SCHOOL OF CHEMICAL, BIOLOGICAL AND ENVIRONMENTAL ENGINEERING

The School of Chemical, Biological, and Environmental Engineering (CxEE) offers three undergraduate programs: Chemical Engineering (CHE), Bioengineering (BIOE), and Environmental Engineering (ENVE). The Bachelor of Science degrees in CHE, BIOE, and ENVE are each separately accredited by ABET, the Accreditation Board for Engineering and Technology. The Bachelor of Art degrees in CHE, BIOE, and ENVE are not accredited by ABET.

The goals of the CxEE undergraduate program are consistent with the mission and goals of the College of Engineering, and focus on creating work- and leadership-ready graduates who will be successful in professional careers as a chemical engineer, bioengineer, or environmental engineer in the private or public sectors, including industry, government, and consulting, as well as for continued graduate study in the same or closely related fields.

Chemical engineering (CHE) is the engineering discipline that focuses on the science and engineering of processes to convert raw materials into valued chemicals and products on a manufacturing scale.

Bioengineering (BIOE) is an interdisciplinary field that applies scientific and engineering principles to the development of new biologics, materials, devices, and processes in the broad areas of bioprocess, biomedical, and bioenvironmental technology.

Environmental engineering (ENVE) is the engineering discipline that applies scientific and engineering principles to improve the natural environment, to provide healthy water, air, and land, and to remediate polluted sites.

The educational objectives and curriculum are described separately for each CHE, BIOE, and ENVE program. The school has a core undergraduate curriculum where CHE, BIOE, and ENVE students take common courses in first through senior years, including first-year engineering, process material and energy balances, thermodynamics and transport phenomena, and senior year laboratory.

The school also offers graduate programs in bioengineering, chemical engineering, and environmental engineering leading to MEng, MS, and PhD degrees.

Undergraduate Programs

Majors

- Bioengineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/bioengineering-ba-bs-hba-hbs)
- Pre-Bioengineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/pre-professional-bioengineering)
- Chemical Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/chemical-engineering-ba-bs-hba-hbs)
- Pre-Chemical Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/pre-chemical-engineering)
- Environmental Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/environmental-engineering-ba-bs-hba-hbs)
- Pre-Environmental Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/pre-environmental-engineering)

Minor

- Environmental Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/environmental-engineering-minor)

Graduate Programs

Majors

- Bioengineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/bioengineering-meng-ms-phd)
- Chemical Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/chemical-engineering-meng-ms-phd)
- Environmental Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/environmental-engineering-meng-ms-phd-mais)

Minors

- Chemical Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/chemical-engineering-graduate-minor)
- Environmental Engineering (http://catalog.oregonstate.edu/college-departments/engineering/school-chemical-biological-environmental-engineering/environmental-engineering-graduate-minor)

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Faculty

Professors Chang, Herman, Jovanovic, Koretsky, Rorrer, Semprini1, Wildenschild, Wood
Associate Professors Bothwell, Dolan, Harper, Higgins, Kelly, Nason, Rochefort
Assistant Professors AuYeung, Arnadottir, Baio, Feng, Fu, Giers, Goulas, Montfort, Navab Daneshmand, Radniecki, Schilke, Simon, Stoerzinger
Professional Practice Engineers Carlisle, Mallette
Linus Pauling Engineer Harding1

1 Licensed professional engineer

Biological Engineering

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.
Prerequisites: (BI 231 with C or better or Z 331 with C or better) and (CHE 332 [C] or CHE 332H [C])

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.
Prerequisites: (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)
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.
Prerequisites: 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.

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.
Prerequisites: 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.
Prerequisites: BIOE 351 with C or better

BIOE 457. BIOREACTORS. (3 Credits)
Design and analysis of bioreactors using suspension and immobilized microbial cultures.
Prerequisites: (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.

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.
Prerequisites: BB 451 with C or better and (CHE 332 [C] or CHE 332H [C])

BIOE 470. REGULATION OF DRUGS AND MEDICAL DEVICES. (2 Credits)
Overview of regulations for pharmaceutical products and medical devices. Food and Drug Administration's approval process. Current good manufacturing practices and process validation is emphasized. Quality control and assurance, compliance, and important analytical methods will be introduced.

BIOE 490. BIOENGINEERING PROCESS DESIGN. (4 Credits)
Prerequisites: CHE 333 with C or better or CHE 333H with C or better Corequisites: BIOE 457

BIOE 491. BIOENGINEERING PRODUCT DESIGN. (4 Credits)
Design of biomedical and biotechnology-based products. Applications of a structured design process, meeting customer needs and regulatory considerations to design.
Prerequisites: BIOE 490 with C or better

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.
Prerequisites: 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 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.
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.

BIOE 557. BIOREACTORS. (3 Credits)
Design and analysis of bioreactors using suspension and immobilized microbial cultures.

BIOE 559. 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.

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.

BIOE 570. REGULATION OF DRUGS AND MEDICAL DEVICES. (2 Credits)
Overview of regulations for pharmaceutical products and medical devices. Food and Drug Administration's approval process. Current good manufacturing practices and process validation is emphasized. Quality control and assurance, compliance, and important analytical methods will be introduced.

BIOE 599. SPECIAL TOPICS. (1-16 Credits)
This course is repeatable for 999 credits.

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

Chemical, Biological and Environmental Engineering

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. Lec/rec/lab.
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. Lec/rec/lab.
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. Lec/lab.
Prerequisites: MTH 112 with C or better or MTH 251 with C or better or MTH 251H with C or better
Equivalent to: CBEE 102H

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. Lec/lab.
Attributes: HNRS – Honors Course Designator
Prerequisites: 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 211. MATERIAL BALANCES AND STOICHIOMETRY. (3 Credits)
Material balances, thermophysical, and thermochemical calculations. Lec/rec.
Prerequisites: MTH 252 with C or better or MTH 252H with C or better
Equivalent to: CBEE 211H

CBEE 211H. MATERIAL BALANCES AND STOICHIOMETRY. (3 Credits)
Material balances, thermophysical, and thermochemical calculations. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisites: MTH 252 with C or better or MTH 252H with C or better
Equivalent to: CBEE 211

CBEE 212. ENERGY BALANCES. (3 Credits)
Energy balances, thermophysical and thermochemical calculations. Lec/rec.
Prerequisites: (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 212H

CBEE 212H. ENERGY BALANCES. (3 Credits)
Energy balances, thermophysical and thermochemical calculations. Lec/rec.
Attributes: HNRS – Honors Course Designator
Prerequisites: (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

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. Lec/lab/rec.
Prerequisites: CBEE 212 with C or better or CBEE 212H with C or better
CBEE 280. MATERIAL AND ENERGY BALANCES. (6 Credits)
Material balances, thermophysical, and thermochemical calculations.
Energy balances, thermophysical and thermochemical calculations.
**Prerequisites:** MTH 256 (may be taken concurrently) with C or better or MTH 256H (may be taken concurrently) with C or better

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.

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
**Prerequisites:** 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 414H

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
**Prerequisites:** 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. CBE 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.
**Prerequisites:** 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

CBEE 507. SEMINAR. (1 Credit)
Graded P/N.
This course is repeatable for 3 credits.

**Chemical Engineering**

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)
This course is repeatable for 99 credits.

CHE 311. THERMODYNAMICS. (3 Credits)
Entropy, the second law of thermodynamics, equations of state, and thermodynamic network.
**Prerequisites:** (CBEE 212 with C or better or CBEE 212H 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.
**Prerequisites:** 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.

CHE 331. TRANSFER PHENOMENA I. (4 Credits)
Fundamentals and application of momentum and energy transfer phenomena to fluid flow for the design of industrial chemical engineering equipment.
**Prerequisites:** (MTH 256 with C or better or MTH 256H with C or better) and (CBEE 212 (may be taken concurrently) [C] or CBEE 212H (may be taken concurrently) [C])
**Equivalent to:** CHE 323, CHE 331H

CHE 331H. TRANSFER PHENOMENA I. (4 Credits)
Fundamentals and application of momentum and energy transfer phenomena to fluid flow for the design of industrial chemical engineering equipment.
**Attributes:** HNRS – Honors Course Designator
**Prerequisites:** (MTH 256 with C or better or MTH 256H with C or better) and (CBEE 212 (may be taken concurrently) [C] or CBEE 212H (may be taken concurrently) [C])
**Equivalent to:** CHE 331

CHE 332. TRANSFER PHENOMENA II. (3 Credits)
A unified treatment using control volume and differential analysis of heat transfer, prediction of heat transfer properties, and introduction to heat transfer operations.
**Prerequisites:** CHE 311 with C or better and (CHE 331 [C] or CHE 331H [C])
**Equivalent to:** CHE 332H

CHE 332H. TRANSFER PHENOMENA II. (3 Credits)
A unified treatment using control volume and differential analysis of heat transfer, prediction of heat transfer properties, and introduction to heat transfer operations.
**Attributes:** HNRS – Honors Course Designator
**Prerequisites:** CHE 311 with C or better and (CHE 331 [C] or CHE 331H [C])
**Equivalent to:** CHE 332

CHE 333. TRANSFER 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.
**Prerequisites:** 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 333H. TRANSFER 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.
**Prerequisites:** 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. TRANSFER PHENOMENA LABORATORY. (2 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.
**Prerequisites:** 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])

4 School of Chemical, Biological and Environmental Engineering
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.
Prerequisites: MTH 256 with C or better or MTH 256H with C or better

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

CHE 401. RESEARCH. (1-16 Credits)
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)
This course is repeatable for 16 credits.

CHE 411. MASS TRANSFER OPERATIONS. (4 Credits)
Mass transfer operations; design of separation processes. Lec/rec.
Prerequisites: 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.
Prerequisites: CBEE 414 with C or better and CHE 411 [C] and CHE 443 [C] and CHE 361 (may be taken concurrently) [C]

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.

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.
Prerequisites: 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. Lec/rec.
Prerequisites: 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.
Prerequisites: 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.

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.

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.

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.

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.
Prerequisites: 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.
Prerequisites: (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 8 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.

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 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.

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.

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.

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.

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.

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.

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. CROSSTLISTED as ECE 611. Equivalent to: ECE 611

CHE 612. PROCESS INTEGRATION. (3 Credits)
Process integration, simulation, and statistical quality control issues related to integrated circuit fabrication. Offered alternate years. CROSSTLISTED as ECE 612. Equivalent to: ECE 612

CHE 613. ELECTRONIC MATERIALS AND CHARACTERIZATION. (3 Credits)
Physics and chemistry of electronic materials and methods of materials characterization. Offered alternate years. CROSSTLISTED as ECE 613. Equivalent to: ECE 613

Environmental Engineering

ENVE 199. SPECIAL TOPICS. (1-16 Credits)
Seminar course that includes invited speakers. Open to all students interested in learning about the Environmental Engineering undergraduate program and potential career opportunities. Graded P/N. This course is repeatable for 16 credits.

ENVE 299. SPECIAL TOPICS. (0-16 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. Prerequisites: 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.
Prerequisites: (CH 222 with C or better or CH 232 with C or better or CH 223H 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.
Prerequisites: CBEE 414 with C or better

ENVE 421. DRINKING WATER TREATMENT PROCESSES. (4 Credits)
Measurement of physical and chemical characteristics of water and wastewater. Engineering principles for the selection and design of treatment processes.
Prerequisites: ENVE 321 with C or better or ENVE 322 with C or better

ENVE 422. ENVIRONMENTAL ENGINEERING DESIGN. (4 Credits)
Design of water and wastewater treatment facilities including physical, chemical, and biological processes.
Prerequisites: 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.
Prerequisites: 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.
Prerequisites: (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 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.
Prerequisites: 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 16 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. WATER AND WASTEWATER CHARACTERIZATION. (4 Credits)
Measurement of physical and chemical characteristics of water and wastewater. Engineering principles for the selection and design of treatment processes.

ENVE 522. ENVIRONMENTAL ENGINEERING DESIGN. (4 Credits)
Design of water and wastewater treatment facilities including physical, chemical, and biological processes.

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.

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.

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.

ENVE 535. PHYSICAL AND CHEMICAL PROCESSES FOR HAZARDOUS WASTE TREATMENT. (4 Credits)
Principles and design of unit operations and processes for the treatment of hazardous waste and contaminated soils.
Prerequisites: ENVE 532 with C or better

ENVE 536. AQUEOUS ENVIRONMENTAL CHEMISTRY LABORATORY. (1 Credit)
Laboratory investigation of acid/base equilibria, coordination chemistry, and precipitation/dissolution chemistry.
Corequisites: ENVE 532
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 542. MICROBIAL PROCESS DESIGN FOR MUNICIPAL AND HAZARDOUS WASTES. (4 Credits)
Principles and design of microbial processes for treatment of municipal and hazardous wastes.
Prerequisites: ENVE 541 with C or better

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.
Prerequisites: 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.
This course is repeatable for 8 credits.