protection, economic optimization, statistics and other skills. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
Prerequisite: (NSE 452 with C or better or NE 452 with C or better) and (NSE 474 [C] or NE 474 [C] or RHP 474 [C])
Equivalent to: RHP 475
NSE 481, RADIATION PROTECTION, 4 Credits
Fundamental principles and theory of radiation protection; regulatory agencies, dose units; source of radiation; biological effects and risk; dose limits; applications of external and internal dosimetry; shielding and atmospheric dispersion.
Prerequisite: NSE 235 with C or better or NE 235 with C or better or RHP 235 with C or better
Equivalent to: NE 481, RHP 481
NSE 483, RADIATION BIOLOGY, 3 Credits
Biological effects of ionizing radiation at the molecular, cellular, and organismal levels with emphasis on vertebrates; both acute and chronic radiation effects are considered.
Prerequisite: NSE 481 with C or better or RHP 481 with C or better or MP 481 with C or better
Equivalent to: MP 483
NSE 488, RADIOECOLOGY, 3 Credits
Radionuclides in the environment: their measurement and identification, uptake and transfer through food chains. Effect of radiation on natural populations of plants and animals.
Prerequisite: NSE 481 with C or better or RHP 481 with C or better or NE 481 with C or better
Equivalent to: RHP 488
NSE 499, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.
Equivalent to: NE 499
NSE 501, RESEARCH, 1-16 Credits
This course is repeatable for 99 credits.
Available via Ecampus
NSE 503, THESIS, 1-16 Credits
This course is repeatable for 99 credits.
Available via Ecampus
NSE 505, READING AND CONFERENCE, 1-16 Credits
This course is repeatable for 16 credits.
Available via Ecampus
NSE 506, PROJECTS, 1-16 Credits
This course is repeatable for 16 credits.
Available via Ecampus
NSE 507, SEMINAR, 1 Credit
Graded P/N.
Equivalent to: MP 507
This course is repeatable for 16 credits.
Available via Ecampus
NSE 510, INTERNSHIP, 1-12 Credits
Supervised technical work experience at approved organizations. Graded P/N.
Equivalent to: MP 510
This course is repeatable for 16 credits.
NSE 515, NUCLEAR RULES AND REGULATIONS, 2 Credits
An introduction to the key nuclear regulatory agencies; major nuclear legislation; current radiation protection standards and organizations responsible for their implementation. Offered alternate years.
Equivalent to: NE 515, RHP 515
NSE 516, RADIOCHEMISTRY, 4 Credits
Selected methods in radiochemical analysis. Actinide chemistry, activation analysis, radionuclide solvent extraction, and microbial reactions with radionuclides. Designed for majors in chemistry, chemical engineering, nuclear engineering, and radiation health physics. Lec/lab. CROSSLISTED as CH 516/NSE 516.
Prerequisite: (NSE 531 with C or better or NE 531 with C or better or RHP 531 with C or better) and (NSE 536 [C] or NE 536 [C] or RHP 536 [C])
Equivalent to: CH 516, RHP 516
Available via Ecampus
NSE 517, RADIONUCLIDES IN LIFE SCIENCES, 4 Credits
Chemistry of actinides and fission products, radioseparations, selected medical generators, radiolabeling of organic molecules. Designed for majors in medical physics, radiation health physics, chemistry, pharmacy.
Prerequisite: (NSE 531 with C or better or NE 531 with C or better or RHP 531 with C or better) and (NSE 536 [C] or NE 536 [C] or RHP 536 [C])
Equivalent to: MP 517, RHP 517
NSE 519, RADIOCHEMICAL ANALYSIS, 4 Credits
Hands-on learning of radiochemistry, practical training with open radiation sources for preparation of irradiation targets, counting samples from contaminated soils or separation of medical radionuclides. Fundamentals of chemical dosimetry are also covered. Designed for a broad range of majors in chemistry, nuclear engineering, radiation health physics, radioecology, chemical and environmental engineering. Lec/lab. The lecture part of the course also is delivered online as video stream via Canvas.
Prerequisite: NSE 536 with C or better or NE 536 with C or better or RHP 536 with C or better
Equivalent to: NE 519, RHP 519
Recommended: NSE 516
NSE 521, RADIOLOGICAL ANATOMY AND PHYSIOLOGY, 4 Credits
Anatomy and physiology with correlating images for use by medical physicists, therapists, dosimetrists. This course adheres to the AAMD requirements for Cross Sectional Anatomy.
Equivalent to: MP 521, RHP 521
NSE 522, NUCLEAR SECURITY SCIENCE, 4 Credits
Explores the nuclear fuel cycle from the perspective of nuclear security and safeguards and in the context of current international nuclear policies. Nuclear threats are balanced with the past history of nuclear weapons use, current nonproliferation technology, and the future international growth of the nuclear industry. Critical thinking will be assessed by way of in-class discussions, journal article reviews, written analysis of fuel cycle signatures, and conducting research. Signatures including radiological and morphological characteristics of nuclear material is introduced as well as the techniques for the detection of special nuclear materials.

NSE 525, NUCLEAR SECURITY SYSTEM DESIGN, 3 Credits
Studies the science and engineering associated with the design, evaluation, and implementation of systems to secure nuclear and radiological materials. Topics include adversary characterization, target categorization and the consequences of failure to protect targets, detection and delay technologies, on-site and off-site response and response strategies, insider threat evaluation, and mathematical methods for evaluating risk due to the threat and the security system design. Students will become familiar with the components of a sustainable nuclear security program and their interconnections, and learn about the planning of nuclear security activities at both the state and facility level.

NSE 526, NUMERICAL METHODS FOR ENGINEERING ANALYSIS, 3 Credits
Equivalent to: ME 526, NE 526
Recommended: Programming experience and previous exposure to numerical methods

NSE 531, RADIOPHYSICS, 3 Credits
Expands understanding of concepts and applications of atomic and nuclear physics to enable continued study in nuclear engineering and health physics. Includes fundamental concepts of nuclear and atomic physics, atomic and nuclear shell structure, radioactive decay, radiation interactions, radiation biology, and the characteristics of fission.
Equivalent to: MP 531
Available via Ecampus

NSE 533, DETECTION OF SPECIAL NUCLEAR MATERIALS, 3 Credits
Designed for students interested in radiation measurements and nuclear security, especially those considering PhD-level work in this area. Covers topics including special nuclear material characteristics, radiation background and it interferences with SNM, an introduction to MCNPX, a brief introduction to Geant4, detection of SNM via counting or imaging, localization of SNM; and characterization of SNM.
Prerequisite: NSE 536 with C or better
Recommended: MTH 251 or MTH 251H

NSE 534, APPLIED DETECTION FOR NUCLEAR SECURITY, 3 Credits
Applied detection techniques currently being deployed globally for nuclear security are presented in lectures and explored in practical exercises. A prominent feature of this class is the unique opportunity to complete the Nuclear Security Education Program (NSEP) Training program hosted at the HAMMER federal training center.
Prerequisite: NSE 536 with C or better

NSE 535, RADIATION SHIELDING AND EXTERNAL DOSIMETRY, 4 Credits
Theoretical principles of shielding for neutron and gamma radiation; external dosimetry fundamentals for neutrons, photons, and charged particles; applications to problems of practical interest; analytical, numerical, and computer solutions emphasized.
Equivalent to: MP 535, NE 535, RHP 535
Available via Ecampus

NSE 536, ADVANCED RADIATION DETECTION AND MEASUREMENT, 4 Credits
Principles and mechanisms underlying nuclear radiation detection and measurements; operation of nuclear electronic laboratory instrumentation; application of gas-filled, scintillation and semiconductor laboratory detectors for measurement of alpha, beta, gamma, and neutron radiation, liquid scintillation equipment; use of Bonner spheres for neutron energy profiles; experimental investigation of interactions of radiation with matter. Lec/lab.
Prerequisite: NSE 531 with C or better or NE 531 with C or better or RHP 531 with C or better or MP 531 with C or better
Equivalent to: MP 536

NSE 537, DIGITAL RADIATION MEASUREMENT AND SPECTROSCOPY, 3 Credits
Principles of digital spectroscopy; application of digital filters in digital processing of detector pulses; hardware implementation of a typical digital spectrometer; introduction of Field-Programmable Gate Array (FPGA) devices programming a digital spectrometer using Hardware Description Language (VHDL); simulation, synthesis and spectroscopy; experimental design tests and evaluation. Lec/lab.
Prerequisite: NSE 536 with C or better or NE 536 with C or better or RHP 536 with C or better
Equivalent to: NE 537

NSE 539, SELECTED TOPICS IN INTERACTION OF NUCLEAR RADIATION, 1-6 Credits
Topics associated with interactions of nuclear radiation not covered in other graduate courses; topics may vary from year to year.
Equivalent to: NE 539
**NSE 540, NUCLEAR FUEL CYCLE AND WASTE MANAGEMENT, 4 Credits**
Mining, milling, conversion, enrichment, fuel fabrication, reprocessing, and waste management of nuclear fuel, including disposal of low- and high-level radioactive waste.
Equivalent to: NE 540
Available via Ecampus

**NSE 541, DIAGNOSTIC IMAGING PHYSICS I, 3 Credits**
An introduction to the production and usage of ionizing radiation in medicine. The course will cover x-ray production, x-ray spectrum, characteristics and manipulation, and how x-rays are utilized to obtain anatomical information in diagnostics imaging. Imaging modalities to be covered in this course are general and portable planar radiography, mammography, and fluoroscopy (including interventional radiography).
Prerequisite: NSE 531 with C or better or MP 531 with C or better or RHP 531 with C or better
Equivalent to: MP 541

**NSE 542, DIAGNOSTIC IMAGING PHYSICS II, 3 Credits**
An introduction to Computed Tomography (CT) and Ultrasound (US) imaging, and their applications in medicine. The course will cover x-ray production, detection, and image processing as it relates specifically to CT, as well as general acoustic physics principles and how they are applied to US imaging. Additionally, clinical radiation protection and dosimetry in diagnostic imaging will be taught.
Prerequisite: NSE 531 with C or better or PP 531 with C or better or RHP 531 with C or better
Equivalent to: MP 542

**NSE 543, ADVANCED DIAGNOSTIC IMAGING PHYSICS, 3 Credits**
An introduction to the areas of health informatics and magnetic resonance imaging (MRI). The health informatics portion of the course will specifically cover picture archiving and communication systems (PACS), including DICOM standards, data transfer and storage, digital image displays, and clinical implementation of PACS systems. The MRI portion of the course will provide instruction on the physical principles behind nuclear magnetic response (NMR) and how these phenomenon are exploited in MRI. Advanced MRI techniques and applications, along with clinical testing requirements, will also be covered.
Prerequisite: NSE 531 with C or better or MP 531 with C or better or RHP 531 with C or better
Equivalent to: MP 543

**NSE 544, NUCLEAR MEDICINE IMAGING, 3 Credits**
An introduction to the uses of radionuclides in medical imaging. The theory and application of detectors and imaging systems in nuclear medicine including collimators, scintillation probes, cameras, SPECT, PET, and hybrid technologies (SPECT/CT, PET/CT, and PET/MRI) will be covered.
Prerequisite: (NSE 541 with C or better or MP 541 with C or better) and (NSE 531 [C] or RHP 531 [C])
Equivalent to: MP 544

**NSE 545, DIAGNOSTIC IMAGING PRACTICUM, 3 Credits**
Provides an introduction to the medical physicist's role in a clinical department; an opportunity to integrate principles learned throughout the graduate program as they apply to diagnostic imaging physics. Observations of procedures in radiography, fluoroscopy, ED, OR, interventional radiology, CT, MRI, ultrasound, and nuclear medicine. Experience in regulatory testing of x-ray equipment; observations of testing of CT and other x-ray modalities. Graded P/N.
Prerequisite: (NSE 541 with C or better or MP 541 with C or better) and (NSE 531 [C] or MP 531 [C] or RHP 531 [C])
Equivalent to: MP 545

**NSE 549, SELECTED TOPICS IN NUCLEAR FUEL CYCLE ANALYSIS, 1-6 Credits**
Topics associated with the nuclear fuel cycle not covered in other graduate courses; topics may vary from year to year.
Equivalent to: NE 549
This course is repeatable for 45 credits.

**NSE 550, PRINCIPLES OF NUCLEAR MEDICINE, 3 Credits**
Basic principles of nuclear medicine; detectors; radiopharmaceutical; dosimetry; imaging procedures.
Equivalent to: RHP 550

**NSE 551, NEUTRONIC ANALYSIS I, 3 Credits**
Physical models of neutronic systems; nuclear physics; steady state and transient neutronic system behavior; introductory neutron transport theory; one speed diffusion theory; numerical methods; fast and thermal spectrum calculations; multigroup methods; transmutation and burnup; reactor fuel management; reactivity control; perturbation theory; neutronic laboratory sessions.
Equivalent to: NE 551

**NSE 552, NEUTRONIC ANALYSIS II, 3 Credits**
Physical models of neutronic systems; nuclear physics; steady state and transient neutronic system behavior; introductory neutron transport theory; one speed diffusion theory; numerical methods; fast and thermal spectrum calculations; multigroup methods; transmutation and burnup; reactor fuel management; reactivity control; perturbation theory; neutronic laboratory sessions.
Equivalent to: NE 552

**NSE 553, ADVANCED NUCLEAR REACTOR PHYSICS, 3 Credits**
Advanced analytic and numerical techniques for the prediction of the neutron population in nuclear reactor systems. Topic will include long characteristic neutron transport, collision probabilities, nodal methods, equivalence theory, and perturbation theory.
Prerequisite: (NSE 551 with C or better or NE 551 with C or better) and (NSE 552 [C] or NE 552 [C])
Equivalent to: NE 553
Recommended: Computer programming experience
NSE 555, REACTOR OPERATOR TRAINING I, 3 Credits
The Oregon State University TRIGA Reactor Operator I class is one of a two-course series. Students interested in participating in this course are expected to enroll in both the NSE 455/555 and NSE 456/556 classes taught during spring and summer terms. Students successfully completing the NSE 455/555 and NSE 456/556 series will culminate their course work with the opportunity to take a certification test proctored by the Nuclear Regulatory Commission.
Equivalent to: NE 555

NSE 556, REACTOR OPERATOR TRAINING II, 4 Credits
The Oregon State University TRIGA Reactor Operator Training II class is one of a two-course series. Students interested in participating in this course must have already taken and successfully passed NSE 455/ NSE 555. Students successfully completing NSE 456/NSE 556 will culminate their course work with the opportunity to take a certification test proctored by the Nuclear Regulatory Commission.
Prerequisite: NSE 555 with C or better or NE 555 with C or better
Equivalent to: NE 556

NSE 557, NUCLEAR REACTOR LABORATORY, 2 Credits
Experimental investigation of the principles of nuclear reactor operation. Use of the OSU TRIGA Reactor and other laboratory facilities. Preparation and presentation of laboratory reports. Lec/lab.
Prerequisite: (NSE 551 with C or better or NE 550 with C or better) and (NSE 552 [C] or NE 552 [C])
Equivalent to: NE 557

NSE 559, SELECTED TOPICS IN NUCLEAR REACTOR ANALYSIS, 1-3 Credits
Topics associated with nuclear reactor theory not covered in other graduate courses; topics may vary from year to year.
Equivalent to: NE 559
This course is repeatable for 45 credits.

NSE 561, NUCLEAR REACTOR SYSTEMS LABORATORY, 3 Credits
Operational aspects of nuclear reactor systems; neutronic and thermal-hydraulic characterization of nuclear reactors; examination of design basis accident prevention and mitigation; loss of coolant accidents; loss of flow accidents; station blackouts. Lec/lab.
Prerequisite: (NSE 553 with C or better or NE 553 with C or better) and (NSE 567 [C] or NE 567 [C])
Equivalent to: NE 561

NSE 562, RADIATION THERAPY, 3 Credits
The physics of radiation generation and delivery relevant to the field of clinical radiation oncology. Topics will include external beam radiation therapy; dosimetric calculations; high dose-rate and low dose-rate brachytherapy; electron beam dosimetry and treatment planning; special techniques in radiotherapy; and clinical radiation protection and quality assurance.
Prerequisite: NSE 531 with C or better or MP 531 with C or better or NE 531 with C or better or RHP 531 with C or better
Equivalent to: MP 562

NSE 563, APPLIED RADIATION THERAPY PHYSICS LABORATORY I, 3 Credits
The applied practice of therapeutic radiation physics for clinical radiation oncology. Topics will include current methodologies in treatment delivery and planning algorithms, best practices and protocols for quality assurance, special techniques in radiotherapy, and oncology.
Prerequisite: NSE 562 with C or better or MP 562 with C or better
Equivalent to: MP 563

NSE 564, APPLIED RADIATION THERAPY PHYSICS LABORATORY II, 3 Credits
Covers the applied practice of therapeutic radiation physics for clinical radiation oncology. Topics include current methodologies in SRS and ARC QA, treatment planning QA, adaptive radiotherapy, eye plaque brachytherapy and HDR brachytherapy.
Equivalen to: MP 564

NSE 565, APPLIED THERMAL HYDRAULICS, 3 Credits
Advanced topics in the computational modeling of the hydrodynamic and heat transfer phenomena of nuclear reactors. Steady-state and transient solutions of one-dimensional nuclear reactor thermal hydraulic models. Nuclear reactor behavior analysis during various accident scenarios.
Equivalent to: NE 565

NSE 567, NUCLEAR REACTOR THERMAL HYDRAULICS, 4 Credits
Hydrodynamics and conductive, convective and radiative heat transfer in nuclear reactor systems. Core heat removal design; critical heat flux, hot spot factors, single- and two-phase flow behavior. Advanced thermal hydraulic computer codes.
Equivalent to: NE 567

NSE 568, NUCLEAR REACTOR SAFETY, 3 Credits
Focused on probability risk assessment and system reliability analysis techniques applied to nuclear reactor safety. Application of these methods will be performed specifically through examination of neutronics and thermal hydraulic transients, effectiveness of emergency systems, accident prevention and mitigation, and assessment of radioactive release to the environment.
Prerequisite: (NSE 551 with C or better or NE 551 with C or better) and (NSE 567 [C] or NE 567 [C])
Equivalent to: NE 568

NSE 569, SELECTED TOPICS IN NUCLEAR REACTOR ENGINEERING, 1-6 Credits
Advanced nuclear engineering design concepts, reactor systems analysis techniques and innovative nuclear engineering applications. Artificial intelligence and expert system applications to nuclear engineering problems. Topics may vary from year to year.
Equivalent to: NE 569
This course is repeatable for 30 credits.
NSE 573, NUCLEAR REACTOR SYSTEMS ANALYSIS, 3 Credits
Analysis of nuclear light water reactor (pressurized water reactor and boiling water reactor) design and operation, including the nuclear steam supply system, engineered safety features and balance of plant systems; regulatory design requirements; industry standards; plant engineering and instrumentation drawings. Advanced reactor system designs.
Prerequisite: NSE 552 with C or better or NE 552 with C or better
Equivalent to: NE 573

NSE 574, NUCLEAR SYSTEMS DESIGN I, 4 Credits
Part I of a two-part series aimed at developing the student's ability to utilize fundamental nuclear and radiation protection skills to transform concepts into practical designs. Design projects involve the integration of neutronics, thermal hydraulics, safety and risk analysis, power production, materials, radiation protection, economic optimization, statistics and other skills.
Equivalent to: RHP 574

NSE 575, NUCLEAR SYSTEMS DESIGN II, 4 Credits
Part II of a two-part series aimed at developing the student's ability to utilize fundamental nuclear and radiation protection skills to transform concepts into practical designs. Design projects involve the integration of neutronics, thermal hydraulics, safety and risk analysis, power production, materials, radiation protection, economic optimization, statistics and other skills.
Prerequisite: (NSE 551 with C or better or NE 551 with C or better) and (NSE 552 [C] or NE 552 [C]) and (NSE 574 [C] or NE 574 [C])
Equivalent to: RHP 575

NSE 582, APPLIED RADIATION SAFETY, 4 Credits
Application of radiation protection as practiced in the fields of nuclear science and engineering; application of health physics principles to reduce health hazards at each of the following stages: design, prevention, assessment, and post-incident. A history of key nuclear regulatory agencies; early and current radiation protection standards and organizations responsible for their formulation; major nuclear legislation; pertinent nuclear rules and regulations and their application. Lec/lab.
Equivalent to: MP 582
Available via Ecampus

NSE 583, RADIATION BIOLOGY, 3 Credits
Biological effects of ionizing radiation at the molecular, cellular, and organismal levels with emphasis on vertebrates; both acute and chronic radiation effects are considered.
Equivalent to: MP 583
Available via Ecampus

NSE 584, RADIATION BIOLOGY II, 3 Credits
Application of radiobiological models in radiation therapy. Some background in radiation biology is strongly recommended.
Equivalent to: MP 584, RHP 584
Available via Ecampus

NSE 588, RADIOECOLOGY, 3 Credits
Radionuclides in the environment: their measurement and identification, uptake and transfer through food chains. Effect of radiation on natural populations of plants and animals.
Equivalent to: RHP 588
Recommended: NSE 481 or RHP 481 or NE 481
Available via Ecampus

NSE 590, INTERNAL DOSIMETRY, 3 Credits
Further development and more in-depth treatment of internal dosimetry concepts, theoretical basis of energy deposition, biokinetics, and estimation of radiation risk from ingested, inhaled, or injected radionuclides.
Prerequisite: NSE 531 with C or better and NSE 535 [C]
Equivalent to: NE 590, RHP 590
Available via Ecampus

NSE 599, SPECIAL TOPICS, 0-16 Credits
This course is repeatable for 16 credits.
Equivalent to: MP 599

NSE 601, RESEARCH, 1-16 Credits
Graded P/N.
Equivalent to: MP 601
This course is repeatable for 99 credits.

NSE 603, THESIS, 1-16 Credits
Equivalent to: MP 603
This course is repeatable for 999 credits.

NSE 605, READING AND CONFERENCE, 1-16 Credits
Graded P/N.
Equivalent to: MP 605
This course is repeatable for 16 credits.

NSE 606, PROJECTS, 1-16 Credits
Equivalent to: MP 606
This course is repeatable for 16 credits.

NSE 607, SEMINAR, 1-16 Credits
Graded P/N.
Equivalent to: MP 607
This course is repeatable for 16 credits.

NSE 610, INTERNSHIP, 1-16 Credits
Equivalent to: MP 610
This course is repeatable for 16 credits.

NSE 654, COMPUTATIONAL PARTICLE TRANSPORT, 3 Credits
Properties of and methods for solution of the linear Boltzmann equation for nuclear reactors; spherical and double-spherical harmonics; integral equation methods; Monte Carlo methods.
Prerequisite: (NSE 551 with C or better or NE 551 with C or better) and (NSE 552 [C] or NE 552 [C])
Equivalent to: NE 654
NSE 667, ADVANCED THERMAL HYDRAULICS, 3 Credits
Advanced topics in single- and two-phase hydrodynamics and heat transfer for nuclear reactors. Two-phase flow patterns, flow instabilities, condensation induced transients, convective boiling heat transfer, and current topics in reactor safety thermal hydraulics. Offered alternate years.
Prerequisite: NSE 567 with C or better or NE 567 with C or better
Equivalent to: NE 667

NSE 699, SPECIAL TOPICS, 0-16 Credits
Equivalent to: NE 699
This course is repeatable for 16 credits.

NSE 808, WORKSHOP, 1-4 Credits
Equivalent to: NE 808
This course is repeatable for 16 credits.

Outdoor Products (OP)
OP 101, INTRODUCTION TO THE OUTDOOR PRODUCTS INDUSTRY, 4 Credits

OP 231, EXPERIENCE OUTDOOR PRODUCTS - WATER, 2 Credits
Hands-on experience with multiple water-related outdoor products in classroom and outdoor settings. Identifying key characteristics for consumers and implications for design, development, marketing, business, and sustainability. Evaluating product performance and developing ideas for objective improvements. Includes one mandatory weekend outdoor-experience outing.

OP 232, EXPERIENCE OUTDOOR PRODUCTS - WINTER, 2 Credits
Hands-on experience with multiple winter-related outdoor products in classroom and outdoor settings. Identifying key characteristics for consumers and implications for design, development, marketing, business, and sustainability. Evaluating product performance and developing ideas for objective improvements. Includes one mandatory weekend outdoor-experience outing.

OP 233, EXPERIENCE OUTDOOR PRODUCTS - LAND, 2 Credits
Hands-on experience with multiple land-related outdoor products in classroom and outdoor settings. Identifying key characteristics for consumers and implications for design, development, marketing, business, and sustainability. Evaluating product performance and developing ideas for objective improvements. Includes one mandatory weekend outdoor-experience outing.

OP 301, OUTDOOR PRODUCTS PROCESS CONNECTIONS, 4 Credits
The interrelated processes and connections of product commercialization. How product design decisions impacts business considerations such as margin, inventory, supply chain, cash flow, and profitability. How design thinking and nurturing a design culture that promotes innovation is necessary for business success and growth. Challenges of product sales and distribution related to design.
Prerequisite: OP 231 with C- or better or OP 232 with C- or better or OP 233 with C- or better

OP 307, OUTDOOR PRODUCTS PRE-PRACTICUM SEMINAR, 1 Credit
Prerequisite: OP 101 with C- or better

OP 309, OUTDOOR PRODUCTS PRACTICUM, 1-6 Credits
Prerequisite: OP 307 with C- or better
This course is repeatable for 6 credits.

OP 351, OUTDOOR PRODUCTS DESIGN AND DEVELOPMENT I, 4 Credits
Explores needs-based design for Outdoor Products. Experiential-based projects related to function and design and understanding Design in context of Consumer Needs. Investigates design choices impact upstream and downstream commercialization processes.
Prerequisite: OP 301 with C- or better

OP 352, OUTDOOR PRODUCTS DESIGN AND DEVELOPMENT II, 4 Credits
Exploration of development and product creation cycles for Outdoor Products. Bridging the design and operations phases of commercialization. Investigate quality, sample production, product testing, and costing. Managing how development decisions impact upstream and downstream commercialization processes.
Prerequisite: OP 351 with C- or better

OP 360, OUTDOOR PRODUCTS BRANDING, MERCHANDISING AND SALES, 4 Credits
Consumer behavior, emerging markets, building and nurturing brands, strategic communication. Content curation, merchandising and communication. Traditional and non-traditional sales channels.
Prerequisite: OP 352 with C- or better

OP 410, OUTDOOR PRODUCTS INTERNSHIP, 1-8 Credits
Prerequisite: OP 307 with C- or better
This course is repeatable for 8 credits.
Robotics (ROB)

**ROB 421, APPLIED ROBOTICS, 4 Credits**
Multidisciplinary teams of students design, build, and demonstrate a robotic system, including all sensing, computation, and actuation. The specific task, such as checkers-playing robots, changes each year, and is designed to be challenging for ambitious students. Robots will compete in a friendly competition at the end of the term. Lec/lab.

**Prerequisite:** ME 430 with C or better

**Equivalent to:** ENGR 421

**ROB 456, INTELLIGENT ROBOTS, 4 Credits**
Foundations of probabilistic reasoning for robotics. Topics include state estimation, robot motion, perception, localization and decision making under uncertainty.

**Prerequisite:** ST 314 with C or better

**Equivalent to:** ME 456

**Recommended:** CS 331, CS 361, ECE 353, or other programming experience

**ROB 501, RESEARCH, 1-16 Credits**
Graded P/N.

*This course is repeatable for 99 credits.*

**ROB 503, THESIS, 1-16 Credits**
*This course is repeatable for 999 credits.*

**ROB 505, READING AND CONFERENCE, 1-16 Credits**
Graded P/N.

*This course is repeatable for 16 credits.*

**ROB 506, PROJECTS, 1-16 Credits**
Graded P/N.

*This course is repeatable for 16 credits.*

**ROB 507, SEMINAR, 1-16 Credits**
Graded P/N.

*This course is repeatable for 16 credits.*

**ROB 514, INTRODUCTION TO ROBOTICS, 4 Credits**
A broad introduction to the field of robotics, and to the graduate Robotics program. The goal of the class is to take students with different backgrounds (mechanical engineering, computer science, electrical engineering, physics, etc.) and give them a common base in the fundamentals of robotics. A secondary goal is to introduce students to the Robotics program, and to give them some of the skills that will make them successful, both in the program and as a professional roboticist.

**ROB 521, RESEARCH ROBOTICS, 4 Credits**
Multidisciplinary teams of students will use the backdrop of a robotics competition to generate a research question, then design, build, and demonstrate a robotic system that is used to answer this research question. An example may be a Jenga-playing robot, where students try a new computer vision algorithm, or test a theory on force control. This directly parallels graduate research in robotics, where systems-building is necessary, and toy problems can illustrate research results, but the important focus is a core research question. The specific competition task changes each year, and robots will compete at the end of the term. Lec/lab.

**Equivalent to:** ENGR 521

**ROB 534, SEQUENTIAL DECISION MAKING IN ROBOTICS, 4 Credits**
Examines sequential decision making in robotics with a focus on motion planning and related optimization problems applied to fielded systems in marine, aerial, and ground domains. Discussions regarding both fundamental background material as well as cutting edge research in the following areas: discrete planning, sampling-based planning, planning under uncertainty, multi-robot systems, optimization, and performance guarantees.

**ROB 537, LEARNING-BASED CONTROL, 4 Credits**
Provides an introduction to learning systems and their application to the control of nonlinear systems. Covered topics include neural networks, reinforcement learning, and evolutionary algorithms. Includes project component in which students write a technical paper and give a conference style presentation based on their project.

**Equivalent to:** ME 537

**ROB 538, MULTIAGENT SYSTEMS, 4 Credits**
Provides an introduction to multiagent systems. In particular, it focuses on how to coordinate agents using different approaches. Covered topics include multiagent learning, game theory, swarms, social choice, and auctions. Includes significant reading and critiquing of assigned papers.

**Equivalent to:** ME 538

**ROB 541, GEOMETRIC MECHANICS, 4 Credits**
An introduction to geometric methods in the analysis of dynamic systems. Using the kinematics of simple robotic systems as a motivating example, we explore topics such as manifolds and Lie groups, representations of velocity, holonomic and nonholonomic constraints, constraint curvature and response to cyclic inputs, distance metrics.

**Recommended:** Prior exposure to linear algebra and differential equations

**ROB 542, ACTUATOR DYNAMICS, 4 Credits**
Focuses on how inertia, spring compliance, and other passive dynamics affect highly dynamic, software-controlled systems. Examples include robotic manipulation tasks, robot-human interaction, CNC machines, or legged locomotion. Lec/lab.

**Recommended:** Prior courses on dynamics and control such as ME 531, ME 533, ME 535

**ROB 545, ROBOTIC MANIPULATION, 4 Credits**
Introduction to the mechanical processes governing manipulation with a focus on the kinematics, statics, and dynamics of interacting rigid bodies. Topics include numerical inverse kinematics, dynamics of open chains, and interaction control. Some manipulation problems considered include grasping, picking and placing, and assembly.
ROB 562, HUMAN CONTROL SYSTEMS, 4
Credits
Covers mechanisms of human motor systems and control of the neuromusculoskeletal anatomy followed by functional analysis of these system components. Then all the components are integrated to study feedback control dynamics. Covers classic to modern theories of motor control, adaptation, cognitive involvement, and rehabilitation techniques.
Equivalent to: ME 539
Recommended: Basic feedback control systems, linear algebra, differential equations

ROB 564, SOFT ROBOTICS, 4
Credits
Soft robotics researchers propose building intelligent machines purely out of stretchable compressible soft materials. The course is centered on term-long projects that will result in real soft robots with the goal of presenting to the international community. The topics covered include rapid digital manufacturing, soft actuators, soft sensors, soft logic, soft energy, applications of soft robotics, and modeling soft mechanics.

ROB 567, HUMAN ROBOT INTERACTION, 4
Credits
The field of human-robot interaction brings together research and application of methodology from robotics, human factors, human-computer interaction, interaction design, cognitive psychology, education and other fields to enable robots to have more natural and more rewarding interactions with humans throughout their spheres of functioning.
Recommended: Background in one of human factors, usability/hci, programming experience, design

ROB 568, SOCIAL ROBOTICS, 4
Credits
In-depth exploration of the leading research, design principles, and challenges in Human-Robot Interaction (HRI), with an emphasis on socially interactive robots. Topics include social embodiment, multi-modal communication, human-robot teamwork, social learning, aspects of social psychology and cognition, as well as applications and evaluation with human subjects. Requires participation, lightning talks, student-led lectures, written critiques of class readings, and a group project involving a hypothetical social robotics project.

ROB 599, SPECIAL TOPICS, 0-16
Credits
This course is repeatable for 32 credits.

ROB 601, RESEARCH, 1-16
Credits
Graded P/N.
This course is repeatable for 99 credits.

ROB 603, THESIS, 1-16
Credits
This course is repeatable for 999 credits.

ROB 605, READING AND CONFERENCE, 1-16
Credits
This course is repeatable for 16 credits.

Software Engineering (SE)
SE 201, SOFTWARE DEVELOPMENT I, 4
Credits
Introduction to collaborative software development of larger, object-oriented systems. Overview of software architecture, and the tools, principles and practice of modern software development.
Prerequisite: CS 162 with C or better

SE 299, SPECIAL TOPICS, 0-16
Credits
This course is repeatable for 16 credits.

SE 303, SOFTWARE ENGINEERING III, 4
Credits
Introduction to refactoring techniques and improving the quality and maintainability of software. Applying continuous integration and deployment tools; containers and virtual development environments.
Prerequisite: CS 362 with C or better

SE 399, SPECIAL TOPICS, 0-16
Credits
This course is repeatable for 16 credits.

SE 467, BUSINESS OF SOFTWARE II, 4
Credits
Become an entrepreneur. Start a real software business, from ideation to sales. Real-world, hands-on learning in a fast-paced startup environment. Development of product ideas, hypotheses, and business models to discover customers. Teamwork, management, and positioning for investment.
Prerequisite: CS 466 with C or better

SE 468, BUSINESS OF SOFTWARE III, 4
Credits
Become an entrepreneur. Start a real software business, from ideation to sales. Real-world, hands-on learning in a fast-paced startup environment. Development of product ideas, hypotheses, and business models to discover customers. Teamwork, management, and positioning for investment.
Prerequisite: SE 467 with C or better

SE 499, SPECIAL TOPICS, 0-16
Credits
This course is repeatable for 16 credits.