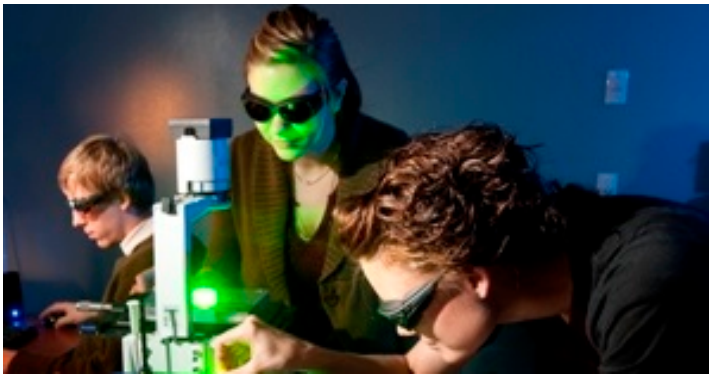
SCHOOL OF BIOMEDICAL AND CHEMICAL ENGINEERING



Scott Bioengineering Building, Suite 225
engr.colostate.edu/bce/ (https://www.engr.colostate.edu/bce/)
(970) 491-7157

Professor Stuart Tobet, Director
Professor Seth Dillard, Interim Director, Undergraduate Programs

The School of Biomedical and Chemical Engineering (SBCE) stands on a foundation of strong faculty and research programs from four CSU colleges: the Walter Scott, Jr. College of Engineering, and the Colleges of Health and Human Sciences, Natural Sciences, and Veterinary Medicine & Biomedical Sciences. The unique structure of the School involves over 70 faculty members representing 14 departments to provide an interdisciplinary focus on improving health, fighting disease, and aiding persons with disabilities. Academic excellence across diverse fields converges into three primary areas of research: (1) regenerative and rehabilitative medicine, (2) imaging and diagnostics, and (3) medical devices and therapeutics.

At the undergraduate level, SBCE offers unique five-year dual degree programs (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/dual-degree-programs/) where graduates receive two B.S. degrees: one in Biomedical Engineering and the other in one of four traditional engineering areas - Chemical & Biological Engineering, Computer Engineering, Electrical Engineering, or Mechanical Engineering. An undergraduate Biomedical Engineering Interdisciplinary Minor (http://catalog.colostate.edu/general-catalog/university-wide-programs/interdisciplinary-studies/biomedical-engineering-interdisciplinary-minor/) and an undergraduate Certificate in Global Biomedical Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/global-biomedical-engineering-certificate/) are also offered.

SBCE also offers an undergraduate degree in Chemical and Biological Engineering. For a broad overview of the field, students can choose to major in the 'standalone' Major in Chemical and Biological Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-biological-engineering-major/), or they can specialize in one of four available concentrations: Advanced Materials, Biomanufacturing, Molecular Medicine, or Sustainable Engineering.

At the graduate level, SBCE offers Master of Science and Ph.D. programs in Bioengineering or Chemical Engineering, Master of Engineering programs with specializations in Biomedical Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/me-biomedical-engineering-specialization/) or Chemical Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/me-chemical-engineering-specialization/), a Professional Science Master's in Biomanufacturing and Biotechnology (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/psm-biomanufacturing-biotechnology/), and two Graduate Certificates: Biomaterials and Tissue Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/biomaterials-tissue-engineering-graduate-certificate/), and Bioprocess Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/graduate-certificate-bioprocess-engineering/).

Biomedical and chemical engineering lies at the interface of engineering, biology, medicine, and sustainability. With over 40 state-of-the-art biomedical and chemical engineering research labs, including the world-renowned Veterinary Teaching Hospital and Animal Cancer Center, we offer hands-on experience for undergraduate and graduate students to work alongside leading researchers. CSU provides a rich environment for interdisciplinary research and day-to-day collaborations and is positioned to offer unique bioengineering degree programs due to our faculty expertise, the interdisciplinary nature of the SBCE, and the highly-ranked veterinary program. Our programs integrate biological, chemical, physical, and mathematical sciences with engineering principles and clinical studies, and our graduates are well prepared for careers in research, education, veterinary or human medicine, and industry.

Biomedical and chemical engineers are involved in a wide variety of activities on a daily basis. Practical applications of biomedical and chemical engineering include development, design, production, research, and/or teaching in areas such as:

- Designing biomedical materials, medical devices, instrumentation and equipment (software/firmware/hardware) for therapeutics such as pacemakers, assistive devices, joint replacement materials, prosthetics, surgical tools.
- Developing or improving therapies for fighting cancer, tuberculosis, or other illnesses and diseases (e.g., nanoscaffolding for localized chemotherapy delivery, telemetric sensors to determine healing rates in bone fractures or to detect key chemicals in live tissue with high temporal and spatial resolution).
- Finding better ways to image and/or diagnose illnesses (e.g., using laser-based imaging to detect viruses, developing ways to increase electrical signals to detect threats to food safety and security, designing biosensors to diagnose cancer cells, developing software to determine toxic pesticide levels in people).
- Designing and improving manufacturing processes for chemicals, fuels, food, pharmaceuticals, and other products, while also ensuring safety, efficiency, and sustainability.
- Designing processes for the production of alternative energy sources and waste prevention.

Undergraduate

Biomedical Engineering Dual Degree Programs (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/dual-degree-programs/):

- Biomedical Engineering, B.S. combined with Chemical and Biological Engineering, B.S. (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-biological-dual-degree-program/)
- Biomedical Engineering, B.S. combined with Computer Engineering, B.S. (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/computer-dual-degree-program/)
- Biomedical Engineering, B.S. combined with Electrical Engineering, B.S., Electrical Engineering Concentration (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/electrical-dual-degree-program/)
- Biomedical Engineering, B.S. combined with Electrical Engineering, B.S., Lasers and Optical Engineering Concentration (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/electrical-lasers-optical-concentration-dual-degree-program/)
- Biomedical Engineering, B.S. combined with Mechanical Engineering, B.S. (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/mechanical-dual-degree-program/)

Major in Chemical and Biological Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-biological-engineering-major/)

- Advanced Materials Concentration (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-biological-engineering-major-advanced-materials-concentration/)
- Biomanufacturing Concentration (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-biological-engineering-major-biomanufacturing-concentration/)
- Molecular Medicine Concentration (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-biological-engineering-major-molecular-medicine-concentration/)
- Sustainable Engineering Concentration (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-biological-engineering-major-sustainable-engineering-concentration/)

Minor

- Interdisciplinary Minor in Biomedical Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/biomedical-engineering-interdisciplinary-minor/)

Certificate

- Certificate in Global Biomedical Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/global-biomedical-engineering-certificate/)

Graduate

Graduate Programs in Biomedical and Chemical Engineering

Students interested in graduate work should refer to the Graduate and Professional Bulletin (http://catalog.colostate.edu/general-catalog/graduate-bulletin/) or the School of Chemical and Biomedical Engineering.

Certificates

- Graduate Certificate in Biomaterials and Tissue Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/biomaterials-tissue-engineering-graduate-certificate/)
- Graduate Certificate in Bioprocess Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/graduate-certificate-bioprocess-engineering/)

Master's Programs

- Master of Engineering, Plan C, Biomedical Engineering Specialization (http://catalog.colostate.edu/general-catalog/colleges/engineering/me-biomedical-engineering-specialization/)
- Master of Engineering, Plan C, Chemical Engineering Specialization (http://catalog.colostate.edu/general-catalog/colleges/engineering/me-chemical-engineering-specialization/)
- Master of Science in Bioengineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/bioengineering-ms/)
- Master of Science in Chemical Engineering, Plan A (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-engineering-ms-plan-a/)
- Master of Science in Chemical Engineering, Plan B (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-engineering-ms-plan-b/)
- Professional Science Master's in Biomanufacturing and Biotechnology (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/psm-biomanufacturing-biotechnology/)

Ph.D. Programs

- Ph.D. in Bioengineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/bioengineering-phd/)
- Ph.D. in Chemical Engineering (http://catalog.colostate.edu/general-catalog/colleges/engineering/biomedical-chemical-engineering/chemical-engineering-phd/)

Courses

Subjects in this department include Biomedical Engineering (BIOM) and Chemical and Biological Engineering (CBE).

Biomedical Engineering (BIOM)

BIOM 100 Overview of Biomedical Engineering Credit: 1 (1-0-0)
Course Description: Overview of the field of biomedical engineering with an emphasis on the roles of mechanical, electrical, and chemical/biological engineering principles.
Prerequisite: None.
Restriction: Must be a: Undergraduate.
Registration Information: Sections may be offered: Online. Credit allowed for only one of the following: BIOM 100, BIOM 101, BIOM 109, or BIOM 180A1.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 101 Introduction to Biomedical Engineering Credits: 3 (3-0-0)
Course Description: Basic principles, fundamentals in biomedical engineering including molecular, cellular and physiological principles, major areas such as biomechanics.
Prerequisite: None.
Registration Information: Credit allowed for only one of the following: BIOM 100, BIOM 101, BIOM 109, or BIOM 180A1. Credit not allowed for both BIOM 101 and BIOM 200.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 109 Principles of Biomedical Engineering Credit: 1 (1-0-0)
Course Description: Fundamental principles of biomedical engineering and commonalities with mechanical, electrical, and chemical/biological engineering. Emphasis on the application of engineering design in a biomedical context. Introduction to industrial and academic career paths.

Prerequisite: None.
Registration Information: Offered as an online course only. Only offered for high school students who are concurrently enrolled in the complementary in-person course at a participating high school. Credit allowed for only one of the following: BIOM 100, BIOM 101, BIOM 109, or BIOM 180A1.
Terms Offered: Fall, Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 200 Fundamentals of Biomedical Engineering Credits: 2 (2-0-0)
Course Description: Application of engineering analysis to physiology and biomedical engineering topics.
Prerequisite: LIFE 102, may be taken concurrently and MATH 160.
Restriction: Must be a: Undergraduate.
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 101 and BIOM 200.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 300 Problem-Based Learning Biomedical Engr Lab Credits: 4 (1-4-1)
Course Description: Group problem-based learning approach to problems spanning all core areas of biomedical engineering.
Prerequisite: (BIOM 200 or CBE 205 and MECH 262, may be taken concurrently) and (MATH 340 or MATH 345).
Restriction: Must not be a: Freshman, Sophomore.
Registration Information: Junior standing. Must register for lecture, lab, and recitation.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: Yes.

BIOM 304 Global Challenges and Collaborations in BME Credits: 3 (3-0-0)
Course Description: Foundational elements of cross-cultural competence in the biomedical engineering field, considering social, political, and economic differences in areas such as medical device design, regulation, technology transfer, and ethics.
Prerequisite: BIOM 100 or BIOM 101.
Restrictions: Must not be a: Freshman. Must be a: Undergraduate.
Registration Information: Sophomore standing. Offered as Mixed Face-to-Face. Credit not allowed for both BIOM 304 and BIOM 380A2.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 306 Bioprocess Engineering Credits: 4 (3-2-0)
Also Offered As: BTEC 306.
Course Description: Material, energy balances; fluid flow, heat exchange, mass transfer; application to operations in food, fermentation, other bioprocess industries.
Prerequisite: (CHEM 107 or CHEM 111) and (PH 121 or PH 141).
Registration Information: Must register for lecture and laboratory. Credit not allowed for both BIOM 306 and BTEC 306.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 350A Study Abroad--Ecuador: Prosthetics Credits: Var[1-3] (0-0-0)
Course Description: Design and fabricate prosthetics for under-served populations in Ecuador. The experience occurs in Quito, Ecuador in partnership with a local university and Range of Motion Project (ROMP), a non-profit healthcare organization.
Prerequisite: None.
Registration Information: Credit not allowed for both BIOM 350A and BIOM 382A.
Term Offered: Summer.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 350B Study Abroad--Portugal: Biomedical Engineering and Healthcare Credit: 1 (0-0-1)
Course Description: Intercultural exchange in Portugal, with a focus on becoming familiar with pharmaceutical production, regulatory affairs and quality control, product development, and practices in biotechnology and biomedical engineering. Visits to historic and cultural sites and pharmaceutical, biomedical, biotechnology, and healthcare facilities.
Prerequisite: None.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 350C Study Abroad--Ireland: Biomedical Engineering and Healthcare Credit: 1 (0-0-1)
Course Description: Intercultural exchange in Ireland, focusing on becoming familiar with the pharmaceutical/medical device industry, regulatory affairs and quality control, product development, the Irish healthcare system, and practices in biotechnology and biomedical engineering. Visits to historic and cultural sites and pharmaceutical, biomedical, biotechnology, and healthcare facilities.
Prerequisite: None.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 403 Intro to Optical Techniques in Biomedical Eng Credits: 3 (3-0-0)
Also Offered As: ECE 403.
Course Description: Engineering design principles of optical characterization techniques for biomedical systems, including optical spectroscopy and microscopy of biomolecules and tissues.
Prerequisite: CHEM 111 and PH 142 with a minimum grade of C.
Restriction: Must not be a: Freshman, Sophomore.
Registration Information: Junior standing. Sections may be offered: Online. Credit allowed for only one of the following: BIOM 403, BIOM 481A3, ECE 403, or ECE 481A3.
Term Offered: Fall (even years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 421 Transport Phenomena in Biomedical Engineering Credits: 3 (3-0-0)
Course Description: Engineering models of active and passive mechanisms of momentum. Heat and mass transport in mammalian cells, tissues, and organ systems.
Prerequisite: (BMS 300) and (CBE 332 or MECH 344).
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 330 and BIOM 421.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 422 Quantitative Systems and Synthetic Biology Credits: 3 (3-0-0)
Course Description: In-depth analysis of the quantitative systems approach to biology and biological engineering at the molecular and cellular scales.
Prerequisite: CBE 320.
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 400 and BIOM 422.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 431 Biomedical Signal and Image Processing Credits: 3 (3-0-0)
Also Offered As: ECE 431.
Course Description: Principles, features and mathematical processing of biomedical signals and images including interference and noise filtering and feature enhancement.
Prerequisite: (ECE 303 with a minimum grade of C or STAT 303 with a minimum grade of C) and (ECE 311 with a minimum grade of C and PH 142 with a minimum grade of C).
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 431 and ECE 431.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 440 Computational Statistics For Bioengineering Credits: 3 (2-2-0)
Also Offered As: CBE 440.
Course Description: Application of computational methods that integrate differential equations and statistical analyses with concepts from cell biology, transport phenomena, and systems biology to analyze experimental data and infer predictive models for natural and synthetic processes in biological and biomedical engineering. Analysis of datasets arising in biological and biomedical engineering, including proteomics, optical microscopy, and RNA sequencing.
Prerequisite: (BIOM 422 and CBE 320) and (CBE 340 or STAT 315).
Registration Information: Must register for lecture and laboratory. Credit allowed for only one of the following: BIOM 440, BIOM 480A5, CBE 440, or CBE 480A5.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 441 Biomechanics and Biomaterials Credits: 3 (3-0-0)
Course Description: Principles of biomechanics, biofluids, and biomaterials.
Prerequisite: (BMS 300, may be taken concurrently and CIVE 360 and MECH 324, may be taken concurrently) and (MECH 331, may be taken concurrently or MECH 331B, may be taken concurrently and MECH 331A, may be taken concurrently) and (MECH 342, may be taken concurrently).
Registration Information: Sections may be offered: Online.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 476 Biomedical Engineering Clinical Practicum Credits: Var[1-3] (0-0-0)
Course Description: Biomedical lab work or research project in hospital, clinical, or other medical environment.
Prerequisite: BMS 300.
Restrictions: Must not be a: Freshman, Sophomore. Must be a: Undergraduate.
Registration Information: Written consent of department chair. Written consent of instructor.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 486A Biomedical Design Practicum: Capstone Design I Credits: 4 (0-0-10)
Course Description:
Prerequisite: (BIOM 300) and (BIOM 422 and CBE 320 and CBE 442 or ECE 342 and BIOM 431 and ECE 311 and ECE 332 or MECH 307 and BIOM 441 and MECH 325).
Restrictions: Must not be a: Freshman, Sophomore, Junior. Must be a: Undergraduate.
Registration Information: Senior standing. Enrollment in biomedical engineering major.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 486B Biomedical Design Practicum: Capstone Design II Credits: 4 (0-0-10)
Course Description:
Prerequisite: (BIOM 486A) and (CBE 451 or ECE 312 or MECH 325 and MECH 344 or PH 353).
Restrictions: Must not be a: Freshman, Sophomore, Junior. Must be a: Undergraduate.
Registration Information: Senior standing. Enrollment in biomedical engineering major.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 495 Independent Study Credits: Var[1-6] (0-0-0)
Course Description:
Prerequisite: None.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 504 Fundamentals of Biochemical Engineering Credits: 3 (3-0-0)
Also Offered As: CBE 504.
Course Description: Application of chemical engineering principles to enzyme kinetics, fermentation and cell culture, product purification, and bioprocess design.
Prerequisite: CBE 205.
Restriction: Must not be a: Freshman, Sophomore, Junior.
Registration Information: Senior standing. Sections may be offered: Online. Credit not allowed for both BIOM 504 and CBE 504.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 517 Advanced Optical Imaging Credits: 3 (3-0-0)
Also Offered As: ECE 517.
Course Description: Engineering design principles of advanced optical imaging techniques and image formation theory.
Prerequisite: ECE 342 with a minimum grade of C or MATH 340 with a minimum grade of C or MATH 345 with a minimum grade of C.
Restriction: Must not be a: Freshman, Sophomore.
Registration Information: Junior standing. Sections may be offered: Online. Credit allowed for only one of the following: BIOM 517, BIOM 581B7, ECE 517 or ECE 581B7.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 518 Biophotonics Credits: 3 (3-0-0)
Also Offered As: ECE 518.
Course Description: Engineering design principles of optical instrumentation for medical diagnostics. Light propagation and imaging in biological tissues.
Prerequisite: ECE 342 with a minimum grade of C or ECE 457 with a minimum grade of C or MATH 340 with a minimum grade of C or MATH 345 with a minimum grade of C.
Restriction: Must not be a: Freshman, Sophomore.
Registration Information: Junior standing. Sections may be offered: Online. Credit allowed for only one of the following: BIOM 518, BIOM 581A9, ECE 518 or ECE 581A9.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 522 Bioseparation Processes Credits: 3 (3-0-0)
Also Offered As: CBE 522.
Course Description: Analysis of processes to recover and purify fermentation products.
Prerequisite: CBE 331.
Registration Information: Sections may be offered: Online. Credit allowed for only one of the following: BIOM 522, CBE 522, or CBE 581A2.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 525 Cell and Tissue Engineering Credits: 3 (3-0-0)
Also Offered As: MECH 525.
Course Description: Cell and tissue engineering concepts and techniques with emphasis on cellular response, cell adhesion kinetics, and tissue engineering design.
Prerequisite: BC 351 or BMS 300 or BMS 500 or BZ 310 or NB 501.
Registration Information: Credit allowed for only one of the following: BIOM 525, CBE 525, MECH 525. Sections may be offered: Online.
Term Offered: Spring. (even years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 526 Biological Physics Credits: 3 (3-0-0)
Also Offered As: ECE 526.
Course Description: Mathematical and physical modeling of biological systems. Mass transport in cellular environments. Electrical/mechanical properties of biomolecules.
Prerequisite: (MATH 340 or MATH 345) and (PH 122 or PH 142).
Restriction: Must not be a: Freshman, Sophomore.
Registration Information: Junior standing. Credit not allowed for both BIOM 526 and ECE 526. Sections may be offered: Online.
Term Offered: Fall (odd years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 527A Biosensing: Cells as Circuits Credit: 1 (1-0-0)
Also Offered As: ECE 527A.
Course Description: Treatment of biological cells as circuits and their electrical time-dependent function and frequency-dependent impedance. Topics include the Hodgkin–Huxley circuit model, diffusion equation, and modeling action potential propagation.
Prerequisite: (BIOM 101 or LIFE 102) and (CHEM 111) and (MATH 340 or MATH 345) and (PH 142).
Registration Information: Junior standing. This is a partial semester course. Credit allowed for only one of the following: BIOM 527A, BIOM 581B1, ECE 527A, or ECE 581B1.
Term Offered: Fall (odd years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 527B Biosensing: Signal and Noise in Biosensors Credit: 1 (1-0-0)
Also Offered As: ECE 527B.
Course Description: Quantitative treatment of concepts of noise, interference and signal including noise types and spectra, filtering, and limitations imposed by noise. Example applications to Biosensors.
Prerequisite: (MATH 340, may be taken concurrently or MATH 345, may be taken concurrently) and (PH 142).
Registration Information: Junior standing. This is a partial semester course. Credit allowed for only one of the following: BIOM 527B, BIOM 581B2, ECE 527B, or ECE 581B2.
Term Offered: Spring (even years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 527C Biosensing: Sensor Circuit Fundamentals Credit: 1 (1-0-0)
Also Offered As: ECE 527C.
Course Description: Introduction to circuit concepts used in sensors, including review of basic circuit elements of resistors, capacitors, and MOS (Metal-Oxide-Semiconductor transistors) elements. Fundamentals of the application of MOS circuits for signal conditioning and amplification and how sensor's backend signal processing is carried out after the sensor signal transduction stage.
Prerequisite: (BIOM 101 or LIFE 102) and (MATH 340, may be taken concurrently or MATH 345, may be taken concurrently) and (PH 142).
Registration Information: Junior standing. This is a partial semester course. Credit allowed for only one of the following: BIOM 527C, BIOM 581B3, ECE 527C, or ECE 581B3.
Term Offered: Fall (odd years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 527D Biosensing: Electrochemical Sensors Credit: 1 (1-0-0)
Also Offered As: ECE 527D.
Course Description: Introduction to the electrochemistry, and applications of electrochemical methods, used for detection of certain classes of chemicals and molecules.
Prerequisite: (BIOM 101 or LIFE 102) and (CHEM 111) and (MATH 255 or MATH 261) and (PH 142).
Registration Information: Junior standing. This is a partial semester course. Credit allowed for only one of the following: BIOM 527D, BIOM 581B5, ECE 527D, or ECE 581B5.
Term Offered: Fall (odd years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 527E Biosensing: Affinity Sensors Credit: 1 (1-0-0)
Also Offered As: ECE 527E.
Course Description: Fundamentals of affinity sensor application and design, including optical and electrical approaches and technologies.
Prerequisite: (BIOM 101 or LIFE 102) and (CHEM 111) and (MATH 340, may be taken concurrently or MATH 345, may be taken concurrently) and (PH 142).
Registration Information: Junior standing. This is a partial semester course. Credit allowed for only one of the following: BIOM 527E, BIOM 581B4, ECE 527E, or ECE 581B4.
Term Offered: Spring (even years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 527F Biosensing: Biophotonic Sensors Using Refractive Index Credit: 1 (1-0-0)
Also Offered As: ECE 527F.
Course Description: Operating principles of optical biosensors based on changes in refractive index, such as thin films, ring-resonators, Mach-Zehnder interferometers, and other evanescent wave sensors. Basic supporting optical concepts, including thin-film interference, optical waveguides and evanescent waves.
Prerequisite: (BIOM 527F or ECE 527F) and (MATH 340, may be taken concurrently or MATH 345, may be taken concurrently) and (PH 142).
Registration Information: Junior standing. This is a partial semester course. Credit allowed for only one of the following: BIOM 527F, BIOM 581B6, ECE 527F, or ECE 581B6.
Term Offered: Spring (even years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 531 Materials Engineering Credits: 3 (3-0-0)
Also Offered As: MECH 531.
Course Description: Selection of structural engineering materials by properties, processing, and economics; materials for biomedical and biotechnology applications.
Prerequisite: MECH 331 or MECH 331A and MECH 331B or MECH 431.
Registration Information: Credit not allowed for both BIOM 531 and MECH 531. Sections may be offered: Online.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 532 Materials Issues in Mechanical Design Credits: 3 (3-0-0)
Also Offered As: MECH 532.
Course Description: Failure mechanisms from materials viewpoint with emphasis on use in design. Fracture, creep, fatigue, and corrosion.
Prerequisite: MECH 331 or MECH 331A and MECH 331B.
Registration Information: Credit not allowed for both BIOM 532 and MECH 532. Sections may be offered: Online.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 533 Biomolecular Tools for Engineers Credits: 3 (2-3-0)
Also Offered As: CIVE 533.
Course Description: Theoretical and practical aspects of biomolecular laboratory tools--PCR, cloning, sequencing, single-molecule optical techniques and live-cell imaging.
Prerequisite: BMS 300 or MIP 300.
Registration Information: Must register for lecture and laboratory. Credit not allowed for BIOM 533, CIVE 533 and ECE 533.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: Yes.

BIOM 537 Biomedical Signal Processing Credits: 3 (3-0-0)
Also Offered As: ECE 537.
Course Description: Modeling and classification of biosignals (e.g. EEG, ECG, EMG), covering adaptive filtering, wavelets, support vector machines, neural networks, and handling problems with overfitting of noisy data.
Prerequisite: ECE 303 or ECE 311 or MATH 340 or STAT 303.
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 537 and ECE 537.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 559 Machine Learning in Imaging and Spectroscopy Credits: 3 (3-0-0)
Also Offered As: ECE 559.
Course Description: Investigate and critique applications of current techniques in biomedical imaging/spectroscopy such as convolutional networks to problems such as deconvolution, computed tomography, phase retrieval, hyperspectral unmixing, and learn how to apply these methods to datasets of their own. A special emphasis on biomedical imaging technologies and applications such as phase contrast microscopy, low-dose x-ray computed tomography, sparse fast magnetic resonance imaging, etc.
Prerequisite: (ECE 312 with a minimum grade of C or ECE 457) and (BIOM 403, may be taken concurrently or ECE 403, may be taken concurrently or ECE 441, may be taken concurrently or ECE 504) and (ECE 303 with a minimum grade of C or STAT 303 with a minimum grade of C or ECE 431 or BIOM 431) and (CS 150B with a minimum grade of C or CS 152 with a minimum grade of C).
Restriction: Must not be a: Freshman, Sophomore.
Registration Information: Junior standing. Sections may be offered: Online. Credit allowed for only one of the following: BIOM 559, BIOM 580C7, ECE 559, or ECE 580C7.
Term Offered: Fall (even years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 570 Bioengineering Credits: 3 (3-0-0)
Also Offered As: MECH 570.
Course Description: Physiological and medical systems analysis using engineering methods including mechanics, fluid dynamics, control electronics, and signal processing.
Prerequisite: CBE 332 or ECE 311 or MECH 331A.
Restriction: Must not be a: Freshman, Sophomore, Junior.
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 570 and MECH 570.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 572 Regenerative Bioengineering with Stem Cells Credits: 3 (3-0-0)
Also Offered As: MECH 572.
Course Description: Current status and future direction of bioengineering and regenerative technologies with stem cells. Topics include tissue-specific applications of pluripotent stem cells and multipotent adult stem cells, genetic and epigenetic engineering, organoids, and manufacturing, including scale-up, sorting and preservation.
Prerequisite: BC 351 or BMS 300 or BZ 310.
Registration Information: Sections may be offered: Online. Credit allowed for only one of the following: BIOM 572, BIOM 580A9, MECH 572, or MECH 580A9.
Term Offered: Spring (even years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 573 Structure and Function of Biomaterials Credits: 3 (3-0-0)
Also Offered As: MECH 573.
Course Description: Structure-function relationships of natural biomaterials; application to analysis of biomimetic materials and biomaterials used in medical devices.
Prerequisite: MECH 331 or MECH 331A and MECH 331B.
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 573 and MECH 573.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 574 Bio-Inspired Surfaces Credits: 3 (3-0-0)
Also Offered As: MECH 574.
Course Description: Analysis of surface functionalities of various biological species; identification of design principles.
Prerequisite: (CHEM 111 or CHEM 120) and (MECH 342).
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 574 and MECH 574.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 576 Quantitative Systems Physiology Credits: 4 (4-0-0)
Also Offered As: MECH 576.
Course Description: Quantitative, model-oriented approach to cellular and systems physiology with design examples from biomedical engineering.
Prerequisite: BMS 300 and CHEM 113 and MATH 340 and PH 142.
Registration Information: Credit not allowed for both BIOM 576 and MECH 576. Sections may be offered: Online.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 578 Musculoskeletal Biosolid Mechanics Credits: 3 (3-0-0)
Also Offered As: MECH 578.
Course Description: Application of engineering concepts to quantify the mechanical behavior of load-bearing biological tissues and orthopaedic implant performance.
Prerequisite: CIVE 360.
Restriction: Must be a: Graduate.
Registration Information: Graduate standing. Sections may be offered: Online. Credit not allowed for both BIOM 578 and MECH 578.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 579 Cardiovascular Biomechanics Credits: 3 (3-0-0)
Also Offered As: MECH 579.
Course Description: Bio-mechanical principles and approaches applied in cardiovascular research.
Prerequisite: MATH 340 and PH 142.
Restriction: Must be a: Graduate.
Registration Information: Graduate students only. Sections may be offered: Online. Credit allowed for only one of the following: BIOM 579, BIOM 581A8, MECH 579, or MECH 581A8.
Term Offered: Fall (odd years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 586A Biomedical Clinical Practicum Credits: 2 (1-2-0)
Course Description: Graduate-level activity that includes biomedical research or design of a new medical device, as well as essential elements of professional development.
Prerequisite: (BMS 300 or BMS 500) and (BIOM 570 or MECH 570).
Registration Information: Must register for lecture and laboratory.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 586B Biomedical Clinical Practicum Credits: 4 (1-6-0)
Course Description: Graduate-level activity, such as biomedical research or design of a new medical device, for exposure to the hospital/clinical environment.
Prerequisite: (BMS 300 or BMS 500) and (BIOM 570 or MECH 570).
Registration Information: Must register for lecture and laboratory.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 592 Seminar Credits: Var[1-3] (0-0-0)
Course Description: Student and research faculty presentations, guest and invited extramural speakers.
Prerequisite: None.
Registration Information: Sections may be offered: Online.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 671 Orthopedic Tissue Biomechanics Credits: 3 (3-0-0)
Also Offered As: MECH 671.
Course Description: Linear elastic, finite deformation, and viscoelastic theories applied to the mechanical behavior of orthopedic tissues (bone, tendon, cartilage).
Prerequisite: CIVE 560.
Restriction: Must be a: Graduate, Professional.
Registration Information: Credit not allowed for both BIOM 671 and MECH 671.
Term Offered: Fall (odd years).
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 684 Supervised College Teaching Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Registration Information: Maximum of 6 credits allowed in course; may not be used to satisfy degree requirements requiring bioengineering courses.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 695 Independent Study Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 699 Thesis Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 750 Grant Proposal Writing and Reviewing Credit: 1 (1-0-0)
Course Description: Preparation and review of applications for fellowships and grants.
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Registration Information: Written consent of instructor.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

BIOM 784 Supervised College Teaching Credits: Var[1-6] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 786 Practicum-Laboratory Rotations Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 795 Independent Study Credits: Var[1-6] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall. Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 798 Research-Laboratory Rotations Credits: Var[1-6] (0-0-0)
Course Description: Doctoral laboratory rotation.
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

BIOM 799 Dissertation Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

Chemical and Biological Engineering (CBE)

CBE 101 Introduction to Chemical and Biological Engr Credits: 3 (2-2-0)
Course Description: Engineering design and problem solving; technical presentation skills; basic computer programming.
Prerequisite: CBE 160, may be taken concurrently.
Registration Information: Must register for lecture and laboratory. Credit not allowed for both CBE 101 and CBE 101A. Credit not allowed for both CBE 101 and CBE 101B. Credit allowed for only one of the following: CBE 101, ENGR 111, or ENGR 123.
Terms Offered: Fall, Spring.
Grade Mode: Traditional.
Special Course Fee: Yes.

CBE 101A Introduction to Chemical and Biological Engr: Lecture Credits: 2 (2-0-0)
Course Description: Overview of fundamentals of chemical and biological engineering, including conservation and rate processes, transport phenomena, engineering design and problem solving, and applications. Complemented by CBE 101B for laboratory experience.
Prerequisite: CBE 160, may be taken concurrently.
Registration Information: Sections may be offered: Online. Credit allowed for only one of the following: CBE 101, CBE 101A, CBE 104A, ENGR 111, or ENGR 123.
Terms Offered: Fall, Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 101B Introduction to Chemical and Biological Engr: Laboratory Credit: 1 (0-2-0)
Course Description: Laboratory experiences to illustrate fundamentals of chemical and biological engineering, including conservation and rate process, fluid flow, and heat and mass transfer.
Prerequisite: CBE 101A, may be taken concurrently.
Registration Information: Credit allowed for only one of the following: CBE 101, CBE 101B, CBE 104A, ENGR 111, or ENGR 123.
Terms Offered: Fall, Spring.
Grade Mode: Traditional.
Special Course Fee: Yes.

CBE 104A Study Abroad--Denmark: Intro to Chemical and Biological Engineering Credits: 3 (0-0-3)
Course Description: Fundamentals of chemical and biological engineering, including conservation and rate process, engineering design and problem solving, and relevant applications. Exploration of engineering practices, challenges, and projects while on site in Denmark through guest lectures, discussions with practicing engineers, and visits to engineering and biotechnology facilities.
Prerequisite: None.
Registration Information: This is a partial semester course. Credit not allowed for CBE 101A and CBE 104A. Credit not allowed for CBE 101B and CBE 104A. Credit allowed for only one of the following: CBE 104A, ENGR 111, or ENGR 123.
Term Offered: Fall.
Grade Mode: S/U Sat/Unsat Only.
Special Course Fee: No.

CBE 160 MATLAB for Chemical and Biological Eng Credit: 1 (0-2-0)
Course Description: Introduction to MATLAB programming for Chemical and Biological Engineering applications.
Prerequisite: None.
Registration Information: Credit not allowed for both CBE 160 and ENGR 111. Credit not allowed for both CBE 160 and ENGR 114. Credit not allowed for both CBE 160 and ENGR 123.
Terms Offered: Fall, Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 201 Material and Energy Balances Credits: 3 (3-0-0)
Course Description: Principles of chemistry, physics, and mathematics applied to development of material and energy balances; illustration of concepts.
Prerequisite: None.
Registration Information: [(CBE 101, may be taken concurrently or CBE 101A, may be taken concurrently or CBE 104A, may be taken concurrently); (CBE 160, may be taken concurrently or MATH 151, may be taken concurrently)] or (ENGR 114, may be taken concurrently or ENGR 123, may be taken concurrently); (CHEM 113 or CHEM 120, may be taken concurrently); LIFE 102, may be taken concurrently; PH 141, may be taken concurrently. Sections may be offered: Online.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 205 Fundamentals of Biological Engineering Credits: 3 (3-0-0)
Course Description: Introduction to the application of the principles of engineering and biology to the analysis, design, and optimization of bioprocesses.
Prerequisite: (CBE 101 or CBE 101A or CBE 104A or CBE 160 or ENGR 114 or ENGR 123 or MATH 151, may be taken concurrently) and (LIFE 102, may be taken concurrently) and (CHEM 113 or CHEM 120, may be taken concurrently).
Registration Information: Sections may be offered: Online.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 210 Thermodynamic Process Analysis Credits: 3 (3-0-0)
Course Description: Thermodynamic fundamentals and applications to ideal and non-ideal mixtures, power cycles, and chemical equilibria.
Prerequisite: CBE 201 with a minimum grade of C and MATH 261, may be taken concurrently.
Registration Information: Sections may be offered: Online. Credit allowed for only one of the following: CBE 210, ENGR 337, MECH 237, MECH 337, MECH 339, or MECH 439.
Term Offered: Spring.
Grade Modes: S/U within Student Option, Traditional.
Special Course Fee: No.

CBE 223 CBE Design and Experimentation I Credits: 2 (0-4-0)
Course Description: Introduction to chemical and biological engineering design principles and experimentation including principles of the design, build, test, learn cycle, laboratory experiments involving material balances, biological engineering, and thermodynamics to reinforce elements of theory-based courses.
Prerequisite: CBE 201 with a minimum grade of C and CBE 205 with a minimum grade of C and CBE 210, may be taken concurrently.
Restriction: Must be a: Undergraduate.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 310 Molecular Concepts and Applications Credits: 3 (3-0-0)
Course Description: Application of modern molecular theory to chemical and biological engineering problems in thermodynamics, chemical kinetics, and transport phenomena.
Prerequisite: (CBE 210 with a minimum grade of C) and (MATH 340).
Registration Information: Sections may be offered: Online.
Terms Offered: Fall, Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 320 Chemical and Biological Reactor Design Credits: 3 (3-0-0)
Course Description: Mechanisms and rates of chemical reactions; design of homogeneous and heterogeneous reactors; biological reactions and reactors.
Prerequisite: CBE 205 with a minimum grade of C and CBE 210 with a minimum grade of C and CBE 330, may be taken concurrently and MATH 340.
Registration Information: Sections may be offered: Online.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 330 Process Simulation Credits: 3 (3-0-0)
Course Description: Analysis of chemical and biological engineering problems by numerical simulation.
Prerequisite: (CBE 210 with a minimum grade of C) and (MATH 340).
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 331 Momentum Transfer and Mechanical Separations Credits: 3 (3-0-0)
Course Description: Fluid properties; conservation equations; compressible and incompressible flow; pumping and metering; mixing; separation of fluid-solid mixtures.
Prerequisite: (CBE 210 with a minimum grade of C) and (MATH 340).
Registration Information: Credit allowed for only one of the following courses: CBE 331, CIVE 300, ENGR 342, or MECH 342.
Term Offered: Fall.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 332 Heat and Mass Transfer Fundamentals Credits: 3 (3-0-0)
Course Description: Thermal processes; steady and unsteady conduction; convective heat transfer; radiation; heat exchanger design; mass transfer by diffusion and convection.
Prerequisite: CBE 330 with a minimum grade of C and CBE 331 with a minimum grade of C.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 333 Chemical and Biological Engineering Lab I Credits: 2 (0-5-0)
Course Description: Laboratory experiments involving material balances, thermodynamics, and momentum and heat transfer. Data analysis; written and oral reports.
Prerequisite: CBE 332.
Registration Information: Credit not allowed for both CBE 333 and CBE 334. Credit not allowed for both CBE 333 and CBE 335.
Term Offered: Fall.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: Yes.

CBE 334 CBE Design and Experimentation II Credit: 1 (0-3-0)
Course Description: Connecting theory into practice with emphasis on concepts from momentum transfer and reactor design. Additional topics include teamwork, safety, experimental design, and technical communication.
Prerequisite: CBE 223 with a minimum grade of C and CBE 320, may be taken concurrently and CBE 330, may be taken concurrently and CBE 332, may be taken concurrently.
Registration Information: Credit not allowed for both CBE 333 and CBE 334.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 335 CBE Design and Experimentation III Credit: 1 (0-3-0)
Course Description: Connecting theory into practice through experimentation and design projects concentrating on heat transfer and data analysis applications. Additional topics include entrepreneurial mindset, ethics, and economic constraints in design.
Prerequisite: CBE 332, may be taken concurrently and CBE 334 with a minimum grade of C and CBE 340, may be taken concurrently.
Registration Information: Credit not allowed for both CBE 333 and CBE 335.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 340 Statistics for CBE Applications Credits: 3 (2-2-0)
Course Description: Fundamentals of statistical analysis and the principles of data science in the context of chemical and biological engineering applications.
Prerequisite: CBE 330, may be taken concurrently.
Registration Information: Must register for lecture and laboratory. Sections may be offered: Online.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 393 Professional Development Seminar Credit: 1 (0-0-1.5)
Course Description: Topics in engineering professional development, including an introduction to engineering ethics and codes of conduct, effective teams, innovation, project management, diversity, and community engagement.
Prerequisite: None.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 406 Introduction to Transport Phenomena Credits: 3 (3-0-0)
Course Description: Fundamental treatment of momentum and mass transport processes; dimensional analysis for parameter identification and order of magnitude estimation.
Prerequisite: CBE 332.
Term Offered: Fall.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 430 Process Control and Instrumentation Credits: 3 (3-0-0)
Course Description: Measurement and control of process variables; transient chemical and biological processes; feedback, feedforward, and computer control concepts.
Prerequisite: CBE 320 with a minimum grade of C and CBE 442 with a minimum grade of C.
Registration Information: Sections may be offered: Online.
Term Offered: Spring.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 440 Computational Statistics For Bioengineering Credits: 3 (2-2-0)
Also Offered As: BIOM 440.
Course Description: Application of computational methods that integrate differential equations and statistical analyses with concepts from cell biology, transport phenomena, and systems biology to analyze experimental data and infer predictive models for natural and synthetic processes in biological and biomedical engineering. Analysis of datasets arising in biological and biomedical engineering, including proteomics, optical microscopy, and RNA sequencing.
Prerequisite: (BIOM 422 and CBE 320) and (CBE 340 or STAT 315).
Registration Information: Must register for lecture and laboratory. Credit allowed for only one of the following: BIOM 440, BIOM 480A5, CBE 440, or CBE 480A5.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 442 Separation Processes Credits: 4 (4-0-0)
Course Description: Analysis of chemical and biological separations based on thermodynamics, diffusion, and convective mass transfer; design of separations equipment.
Prerequisite: CBE 332 with a minimum grade of C.
Term Offered: Fall.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 443 Chemical and Biological Engineering Lab II Credits: 2 (0-5-0)
Course Description: Laboratory experiments involving advanced chemical and biological engineering concepts. Data analysis; written and oral reports.
Prerequisite: CBE 442.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: Yes.

CBE 451 Chemical and Biological Engineering Design I Credits: 3 (2-2-0)
Course Description: Chemical and biological process synthesis and simulation; engineering economics principles.
Prerequisite: CBE 442, may be taken concurrently and CBE 320 with a minimum grade of C.
Registration Information: Must register for lecture and laboratory.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 452 Chemical and Biological Engineering Design II Credits: 3 (2-2-0)
Course Description: Projects requiring students to design a chemical and/or biological process with cost estimation and constraint analysis; written and oral reports.
Prerequisite: CBE 442 with a minimum grade of C and CBE 451 with a minimum grade of C.
Registration Information: Must register for lecture and laboratory.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 495 Independent Study Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

CBE 496 Group Study Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

CBE 500 Chem & Biological Engineering Fundamentals Credits: 4 (4-0-0)
Course Description: Fundamental chemical and biological engineering principles including kinetics, thermodynamics, and transport phenomena, with a focus on their applications in biological systems. Topics covered range from the First and Second Laws, chemical and phase equilibria, conservation laws, diffusion processes, fluid flow, to enzyme kinetics, gene expression, cellular metabolism, and network dynamics.
Prerequisite: MATH 340 and PH 142.
Restriction: Must not be a: Freshman, Sophomore.
Registration Information: Junior standing.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 501 Chemical Engineering Thermodynamics Credits: 3 (3-0-0)
Course Description: Definition, correlation, and estimation of thermodynamic properties; nonideal chemical and physical equilibria.
Prerequisite: CBE 202 and MATH 340.
Term Offered: Fall.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 502 Advanced Reactor Design Credits: 3 (3-0-0)
Course Description: Nonideal flow and tracers, reactions and diffusion, evaluation of complex kinetics, stability of reactors. Biochemical reactor examples.
Prerequisite: CBE 320 and CBE 332.
Term Offered: Fall.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 503 Transport Phenomena Fundamentals Credits: 3 (3-0-0)
Course Description: General topics in transport phenomena; analytical and numerical solutions of laminar flows; perturbation techniques; coupled transport.
Prerequisite: CBE 406.
Term Offered: Spring.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 504 Fundamentals of Biochemical Engineering Credits: 3 (3-0-0)
Also Offered As: BIOM 504.
Course Description: Application of chemical engineering principles to enzyme kinetics, fermentation and cell culture, product purification, and bioprocess design.
Prerequisite: CBE 205.
Restriction: Must not be a: Freshman, Sophomore, Junior.
Registration Information: Senior standing. Sections may be offered: Online. Credit not allowed for both BIOM 504 and CBE 504.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 505 Biochemical Engineering Laboratory Credit: 1 (0-3-0)
Course Description: Fermentation technology, bioprocess control, and protein purification.
Prerequisite: CBE 504, may be taken concurrently.
Term Offered: Fall (odd years).
Grade Mode: Traditional.
Special Course Fee: Yes.

CBE 514 Polymer Science and Engineering Credits: 3 (3-0-0)
Course Description: Fundamentals of polymer science: synthesis, characterization, processing of polymers. Physical properties of polymers; rheology of melts and solutions.
Prerequisite: (CHEM 343 or CHEM 346) and (CBE 310 or CHEM 474).
Term Offered: Spring.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 521 Mathematical Modeling for Chemical Engineers Credits: 3 (3-0-0)
Course Description: Application of mathematical models to analysis and design of chemical reactors and separation processes.
Prerequisite: MATH 340.
Term Offered: Fall.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 522 Bioseparation Processes Credits: 3 (3-0-0)
Also Offered As: BIOM 522.
Course Description: Analysis of processes to recover and purify fermentation products.
Prerequisite: CBE 331.
Registration Information: Sections may be offered: Online. Credit allowed for only one of the following: BIOM 522, CBE 522, or CBE 581A2.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 524 Bioremediation Credit: 1 (1-0-0)
Course Description: Use of biotechnology for site remediation. Biodegradation, bioreactor design, and in situ bioremediation.
Prerequisite: CBE 540 or CIVE 540.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 540 Advanced Biological Wastewater Processing Credits: 3 (3-0-0)
Also Offered As: CIVE 540.
Course Description: Fundamentals of environmental biotechnology: environmental microbiology, microbial kinetics, basic reactor design, wastewater treatment.
Prerequisite: CBE 320 or CIVE 339 or CIVE 438.
Registration Information: Sections may be offered: Online. Credit not allowed for both CBE 540 and CIVE 540.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 543 Membranes for Biotechnology and Biomedicine Credits: 3 (3-0-0)
Course Description: Polymeric membrane formation, modification, module design and applications to bioseparation and biomedical separations and tissue engineering.
Prerequisite: CHEM 343 and CBE 310.
Registration Information: Sections may be offered: Online. Credit not allowed for both BIOM 543 and CBE 543.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 560 Engineering of Protein Expression Systems Credits: 3 (3-0-0)
Course Description: Application of engineering principles to the design, optimization, and manufacturing of engineered microbial strains and mammalian cell lines for the production of recombinant proteins.
Prerequisite: CBE 205.
Registration Information: Sections may be offered: Online. Credit not allowed for both CBE 560 and CBE 581A1.
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 570 Biomolecular Engineering/Synthetic Biology Credits: 3 (3-0-0)
Course Description: Rational design and evolutionary methods for engineering functional protein and nucleic acid systems.
Prerequisite: (BC 351) and (CHEM 341 or CHEM 345).
Term Offered: Spring.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 613 Advanced Transport Phenomena Credits: 3 (3-0-0)
Course Description: Fundamental studies of multicomponent mass, energy, and momentum transport, with applications in advanced materials, biomedical and biochemical systems.
Prerequisite: (MATH 530) and (ATS 601 or CIVE 502 or CBE 503).
Restriction: Must be a: Graduate, Professional.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 621 Advanced Process Control Credits: 3 (3-0-0)
Course Description: Application of modern control theory to chemical processes. Computer control aspects emphasized.
Prerequisite: CBE 430.
Restriction: Must be a: Graduate, Professional.
Grade Modes: S/U within Student Option, Trad within Student Option.
Special Course Fee: No.

CBE 660 System and Parameter Identification Credits: 3 (3-0-0)
Course Description: Principles and methods for selecting the most appropriate equations, and properties within those equations, to mathematically simulate physical phenomena.
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Registration Information: Graduate standing.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 687 Internship Credits: Var[1-10] (0-0-0)
Course Description: Supervised work at an approved organization with periodic faculty evaluation.
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Registration Information: Written consent of instructor.
Terms Offered: Fall, Spring, Summer.
Grade Mode: S/U Sat/Unsat Only.
Special Course Fee: No.

CBE 693 Research Conduct and Practices Credit: 1 (0-0-1)
Course Description: Introduction to research, the graduate degree process, and the graduate chemical engineering program, including responsible conduct in research, developing research questions, keeping research notebooks, and laboratory safety.
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Term Offered: Fall.
Grade Mode: S/U Sat/Unsat Only.
Special Course Fee: No.

CBE 695 Independent Study Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

CBE 699 Thesis Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

CBE 707 Advanced Topics in Biochemical Engineering Credit: 1 (1-0-0)
Course Description: Advanced biochemical engineering topics.
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Term Offered: Fall.
Grade Mode: Traditional.
Special Course Fee: No.

CBE 793 Seminar Credit: 1 (0-0-1)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring.
Grade Mode: S/U Sat/Unsat Only.
Special Course Fee: No.

CBE 795 Independent Study Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.

CBE 799 Dissertation Credits: Var[1-18] (0-0-0)
Course Description:
Prerequisite: None.
Restriction: Must be a: Graduate, Professional.
Terms Offered: Fall, Spring, Summer.
Grade Mode: Instructor Option.
Special Course Fee: No.