Bachelor of Science in Chemical Engineering

Program Description

The Chemical and Biological Engineering Program offers an in-depth undergraduate curriculum that draws from the fundamentals of biology, chemistry, mathematics, and physics to encompass technologies and industries where chemical processing is utilized in any form. To explore the many opportunities available as a chemical or biological engineer, students may choose a track which provides depth in specific areas, e.g., biological engineering, process engineering, or Honors Research.

Chemical engineering coursework focuses on how materials are produced and processed both in the laboratory and large industrial-scale facilities. Courses such as fluid mechanics, heat and mass transfer, thermodynamics, reaction kinetics, and chemical process control are at the heart of the chemical engineering curriculum at Mines. The undergraduate program is exemplified by intensive integration of computer-aided simulation and process modeling and by our foundational, six-week intensive unit operations laboratory sequence offered in the summer; here, the fundamentals of heat, mass, and momentum transfer and applied thermodynamics are reviewed in a practical, applications-oriented setting. Our facilities are among the best in the nation; students can study polymer properties, measure reaction kinetics, characterize transport phenomena, and study chemical unit operations.

Students with baccalaureate Chemical Engineering degrees (BS) from Mines can find employment in many diverse fields, including advanced materials synthesis and processing, product and process research and development, food and pharmaceutical processing and synthesis, biochemical and biomedical materials and products, microelectronics manufacturing, petroleum and petrochemical processing, and process and product design.

Program Educational Objectives

In addition to contributing toward achieving the educational objectives described in the Mines Graduate Profile, the Chemical and Biological Engineering Department at Mines has established three program-wide educational objectives for all of its graduates. Within three to five years of completing their degree, our graduates will:

- Be in graduate school or in the workforce utilizing their education in chemical engineering fundamentals
- Be applying their knowledge of, and skills in, engineering fundamentals in conventional areas of chemical engineering and in contemporary and growing fields
- Have demonstrated both their commitment to continuing to develop personally and professional and an appreciation for the ethical and social responsibilities associated with being an engineer and a world citizen.

Student Learning Outcomes

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

ABET Accreditation Status

The Bachelor of Science in Chemical Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria and Program Criteria for Chemical, Biochemical, Biomolecular Engineering.

Please visit our webpage for contact points and more information on the degree program, including details on how to apply for the Honors Research track at https://chemeng.mines.edu/.

Primary Contact

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Curriculum

The Chemical Engineering curriculum is structured according to the goals outlined above. Accordingly, the programs of study are organized to include three semesters of science and general engineering fundamentals followed by five semesters of chemical engineering fundamentals and applications.

A. Chemical Engineering Fundamentals

The following courses represent the basic knowledge component of the Chemical Engineering curriculum at Mines.

CBEN201	MATERIAL AND ENERGY BALANCES	3.0
CBEN307	FLUID MECHANICS	3.0
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER	4.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS	3.0

B. Chemical Engineering Applications

The following courses are applications-oriented courses that build on the student's basic knowledge of science and engineering fundamentals:

CBEN312	UNIT OPERATIONS LABORATORY	3.0
CBEN313	UNIT OPERATIONS LABORATORY	3.0
CBEN402	CHEMICAL ENGINEERING DESIGN	3.0

CBEN403	PROCESS DYNAMICS AND CONTROL	3.0
CBEN414	CHEMICAL PROCESS SAFETY	1.0
CBEN418	KINETICS AND REACTION ENGINEERING	3.0

Technical Electives for Chemical Engineering

C. Electives for Chemical Engineering

Chemical Engineering majors have elective credit requirements that may be fulfilled with several different courses. Technical Electives I and II are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement. CBEN electives are courses offered by the CBE department with engineering content, one of the two required classes must be at the 400-level. Lastly, one CBEN/CHGN elective is required at the 300-level or higher. Some or all of these electives may be grouped together to earn a specialty track in chemical engineering as described below.

D. Specialty Tracks in Chemical Engineering

NOTE: Below is a suggested curriculum path. Electives may be taken any time they fit into your schedule, but note that not all courses are offered all semesters. Please refer to https://chemeng.mines.edu/undergraduate-program/ for the most updated flowsheet.

Degree Requirements (Chemical Engineering)

First Year				
		lec	**lab**	**sem.hrs**
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W	SUCCESS AND WELLNESS			1.0
				32.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
EBGN321	ENGINEERING ECONOMICS			3.0
HASS215	FUTURES			3.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
ELECTIVE	CULTURE AND SOCIETY (CAs) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
TECH	TECH ELECTIVE			3.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
CBEN ELECT	CHEMICAL ENGINEERING ELECTIVE			3.0
TECH	TECH ELECTIVE			3.0

		lec	lab	sem.hrs
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN ELECT	400-LEVEL CHEMICAL ENGINEERING ELECTIVE			3.0
CHGN/CBEN ELECT	CHGN or CBEN Elective (300 or higher)*			3.0
FREE	FREE ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0

Total Semester Hrs: 133.0

TECH Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

CBEN Electives

6 hours are required with 3 hours being at the 400-level.

CBEN250	INTRODUCTION TO CHEMICAL ENGINEERING ANALYSIS AND DESIGN	3.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0
CBEN315	INTRODUCTION TO ELECTROCHEMICAL ENGINEERING	3.0
CBEN340	COOPERATIVE EDUCATION	1-3
CBEN350	HONORS UNDERGRADUATE RESEARCH	1-3
CBEN360	BIOPROCESS ENGINEERING	3.0
CBEN365	INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE	3.0
CBEN372	INTRODUCTION TO BIOENERGY	3.0
CBEN398	SPECIAL TOPICS	1-6
CBEN399	INDEPENDENT STUDY	1-6
CBEN401	PROCESS OPTIMIZATION	3.0
CBEN408	NATURAL GAS PROCESSING	3.0
CBEN409	PETROLEUM PROCESSES	3.0
CBEN415	POLYMER SCIENCE AND TECHNOLOGY	3.0
CBEN416	POLYMER ENGINEERING AND TECHNOLOGY	3.0
CBEN420	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3.0
CBEN422	CHEMICAL ENGINEERING FLOW ASSURANCE	3.0
CBEN424	COMPUTER-AIDED PROCESS SIMULATION	3.0
CBEN426	ADVANCED FUNCTIONAL POROUS MATERIALS	3.0
CBEN430	TRANSPORT PHENOMENA	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN435	INTERDISCIPLINARY MICROELECTRONICS	3.0
CBEN440	MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING	3.0
CBEN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
CBEN450	HONORS UNDERGRADUATE RESEARCH	1-3
CBEN498	SPECIAL TOPICS	1-6
CBEN499	INDEPENDENT STUDY	1-6
CBEN428	ADVANCED REACTOR DESIGN	

Degree Requirements (Biological Engineering Track)

First Year

		lec	lab	sem.hrs
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W	SUCCESS AND WELLNESS			1.0
				32.0

Sophomore

Fall		**lec**	**lab**	**sem.hrs**
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0

		lec	lab	sem.hrs
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN428	BIOCHEMISTRY			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
HASS215	FUTURES			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
CBEN360	BIOPROCESS ENGINEERING			3.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
BIO TECH ELECT	BIO TECH ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE II			3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I			4.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
BIO TECH ELECT	BIO TECH ELECTIVE			3.0
CBEN ELECT	400-LEVEL CHEMICAL ENGINEERING ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0

Total Semester Hrs: 133.0

* The CHGN/CBEN elective course may be any CBEN or CHGN course at the 300-or higher level.

Tech Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

Biological Tech Electives

Six elective credits are required.

BIOL300	QUANTITATIVE BIOLOGY I	3.0
BIOL301	QUANTITATIVE BIOLOGY II	3.0
BIOL500	CELL BIOLOGY AND BIOCHEMISTRY	4.0
BIOL510	BIOINFORMATICS	3.0
BIOL520	SYSTEMS BIOLOGY	3.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	GENETICS	3.0
CBEN331	GENETICS LABORATORY	1.0
CBEN324	INTRODUCTION TO BREWING SCIENCE	3.0
CBEN372	INTRODUCTION TO BIOENERGY	3.0
CBEN412	PHARMACOKINETICS	3.0
CBEN413	QUANTITATIVE HUMAN BIOLOGY	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN454	APPLIED BIOINFORMATICS	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CHGN409	BIOLOGICAL INORGANIC CHEMISTRY	3.0
CHGN429	BIOCHEMISTRY II	3.0
CHGN431	INTRODUCTORY BIOCHEMISTRY LABORATORY	2.0
CHGN435	PHYSICAL BIOCHEMISTRY	3.0
CHGN441	THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS	3.0
CHGN462	MICROBIOLOGY	3.0
PHGN433	BIOPHYSICS	3.0

400-Level CBEN Electives

CBEN401	PROCESS OPTIMIZATION	3.0
CBEN408	NATURAL GAS PROCESSING	3.0
CBEN409	PETROLEUM PROCESSES	3.0
CBEN415	POLYMER SCIENCE AND TECHNOLOGY	3.0
CBEN416	POLYMER ENGINEERING AND TECHNOLOGY	3.0

CBEN420	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3.0
CBEN422	CHEMICAL ENGINEERING FLOW ASSURANCE	3.0
CBEN424	COMPUTER-AIDED PROCESS SIMULATION	3.0
CBEN426	ADVANCED FUNCTIONAL POROUS MATERIALS	3.0
CBEN430	TRANSPORT PHENOMENA	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN435	INTERDISCIPLINARY MICROELECTRONICS	3.0
CBEN440	MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING	3.0
CBEN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
CBEN450	HONORS UNDERGRADUATE RESEARCH	1-3
CBEN498	SPECIAL TOPICS	1-6
CBEN499	INDEPENDENT STUDY	1-6
CBEN428	ADVANCED REACTOR DESIGN	3.0

Degree Requirements (Process Engineering Track)

First Year

		lec	lab	sem.hrs
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W	SUCCESS AND WELLNESS			1.0
				32.0

Sophomore

Fall		**lec**	**lab**	**sem.hrs**
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Spring		**lec**	**lab**	**sem.hrs**
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
HASS215	FUTURES			3.0
CBEN365	INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE			3.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
				16.0

Summer		**lec**	**lab**	**sem.hrs**
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0

		lec	lab	sem.hrs
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
PROCESS TECH	PROCESS TECH ELECTIVE			3.0
PROCESS TECH	PROCESS TECH ELECTIVE			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
PROCESS ELECT	400-LEVEL PROCESS TECH ELECTIVE			3.0
CHGN/CBEN ELECT	CHGN or CBEN Elective (300 or higher)*			3.0
FREE	FREE ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0
Total Semester Hrs: 133.0				

* The CHGN/CBEN elective course may be any CBEN or CHGN course at the 300-level or higher.

Tech Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

Process Electives

Students are required to take 9 hours of the follow courses. At least 3 hours must be a 400-level CBEN course.

CBEN372	INTRODUCTION TO BIOENERGY	3.0
CBEN401	PROCESS OPTIMIZATION	3.0
CBEN408	NATURAL GAS PROCESSING	3.0
CBEN409	PETROLEUM PROCESSES	3.0
CBEN422	CHEMICAL ENGINEERING FLOW ASSURANCE	3.0
CBEN424	COMPUTER-AIDED PROCESS SIMULATION	3.0
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
EBGN453	PROJECT MANAGEMENT	3.0
EBGN553	PROJECT MANAGEMENT	3.0
CBEN428	ADVANCED REACTOR DESIGN	3.0

Degree Requirements (Chemical Engineering Honors Research Track)

Registration into the Honors Research track will be by application only. Applications will be due in the spring semester. The track is designed to fit sophomore-level applicants, though it can also be completed by junior-level students, especially if some research work has already been completed. In addition to the 12 hours of coursework, the following three requirements must be met to earn the Honors Research track. Please see the CBE webpage for additional details.

1) Public dissemination of research work

2) Submission and acceptance of a written undergraduate thesis

3) Complete CBE degree with overall GPA greater than or equal to 3.5

First Year				
		lec	**lab**	**sem.hrs**
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W	SUCCESS AND WELLNESS			1.0
				32.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN307	FLUID MECHANICS			3.0

		lec	lab	sem.hrs
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
HASS215	FUTURES			3.0
CBEN368	INTRODUCTION TO UNDERGRADUATE RESEARCH			1.0
CBEN350	HONORS UNDERGRADUATE RESEARCH, 351, 450, or 451			2.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
CBEN351	HONORS UNDERGRADUATE RESEARCH, 350, 450, or 451			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
CBEN430	TRANSPORT PHENOMENA			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN ELECT	400- or 500-LEVEL CHEMICAL ENGINEERING ELECTIVE			3.0
TECH	TECH ELECTIVE*			3.0
FREE	FREE ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0

Total Semester Hrs: 133.0

Tech Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CBEN100 through CBEN599, inclusive

Combined Baccalaureate/Masters Degree Program

The Chemical and Biological Engineering Department offers the opportunity to begin work on a Master of Science (with or without thesis) degree while completing the requirements of the BS degree. These combined BS/MS degrees are designed to allow undergraduates engaged in research, or simply interested in furthering their studies beyond a BS degree, to apply their experience and interest to an advanced degree.

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

The requirements for the (non-thesis) MS degree consist of the four core graduate courses:

CBEN507	APPLIED MATHEMATICS IN CHEMICAL ENGINEERING	3.0
or CBEN505	NUMERICAL METHODS IN CHEMICAL ENGINEERING	
CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	ADVANCED TRANSPORT PHENOMENA	3.0
or CBEN530	TRANSPORT PHENOMENA	
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
or CBEN519	ADVANCED TOPICS IN HETEROGENEOUS CATALYSIS	

ELECT	Approved Electives	18.0
Total Semester Hrs		**30.0**

It is expected that a student would be able to complete both degrees in four and a half to five years. To take advantage of the combined program, students are encouraged to engage in research and take some graduate coursework during their senior year. The application process and requirements are identical to our normal MS degree programs. Applications may be completed online and require three letters of recommendation and a statement of purpose. For students who intend to begin the BS/MS program in fall, applications are due by July 1. The deadline is November 1 for students intending to enroll in the spring semester. Students must have a GPA greater than 3.0 to be considered for the program. Interested students are encouraged to get more information from their advisor and/or the current faculty member in charge of Graduate Affairs.

COURSES

CBEN110. FUNDAMENTALS OF BIOLOGY I. 4.0 Semester Hrs.
Equivalent with BIOL110,
(I, II) Fundamentals of Biology with Laboratory I. This course will emphasize the fundamental concepts of biology and use illustrative examples and laboratory investigations that highlight the interface of biology with engineering. The focus will be on (1) the scientific method; (2) structural, molecular, and energetic basis of cellular activities; (3) mechanisms of storage and transfer of genetic information in biological organisms; (4) a laboratory 'toolbox' that will carry them forward in their laboratory-based courses. This core course in biology will be interdisciplinary in nature and will incorporate the major themes and mission of this school - earth, energy, and the environment. Lecture Hours: 3; Lab Hours: 3; Semester Hours: 4.
Course Learning Outcomes

- Design and conduct experiments to predict and explain simple chemical and biological principles.
- Explain how the first and second laws of thermodynamics predict the interactions of molecules.
- Describe life's underlying chemical composition, including the basic features of atomic structure and bonding, the importance of water in living systems, and the general structure and function of carbohydrates, phospholipids, proteins, enzymes and nucleic acids.
- Compare & contrast cells of the three domains: Bacteria, Archaea and Eukarya Correlate the molecular composition of cells with their cell structures; explain the structure and function of eukaryotic organelles.
- Describe the physical structures of phospholipid bilayer membranes and their associated proteins in cells, and explain the various mechanisms by which small molecules interact with or traverse cell membranes to change cell behavior.
- Describe the properties and processes common to all cells, including exchange with the external environment, transport across selectivity permeable membranes, homeostasis, and the enzymatic promotion of chemical reactions
- Explain the concept that cells transform energy and recycle matter; specifically, that photosynthesis transforms light energy to chemical energy that is then accessible to all cells through cellular respiration. Diagram energetic coupling and the energetics and metabolism of cells and organisms.
- Describe how one cell becomes two. Explain the roles of cellular reproduction in living cells, including the processes and outcomes of DNA replication, mitosis and meiosis.
- Describe the structure and heritable nature of genetic material. Explain how genotype controls phenotype in simple Mendelian and non-Mendelian inheritance patterns. Use the principles of independent assortment and segregation of alleles to predict the results of genetic crosses involving two or more traits when the genes involved are linked or unlinked.
- Use the Central Dogma to explain how a gene encodes for a protein. Diagram the structure and regulation of DNA and RNA, and the information flow that results in a protein. Explain how gene expression is regulated and how this idea relates to cellular differentiation.
- Explain the biological basis of biotechnology tools and how they are used to engineer solutions to biological problems.
- Discuss basic ideas of the theory of evolution, including mutation, variation, and natural selection.
- Analyze scientific data and apply quantitative skills to biological situations.
- Compose written reflections on the ethical considerations of modern biological problems and laboratory techniques.

CBEN120. FUNDAMENTALS OF BIOLOGY II. 4.0 Semester Hrs.
Equivalent with CBEN323,
This is the continuation of Fundamentals of Biology I. Emphasis in the second semester is placed on an examination of organisms as the products of evolution and the diversity of life forms. Special attention will be given to how form fits function in animals and plants and the potential for biomimetic applications. Prerequisite: CBEN110. Fundamentals of Biology I or equivalent. 3 hours lecture; 3 hours laboratory; 4 semester hours.
Course Learning Outcomes

- Describe and explain the processes and patterns of evolution, including mutation, variation, and natural selection.
- Describe and explain the properties common within the three domains of life and the innovations that arose in evolutionary time as organisms diversified and adapted to terrestrial environments.
- Use illustrative examples from key animal and plant physiological systems to explain how form fits function in the context of homeostasis and intercellular signaling, development and reproduction, resource acquisition and transport, and to discuss biomimetic and engineering applications of these biological concepts.
- Explain and use the key principles of the scientific process to assess and design experiments.
- Evaluate the credibility of scientific information from various sources.
- Utilize instrumentation and methods for data acquisition and analysis, including tissue preparation for microscopy, dissection and tissue culture.

CBEN121. GENERAL BIOLOGY II LABORATORY. 1.0 Semester Hr.
This Course provides students with laboratory exercises that complement lectures given in CBEN303, the second semester introductory course in Biology. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues and systems) and how it functions. Co-requisite or 3 hours laboratory; 1 semester hour. Prerequisites: CBEN 120 or equivalent.

CBEN198. SPECIAL TOPICS. 0-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN199. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of “Independent Study” form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN200. COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Fundamentals of mathematical methods and computer programming as applied to the solution of chemical engineering problems. Introduction to computational methods and algorithm development and implementation. 3 hours lecture; 3 semester hours. Prerequisite: MATH112. Co-requisite: CBEN210.
Course Learning Outcomes

- Excel Basics – calculations, functions, and data plotting common in engineering problem solving, as well as formatting spreadsheets for professional presentation. Numerical solution tools including Solver are introduced.
- Data Analysis – including linear regression, the basics of non-linear optimization, statistical analysis, plotting multiple data sets, linear interpolation, and numerical integration.
- Excel Macros – Visual Basic programming in Excel as a means to customize a calculation approach and create analysis algorithms.
- Nonlinear equation systems and ordinary differential equation solution techniques in MATLAB.
- Multiple Equation Solving Tools – solving systems of equations using Excel and MATLAB to model coupled algebraic and ordinary differential equations.
- Construction of Aspen Plus process simulation models to analyze a variety of process configurations that incorporate many of the common unit operations. The simulations in this class focus on understanding mass and energy balance considerations and implications in the Aspen Plus simulation environment.

CBEN201. MATERIAL AND ENERGY BALANCES. 3.0 Semester Hrs.
Equivalent with CHEN201,
Introduction to the formulation and solution of material and energy balances on chemical processes. Establishes the engineering approach to problem solving, the relations between known and unknown process variables, and appropriate computational methods. 3 hours lecture; 3 semester hours. Prerequisite: CHGN122. Co-requisite: CBEN210, CBEN200, MATH213, MATH225.
Course Learning Outcomes

- Solve material balance problems for processes which may contain chemical reactions, multiphase equilibria, recycle streams, and/or purge streams.
- Solve simple vapor-liquid, solid-liquid, and liquid-liquid equilibrium problems using Raoult's law and/or tabular and graphical data.
- Sketch simple phase diagrams and label ideal phase boundaries.
- Solve combined mass and energy balance calculations for processes involving external heat and work in open and closed non-reacting steady-state and transient systems.
- Solve combined mass and energy balance calculations for reacting systems.
- Calculate thermal properties such as the heat of reaction using heats of formation, phase change data, and heat capacity data.
- Demonstrate a mastery of "chemical engineering vocabulary."

CBEN202. CHEMICAL PROCESS PRINCIPLES LABORATORY. 1.0 Semester Hr.
Laboratory measurements dealing with the first and second laws of thermodynamics, calculation and analysis of experimental results, professional report writing. Introduction to computer-aided process simulation. 3 hours lab; 1 semester hour. Co-requisite: CBEN210, CBEN201, MATH225, EDNS251.

CBEN210. INTRO TO THERMODYNAMICS. 3.0 Semester Hrs.
Introduction to the fundamental principles of classical engineering thermodynamics. Application of mass and energy balances to closed and open systems including systems undergoing transient processes. Entropy generation and the second law of thermodynamics for closed and open systems. Introduction to phase equilibrium and chemical reaction equilibria. Ideal solution behavior. May not also receive credit for CHGN209, MEGN261, or GEGN330. Prerequisite: CHGN121, CHGN122, MATH111. Co-requisite: MATH112, PHGN100.
Course Learning Outcomes

- Demonstrate logical and rigorous engineering problem solving ability.
- Compute thermodynamic properties (v, u , h, s) of pure fluids (tables) and ideal gases (equations of state) as functions of temperature and pressure.
- Sketch and label simple phase diagrams and draw process paths.
- Apply First and Second Law thermodynamic analysis to simple machines such as piston-cylinders devices, heat exchangers, and turbines & compressors. This includes both open and closed systems operating under steady state and transient conditions.
- Calculate heat and work terms and efficiencies for heat engines, refrigerators, and heat pumps.
- Solve coupled First and Second Law problems to assess process feasibility, second law efficiency, or lost work.
- Evaluate energy balances for reacting systems such as combustion.
- Demonstrate a comprehension of the vocabulary used in engineering thermodynamics.

CBEN250. INTRODUCTION TO CHEMICAL ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.
Introduction to chemical process industries and how analysis and design concepts guide the development of new processes and products. Use of simple mathematical models to describe the performance of common process building blocks including pumps, heat exchangers, chemical reactors, and separators. Prerequisites: Concurrent enrollment in CBEN210. 3 hours lecture; 3 semester hours.

CBEN298. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN299. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of “Independent Study” form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN299. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CBEN299. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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CBEN299. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CBEN304. ANATOMY AND PHYSIOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN404,
This course will cover the basics of human anatomy and physiology of the cardiovascular system and blood, the immune system, the respiratory system, the digestive system, the endocrine system, the urinary system and the reproductive system. We will discuss the gross and microscopic anatomy and the physiology of these major systems. Where possible, we will integrate discussions of disease processes and introduce biomedical engineering concepts and problems. Check with department for semester(s) offered. 3 hours lecture; 3 semester hours. Prerequisite: General Biology I.

CBEN305. ANATOMY AND PHYSIOLOGY LAB. 1.0 Semester Hr.
Equivalent with CBEN405,
In this course we explore the basic concepts of human anatomy and physiology using simulations of the physiology and a virtual human dissector program. These are supplemented as needed with animations, pictures and movies of cadaver dissection to provide the student with a practical experience discovering principles and structures associated with the anatomy and physiology. Co-requisite: CBEN404.

CBEN307. FLUID MECHANICS. 3.0 Semester Hrs.
This course covers theory and application of momentum transfer and fluid flow. Fundamentals of microscopic phenomena and application to macroscopic systems are addressed. Course work also includes computational fluid dynamics. 3 hours lecture; 3 semester hours. Prerequisite: MATH225, grade of C- or better in CBEN201.
Course Learning Outcomes

- Define shear stress, shear rate, and absolute viscosity and identify common classes of fluids (e.g. Newtonian, Bingham Plastic, pseudoplastic, dilatant).
- Compute hydrostatic forces including buoyancy and other forces on submerged objects.
- Write and apply macroscopic mass, energy, and momentum balances on chemical engineering flow processes and systems.
- Use the extended Bernoulli equation and macroscopic energy balance to evaluate friction losses and pressure drop and size common fluid flow equipment (e.g. pumps, piping, valves).
- Describe the concept of choking in compressible flow and estimate pressure drop for compressible pipe flow of an ideal gas under isothermal or adiabatic expansion.
- Apply the concept of drag coefficients to evaluate the drag force and settling velocity for spherical and non-spherical objects.
- Compute the pressure drop through a packed bed and estimate the minimum fluidization velocity of the bed.
- Describe the boundary layer development for flow over a flat plate including the velocity profile and boundary layer thickness and describe the phenomenon of pipe entrance length using boundary layer development.
- Use the Navier-Stokes and continuity equations to evaluate shear stress profile, velocity profile, and friction factors for simple one-dimensional flows.
- Apply finite difference techniques to numerically solve differential equations.

CBEN310. INTRODUCTION TO BIOMEDICAL ENGINEERING. 3.0 Semester Hrs.
Introduction to the field of Biomedical Engineering including biomolecular, cellular, and physiological principles, and areas of specialty including biomolecular engineering, biomaterials, biomechanics, bioinstrumentation and bioimaging. Prerequisite: CBEN110, MATH112.

CBEN311. NEUROSCIENCE. 3.0 Semester Hrs.
This course is the general overview of brain anatomy, physiology, and function. It includes perception, motor, language, behavior, and executive function. This course will review what happens with injury and abnormalities of thought. It will discuss the overview of brain development throughout one's lifespan. Prerequisite: CBEN110, CHGN121, CHGN122, PHGN100, PHGN200.

CBEN312. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.
Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. 9 hours lab; 3 semester hours. Prerequisite: CBEN201, CBEN202 OR CBEN200, CBEN307, CBEN314, CBEN357, CBEN375.
Course Learning Outcomes

- Apply concepts from fluid mechanics, heat transfer, and mass transfer to the identification, formulation, and solution of unit operations problems.
- Apply concepts from mathematics courses to model and solve unit operations problems.
- Design and conduct experiments to collect data to satisfy experimental objectives.
- Analyze experimental data to obtain parameters and correlations of engineering significance.
- Synthesize concepts from multiple topical areas to conduct experiments.
- Evaluate the quality of experimental results by comparison with accepted correlations and theories.
- Evaluate the validity of accepted correlations and theories and the assumptions therein as applied under different operating conditions.
- Interpret experimental results and trends to develop valid conclusions.
- Demonstrate effective team skills including goal-setting, consensus-building, listening, role-setting, and time management.
- Produce professional-quality written reports which present, analyze, and interpret experimental results logically and which are well organized and easy to read.
- Produce professional quality oral presentations which present, analyze, and interpret experimental results logically and which are well organized and delivered.

CBEN313. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.
Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. 9 hours lab; 3 semester hours. Prerequisite: CBEN201, CBEN202 OR CBEN200, CBEN307, CBEN314, CBEN357, CBEN375.
Course Learning Outcomes

- Design and conduct experiments to collect data to satisfy experimental objectives.

- Analyze experimental data to obtain parameters and correlations of engineering significance.
- Synthesize concepts from multiple topical areas to conduct experiments.
- Evaluate the quality of experimental results by comparison with accepted correlations and theories.
- Evaluate the validity of accepted correlations and theories and the assumptions therein as applied under different operating conditions.
- Interpret experimental results and trends to develop valid conclusions.
- Demonstrate effective team skills including goal-setting, consensus-building, listening, role-setting, and time management.
- Produce professional-quality written reports which present, analyze, and interpret experimental results logically and which are well organized and easy to read.
- Produce professional quality oral presentations which present, analyze, and interpret experimental results logically and which are well organized and delivered.

CBEN314. CHEMICAL ENGINEERING HEAT AND MASS TRANSFER. 4.0 Semester Hrs.

This course covers theory and applications of energy transfer: conduction, convection, and radiation and mass transfer: diffusion and convection. Fundamentals of microscopic phenomena and their application to macroscopic systems are addressed. Course work also includes application of relevant numerical methods to solve heat and mass transfer problems. Prerequisite: MATH225, CBEN307 with a grade of C- or better. Co-requisite: CBEN200.

Course Learning Outcomes

- Explain in your own words the three modes of heat transfer: conduction, convection, radiation; in terms of each mode's relevant driving force, proportionality constant, and area for heat transfer and for each mode describe a physical situation in which that mode dominates or contributes significantly to the overall heat transfer.
- Go through the process of solving a steady state heat transfer problem. This includes determining the relevant heat transfer mode or modes operating for a given system and set of conditions; interpreting and gathering necessary data on solid and fluid properties; evaluating conduction, convection and radiation heat transfer fluxes/resistances; and combining them in the appropriate network to determine overall heat transfer rates.
- Derive the fundamental conduction/diffusion equations for a given system from microscopic energy and component mass balances on the system.
- Identify for a given time-dependent system the appropriate transient heat conduction equations and apply them to solve for temperature profiles and heat transfer rates in 0-D, 1-D and multidimensional systems.
- Select and apply appropriate convective heat and mass transfer correlations and use them to calculate transfer coefficients. For heat transfer, this includes internal and external flows with sensible as well as latent heats (temperature and phase changes). For mass transfer, this includes film and overall mass transfer coefficients.
- Recognize the differences between diffusive and convective mass transfer including diffusion coefficients and mass transfer coefficients. Use correlations to estimate mass transfer coefficients and diffusion coefficients for specified systems and use these to calculate such macroscopic quantities as component fluxes.
- Define common dimensionless groups arising in transport problems (Reynolds, Prandtl, Schmidt, Sherwood, Raleigh, and Nusselt numbers), explain what the parameters represent physically, and relate analogous groups to one another.
- Design heat exchangers for given performance and predict performance for given heat exchanger configuration and area using the LMTD and NTU methods.
- Design separation units for given performance and predict performance given configuration.
- Evaluate and communicate in writing ways to improve heat exchanger and transport-based separation unit performance based on evaluating controlling resistance(s).

CBEN315. INTRODUCTION TO ELECTROCHEMICAL ENGINEERING. 3.0 Semester Hrs.

Introduction to the field of Electrochemical Engineering including basic electrochemical principles, electrode kinetics, ionic conduction, as applied to common devices such as fuel cells, electrolyzers, redox flow cells and batteries. 3 hours lecture; 3 semester hours. Prerequisite: CBEN210.

Course Learning Outcomes

- Describe the various principles that are important to Electrochemical engineering, including electrode kinetics and electrocatalysis, double layer capacitance, mass transfer, ionic conduction, Pourbaix diagrams and durability issues, and materials and systems limitations.
- Define the specific areas of specialty in Electrochemical engineering and explain their basic principles (Fuel Cells, Electrolyzers, Batteries, Redox Flow Batteries, Super Capacitors).

CBEN320. CELL BIOLOGY AND PHYSIOLOGY. 3.0 Semester Hrs.

Equivalent with CBEN410,

An introduction to the morphological, biochemical, and biophysical properties of cells and their significance in the life processes. Prerequisite: CBEN110, CHGN221.

CBEN321. GENETICS. 3.0 Semester Hrs.

A study of the mechanisms by which biological information is encoded, stored, and transmitted, including Mendelian genetics, molecular genetics, chromosome structure and rearrangement, cytogenetics, and population genetics. 3 hours lecture, 3 hours laboratory; 4 semester hours. Prerequisite: CBEN110, CHGN 221.

CBEN322. BIOLOGICAL PSYCHOLOGY. 3.0 Semester Hrs.

This course relates the hard sciences of the brain and neuroscience to the psychology of human behavior. It covers such topics as decision making, learning, the brain's anatomy and physiology, psychopathology, addiction, the senses, sexuality, and brainwashing. It addresses the topics covered on the psychology section of the MCAT examination. Prerequisite: CBEN110, CHGN122, PHGN200.

Course Learning Outcomes

- Identify the major brain areas and their function.
- Identify microscopic anatomy of cortical layers and columns.
- Describe action potentials, nerve impulses, and networking of brain cells.
- Identify Limbic system components and their part in emotional memory.
- Describe normal and abnormal human behavior.
- Discuss short-term versus long-term memory.
- Describe how explicit and implicit memory work and the differences.
- Describe/compare modern theories of neuroscience and psychology.

- Be able to comprehend current literature (i.e. articles/books) in neuroscience and psychology.
- Describe life span development of the brain, behavior, and social interactions.
- Describe how the brain handles emotion, aggression, and stress.
- Combine the above concepts to discuss the biological foundations of behavior.

CBEN324. INTRODUCTION TO BREWING SCIENCE. 3.0 Semester Hrs.
Introduction to the field of Brewing Science including an overview of ingredients and the brewing process, the biochemistry of brewing, commercial brewing, quality control, and the economics of the brewing industry. Students will malt grain, brew their own beer, and analyze with modern analytical equipment. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisites: CBEN110; Student must be at least 21 years of age at beginning of semester.
Course Learning Outcomes

- Name traditional beer ingredients and the role of each ingredient in the finished product
- Describe the brewing process and the purpose of each step in the brewing process
- Describe the biochemistry of malting, brewing process, fermentation, and beer aging
- Name and describe alternatives to traditional ingredients, process, and fermentation
- Design (with detailed notes) a modern brewing facility
- Describe important characteristics of beer appearance, aroma, flavor, mouthfeel, & stability
- Describe how brewing ingredients, process, and fermentation can be manipulated to affect important beer characteristics
- Formulate a recipe for a BJCP beer style and perform an economic analysis on the recipe in the system designed in 5), above
- Discuss important current topics in brewing

CBEN325. MCAT REVIEW. 3.0 Semester Hrs.
The MCAT Review course is specifically for preparation of the Medical College Admissions Test [MCAT]. It will look at test taking skills, the information required to study for the MCAT, and will go over in detail the psychology information and the critical analysis and reading skills sections of the exam as well as doing practice exams. 3 hours lecture; 3 semester hours. Prerequisite: CBEN110, PHGN200, CHGN222. Co-requisite: CBEN120.
Course Learning Outcomes

- Describe test taking skills.
- Schedule test preparation time over several months.
- Name types of subjects in the MCAT exam.
- Describe important strategies for major testing and exams.
- Use representative concepts from the basic sciences for a more in depth comprehension.
- Describe critical analysis in reading passages.
- Provide specific examples of critical analysis.
- Apply test taking skills to the actual testing format.
- Contrast and compare theories through reading analysis.

CBEN331. GENETICS LABORATORY. 1.0 Semester Hr.
This lab provides hands-on experience in designing and conducting genetic experiments while applying molecular and classical genetics principles. Students will develop and refine experimental designs, analyze results, and troubleshoot issues using both quantitative and qualitative methods. Emphasis is placed on maintaining detailed and consistent electronic lab records, ensuring reproducibility and transparency in research. Through critical analysis of primary literature, students will contextualize their work and enhance their understanding of genetic research. This lab course can only be taken concurrently with CBEN321 or with instructor approval. Prerequisites: CBEN110, CHGN221. Co-requisites: CBEN321.
Course Learning Outcomes

- Design and Implement Genetic Experiments
- Critically Evaluate Primary Genetic Literature
- Interpret and Apply Experimental Data
- Maintain Comprehensive and Consistent Laboratory Records
- Communicate Scientific Findings Effectively

CBEN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
Cooperative work/education experience involving employment of a chemical engineering nature in an internship spanning at least one academic semester. Prerequisite: none. 1 to 3 semester hours. Repeatable to a maximum of 6 hours.

CBEN350. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Scholarly research of an independent nature. Prerequisite: Junior standing. 1 to 3 semester hours.

CBEN351. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Scholarly research of an independent nature. Prerequisite: junior standing. 1 to 3 semester hours.

CBEN357. CHEMICAL ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.
Introduction to non-ideal behavior in thermodynamic systems and their applications. Phase and reaction equilibria are emphasized. Relevant aspects of computer-aided process simulation are incorporated. 3 hours lecture; 3 semester hours. Prerequisite: CBEN210 (or equivalent), MATH225, grade of C- or better in CBEN201.
Course Learning Outcomes

- Find the relationship between any thermodynamic property (e.g. U, H, S, A, G) and measurable properties (e.g. T, P, V, heat capacity).
- Apply simple equations of state (e.g. ideal gas law, virial equation, Soave-Redlich-Kwong equation, Peng-Robinson equation) to calculate properties (e.g. enthalpy, entropy) of pure fluids using residual properties.
- Calculate differences among ideal gas, ideal solution, and non-ideal solution properties of mixture fluids at low and high pressure.#Calculate the fugacity of components in a mixture, residual properties, and properties of mixing such as volume, enthalpy, and entropy changes.
- Calculate equilibrium constants and the maximum extent of reaction for a single reaction or multiple reaction systems.
- Combine thermodynamic concepts to analyze complex problems (e.g. flow of a dew point gas through a turboexpander, chemical reaction of components in a multi-phase equilibrium system).

- Apply the first and second laws to analyze power and refrigeration cycles.
- Analyze a set of phase equilibrium measurements to obtain activity coefficient parameters.
- Draw and label process paths on standard thermodynamic diagrams.
- Calculate the equilibrium distribution of components in each phase of a binary mixture with up to three phases using either activity coefficients or an equation of state.

CBEN358. CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY. 1.0 Semester Hr.
This course includes hands-on laboratory measurements of physical data from experiments based on the principles of chemical engineering thermodynamics. Methods and concepts explored include calculation and analysis of physical properties, phase equilibria, and reaction equilibria and the application of these concepts in chemical engineering. 3 hours lab; 1 semester hour. Prerequisite: CBEN200 and CBEN210 or CHGN209.
Course Learning Outcomes

- Simulate four basic unit operations (and combination thereof) in chemical engineering: 1) a valve, 2) a heat exchanger, 3) a compressor/expander, and 4) a flash separator.
- Evaluate the design of these unit operations using simple thermodynamic relations such as 1) ideal gas, 2) residual properties, and 3) PH and HS charts.
- Build and solve a variety of process simulation models that focus on understanding the thermodynamic considerations and implications in the simulation environment.
- Given basic laboratory measurement objectives, a description of the lab apparatus used to obtain the data value, and a resulting data set from the experiment, fully analyze the data set and use it to determine associated thermodynamic parameters. The wet labs may include, as part of the evaluation, building the system into a process simulation model as a means to validate lab results or test the validity of thermodynamic models.
- Given a set of measured data, fully analyze the data set and use it to determine associated thermodynamic parameters. Effectively use spreadsheets to analyze experimental data and report simulation results.

CBEN360. BIOPROCESS ENGINEERING. 3.0 Semester Hrs.
The analysis and design of microbial reactions and biochemical unit operations, including processes used in conjunction with bioreactors, are investigated in this course. Industrial enzyme technologies are developed and explored. A strong focus is given to the basic processes for producing fermentation products and biofuels. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction are presented. Computer-aided process simulation is incorporated. 3 hours lecture; 3 semester hours. Prerequisites: CHGN428, CBEN201, CBEN358.
Course Learning Outcomes

- Describe the growth and decay manipulation of yeast and bacteria, and know what basic cell types are used in / found in various “bioprocess” applications.
- Describe kinetic mechanisms of cell growth and decay, and where appropriate write mathematical models describing the growth processes.
- Draw chemical structures of biological molecules including fats, lipids, amino acids, and proteins.
- Define enzyme and describe mechanistic models for enzyme function; demonstrate a comprehension of Michaelis-Menten and Quasi Steady-State Kinetics by working applied quantitative problems, including aspects of enzyme inhibition. Describe industrial uses of enzyme technologies.
- Summarize and apply the basics of a wide range of “bioprocess” principles such as those of metabolism, biochemical conversion, thermochemical conversion, and direct chemical conversion.
- Describe the basic processes for producing biofuels, fermentation products, and bio-pharmaceuticals by drawing representative process flow diagrams listing the required unit operations.
- Interview successfully for a job in the biochemical process industries by conversing intelligently with the interviewer about technical aspects of biological sciences and biochemical engineering.
- Collect and analyze data for biological processes such as extraction, enzyme kinetics, and aeration.

CBEN365. INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE. 3.0 Semester Hrs.
Builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving approached in an integrated teamwork environment, and initial technical content specific to the Chemical Engineering degree program to solve a range of chemical process engineering problems. Technical content necessary for process analysis and design activity is presented. This course emphasizes steady-state design in areas such as fuels, food sciences, chemicals, and pharmaceuticals, wherein creative and critical thinking skills are necessary. Projects may involve computer-based optimization to obtain a solution. 3 hours lecture; 3 semester hours. Prerequisite: EDNS151 or EDNS155, CBEN 200, CBEN201.
Course Learning Outcomes

- Apply creative and critical thinking skills to chemical engineering projects with an emphasis on process/system designs and data analysis, demonstrated via classroom activities and presentations and through content presented in design reports.
- Analyze design alternatives for a chemical system, identifying best options based on socio-technical-economic design criteria as well as core engineering design criteria, with evidence that supports an optimal design approach, validated using comparative assessment tools (e.g., software tools and design heuristics).
- Actively contribute to design teams, demonstrating commitment to solving open-ended problems through appropriate application of course content/material and incorporating a range of resource management strategies.
- Prepare communication material (presentations and reports) that clearly support engineering design by communicating the technical, economic, and social feasibility of an engineering strategy.

CBEN368. INTRODUCTION TO UNDERGRADUATE RESEARCH. 1.0 Semester Hr.
Introduction to Undergraduate Research. This course introduces research methods and provides a survey of the various fields in which CBE faculty conduct research. Topics such as how to conduct literature searches, critically reading and analyzing research articles, ethics, lab safety, and how to write papers are addressed. Prerequisite: None.

CBEN372. INTRODUCTION TO BIOENERGY. 3.0 Semester Hrs.
In this course the student will gain an understanding about using biological sources and processes for energy uses, both electricity and fuels. There is an emphasis on using chemical engineering principles and tools to aid in the analysis of these bioenergy systems. Specific

technologies will be addressed that have historical use and future potential, such as biochemical conversion routes to biofuels (chemical vs. enzymatic hydrolysis followed by fermentation), gasification followed by Fischer-Tropsch synthesis, application of anaerobic digestion, and others. Since products are to be used as energy carriers there will an emphasis on the energy efficiency of transformations and comparing the efficiencies of competing transformation pathways. Prerequisite: CBEN201, CBEN210.
Course Learning Outcomes

- Summarize & discuss the science, engineering, and business fundamentals associated with the bioenergy & biofuels industries
- Analyze the bioenergy industry applying science & engineering fundamentals to feedstocks, conversion technologies, & potential biorefinery configurations
- Specifically apply chemical engineering techniques & process simulation software to analyze bioenergy and biofuel processes

CBEN375. CHEMICAL ENGINEERING SEPARATIONS. 3.0 Semester Hrs.
This course covers fundamentals of stage-wise and diffusional mass transport with applications to chemical engineering systems and processes. Relevant aspects of computer-aided process simulation and computational methods are incorporated. 3 hours lecture; 3 semester hours. Prerequisite: grade of C- or better in CBEN357.
Course Learning Outcomes

- Determine two methods to specify phase equilibria. Given a binary system and any two of the four variables T, P, x1 and y1 show how to calculate the other two.
- Define and compute flash calculations of dew points, bubble points, intermediate conditions, flow rates, compositions, temperatures and pressures for both adiabatic and isothermal cases, using both hand calculations and ASPEN calculations.
- Determine the number of equilibrium stages and perform conceptual designs for the binary distillation, absorption, stripping and dilute extraction processes using the McCabe-Thiele method.
- Design a multicomponent distillation column using short-cut methods for determining the reflux, number of stages, and feed stage locations.
- Design a multicomponent distillation column using short-cut methods for determining the reflux, number of stages, and feed stage locations, and model this in Aspen.
- Calculate extraction design parameters such as the number of equilibrium stages, minimum ratio of solvent to feed, discharge conditions and flow rates.
- Explain the differences between diffusive and convective mass transfer. Know the differences between DAB and kc and apply each to the appropriate situation. Use correlations to calculate kc for a given physical situation and calculate component fluxes.
- Calculate and use overall transfer coefficients for interphase mass transfer. Apply the film theory and resistance in series models.
- Apply (or calculate) overall capacity coefficients, kca, in the design of packed towers.
- Design a packed column using the HTU-NTU and HETP approaches.
- Design and diagram a membrane separation process.
- Explain how molecular adsorption works and describe pressure-swing adsorption.
- Graphically represent phase behavior of two and three component vapor-liquid and liquid-liquid equilibria.

CBEN398. SPECIAL TOPICS. 0-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN398. SPECIAL TOPICS. 1-6 Semester Hr.

CBEN398. SPECIAL TOPICS. 1-6 Semester Hr.

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CBEN398. SPECIAL TOPICS. 1-6 Semester Hr.

CBEN399. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of “Independent Study” form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN399. INDEPENDENT STUDY. 1-6 Semester Hr.

CBEN401. PROCESS OPTIMIZATION. 3.0 Semester Hrs.
This course introduces skills and knowledge required to develop conceptual designs of new processes and tools to analyze troubleshoot, and optimize existing processes. Prerequisite: CBEN201, CBEN314, CBEN307, CBEN357, CBEN375, CBEN402.

CBEN402. CHEMICAL ENGINEERING DESIGN. 3.0 Semester Hrs.
This course covers simulation, synthesis, analysis, evaluation, as well as costing and economic evaluation of chemical processes. Computer-aided process simulation to plant and process design is applied. Prerequisite: CBEN307, CBEN 314, CBEN357, CBEN375. Co-requisite: CBEN358, CBEN418.
Course Learning Outcomes

- Apply process design principles and heuristics to complete a conceptual design for the production of a specified chemical or biochemical product.
- Develop both detailed and integrated designs for selected portions of a given conceptual process design using the Aspen Plus process simulator program.
- Identify and analyze process improvements using Aspen Plus and/or other heuristics presented in class and the design textbook.
- Use heuristics, successive approximations, and engineering judgment to design chemical process equipment and evaluate the design and/or rating results.
- Apply principles of industrial health, safety, and HAZOP analysis to chemical processes.
- Apply principles of engineering economics to analyze process economics.
- Apply appropriate tools and skills (e.g. computer software, teaming, oral and written communications, etc.) to complete a process design project.

CBEN403. PROCESS DYNAMICS AND CONTROL. 3.0 Semester Hrs.
Mathematical modeling and analysis of transient systems. Applications of control theory to response of dynamic chemical engineering systems and processes. 3 hours lecture; 3 semester hours. Prerequisites: CBEN201, CBEN307, MATH225. Co-requisites: CBEN314, CBEN375.
Course Learning Outcomes

- Describe the fundamentals of modern process control systems including the needs and incentives for process control, the hardware

elements involved in a control system and the importance of digital computers in present and future applications of process control.
- Derive process models involving unsteady heat and mass balances.
- Linearize differential equations using Taylor series expansions.
- Find the solution to systems of linear differential equations using Laplace transforms.
- Define the transfer function for a system with one input and one output.
- Describe the dynamics of first, second and higher order systems by computing system response to inputs like step changes.
- Describe the concept of a feedback controller, perform stability analysis on a feedback system and quantitatively describe the dynamic behavior of a feedback control system by using block diagram algebra.
- Write the control law expression for the control signal to the output device for a general Proportional Integral Derivative (PID) controller.#Understand the advantages and disadvantages of using different configurations (i.e. P, PI and PID).
- Design simple one input, one output, feedback control loops.
- Demonstrate a conceptual understanding of feed forward control, cascade control and ratio control#by sketching input-output diagrams for each.

CBEN408. NATURAL GAS PROCESSING. 3.0 Semester Hrs.
Application of chemical engineering principles to the processing of natural gas. Emphasis on using thermodynamics and mass transfer operations to analyze existing plants. Relevant aspects of computer-aided process simulation. Prerequisite: CHGN221, CBEN314, CBEN375.

CBEN409. PETROLEUM PROCESSES. 3.0 Semester Hrs.
Application of chemical engineering principles to petroleum refining. Thermodynamics and reaction engineering of complex hydro carbon systems. Relevant aspects of computer-aided process simulation for complex mixtures. 3 hours lecture; 3 semester hours. Prerequisite: CHGN221, CBEN375.

CBEN411. NEUROSCIENCE, MEMORY, AND LEARNING. 3.0 Semester Hrs.
Equivalent with CBEN511,
This course relates the hard sciences of the brain and neuroscience to memory encoding and current learning theories. 3 hours lecture, 3 semester hours. Prerequisites: CBEN110, CBEN120, CHGN221, CHGN222, PHGN100, PHGN200.

CBEN412. PHARMACOKINETICS. 3.0 Semester Hrs.
This course introduces the concepts of pharmacokinetics and biopharmaceuticals. It will discuss the delivery systems for pharmaceuticals and how they change with disease states. It will cover the modeling of drug delivery, absorption, excretion, and accumulation. The course will cover the different modeling systems for drug delivery and transport. 3 hours lecture; 3 semester hours. Prerequisite: CBEN110, CBEN120, CHGN121, CHGN122.

CBEN413. QUANTITATIVE HUMAN BIOLOGY. 3.0 Semester Hrs.
This course examines the bioelectric implications of the brain, heart, and muscles from a biomedical engineering view point. The course covers human brain, heart, and muscle anatomy as well as the devices currently in use to overcome abnormalities in function. Prerequisite: CBEN 110, CBEN 120.
Course Learning Outcomes

- 1) Describe the mechanisms that make a membrane excitable.
- 2) Order the steps in the production and maintenance of a membrane potential
- 3) Name and define fundamental aspects of brain, heart, and muscle anatomy.
- 4) Describe important roles of the electric components in the brain, heart, and muscle
- 5) Using current monitoring devices, illustrate & compare brain, heart, and muscle recordings.
- 6) Describe critical pathophysiology of the bioelectric systems.
- 7) Provide specific examples of current bioelectrical devices and what they do.
- 8) Describe critical advances in bioelectrical engineering.
- 9) Relate the imaging modalities for the brain and heart as a process of imaging function.
- 10) Describe homeostasis of the bioelectrical pathways by medical intervention.
- 11) Describe how the organs store energy and change the chemical energy into electrical

CBEN414. CHEMICAL PROCESS SAFETY. 1.0 Semester Hr.
This course considers all aspects of chemical process safety and loss prevention. Students are trained for the identification of potential hazards and hazardous conditions associated with the processes and equipment involved in the chemical process industries, and methods of predicting the possible severity of these hazards and presenting, controlling or mitigating them. Quantitative engineering analysis training delivered by each of the CHEN core courses is applied: applications of mass and energy balances, fluid mechanics of liquid, gas, and two-phase flows, heat transfer, the conservation of energy, mass transfer, diffusion and dispersion under highly variable conditions, reaction kinetics, process control, and statistical analysis. 1 hour lecture; 1 semester hour. Prerequisite: CBEN375. Corequisite: CBEN418.
Course Learning Outcomes

- Students will understand the professional and ethical elements of an outstanding safety program.
- Students will be familiar with government agencies, regulatory bodies, codes, and standards that govern the global, societal, and environmental impact of plant design projects.
- Students will understand how unsound science or unethical behavior had a negative impact on society.
- Students will be able to perform quantitative engineering analysis based upon the applications of mass and energy balance, fluid mechanics of liquid, gas, and two-phase flows, heat transfer and the conservation of energy, mass transfer, diffusion and dispersion under highly variable conditions, reaction kinetics, process control, and statistics.
- Students will be able to work effectively in teams and develop problem solving skills. Each team will prepare and present a professional project report.

CBEN415. POLYMER SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHGN430,MLGN530,
Chemistry and thermodynamics of polymers and polymer solutions. Reaction engineering of polymerization. Characterization techniques based on solution properties. Materials science of polymers in varying physical states. Processing operations for polymeric materials and use in

separations. 3 hours lecture; 3 semester hours. Prerequisite: CHGN222 Co-requisite: CBEN357.

CBEN416. POLYMER ENGINEERING AND TECHNOLOGY. 3.0 Semester Hrs.

Polymer fluid mechanics, polymer rheological response, and polymer shape forming. Definition and measure ment of material properties. Interrelationships between response functions and correlation of data and material response. Theoretical approaches for prediction of polymer properties. Processing operations for polymeric materials; melt and flow instabilities. Prerequisite: CBEN307, MATH225. 3 hours lecture; 3 semester hours.

CBEN418. KINETICS AND REACTION ENGINEERING. 0-3 Semester Hr.

This course emphasizes applications of the fundamentals of thermodynamics, physical chemistry, organic chemistry, and material and energy balances to the engineering of reactive processes. Key topics include reactor design, acquisition and analysis of rate data, and heterogeneous catalysis. Computational methods as related to reactor and reaction modeling are incorporated. Prerequisite: CBEN314, CBEN357, MATH225, CHGN221. Co-requisite: CHGN351.

Course Learning Outcomes

- Calculate equilibrium concentrations of reactants and products for single and multiple reactions.#Estimate the effects of temperature, pressure, and initial concentrations on reaction equilibria.
- Quantitatively describe reaction rates in commonly used forms such as power law and rational expressions.
- Apply material balances to derive and use design equations for ideal, isothermal, isobaric reactors (e.g. batch, CSTR, PFR).
- Employ analytical and numerical methods for solving single or coupled differential equations that arise from reactor material balances.
- Analyze and interpret laboratory rate data by determining rate expressions from experimental measurements.
- Conduct laboratory experiments to obtain rate data and generate engineering reports on the findings.
- Apply coupled mass and energy balances to design non-isothermal reactors and apply fluid mechanics principles to design non-isobaric reactors.
- Specify the mechanism, rate expressions, and models needed for heterogeneous reactor systems.
- Be able to solve reactor engineering problems in the presence of both internal and external transport limitations and understand and apply the concepts of Damkohler number, Thiele modulus, and effectiveness factor.

CBEN420. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Engineering applications of data analytics and numerical methods, including numerical integration/differentiation, systems of algebraic equations, linear algebra, and ordinary/partial differential equations. Practical implementation in modern programming languages and computational environments discussed. Emphasis on chemical engineering problems that cannot be solved by analytical methods. 3 hours lecture; 3 semester hours. Prerequisite: MATH225, CHGN209 or CBEN210, CBEN307, CBEN357.

CBEN421. SYNTHETIC BIOLOGY. 3.0 Semester Hrs.

Equivalent with CHEN421,EBGN321,EBGN421,

Synthetic biology is at the forefront of a technological revolution that has the potential to transform industries and improve lives. This course will give you a holistic understanding of how synthetic biology is used to engineer organisms for specific purposes, the ethical considerations involved, and the future possibilities that this field holds. We'll cover everything from foundational concepts to cutting-edge technologies, ensuring you have a solid grasp of both the science and its applications. This course is structured to give you a comprehensive understanding of synthetic biology. We'll explore key concepts such as gene editing, synthetic gene networks, and the ethical implications of creating artificial life. Whether you're interested in research, industry applications, or just fascinated by the possibilities, this course will provide the tools you need to succeed. Prerequisites: CBEN321, CHGN428 or graduate status.

Course Learning Outcomes

- Analyze and Critique Synthetic Biology Techniques: Students will be able to critically analyze various advanced technologies in synthetic biology, including DNA synthesis, sequencing technologies, and CRISPR-Cas systems. They will evaluate the strengths, limitations, and potential ethical implications of these technologies in real-world applications.
- Design Synthetic Biological Systems: Utilize knowledge of synthetic promoters, genome design, and assembly tools to design innovative synthetic biological systems for applications in medicine, agriculture, and industry. This includes developing synthetic minimal cells, designing RNA-based sensors, and engineering cell-based therapies.
- Develop Synthetic Genomes: Apply principles of synthetic genomics to create synthetic genomes, employing emerging tools for genome design and assembly. Students will understand the process from conceptualization to the practical challenges of constructing synthetic genomes, including ethical considerations.
- Implement Computational Tools in Synthetic Biology: Leverage computational tools and mathematical models to design and analyze synthetic genetic circuits. Students will demonstrate the ability to use computational tools for gene optimization and the design of higher-order information processing systems in synthetic biology.
- Innovate in Protein Engineering: Apply advanced strategies in protein engineering to innovate and improve protein function for specific applications. This includes using computer-aided design and understanding current trends and future perspectives in protein engineering within synthetic biology.
- Synthesize and Apply Xeno Nucleic Acids (XNAs): Demonstrate the ability to understand the structural diversity of XNAs and their applications. Students will engage in the de novo design and synthesis of biomolecules, expanding the genetic code alphabet for novel biotechnological applications.
- Ethically Evaluate Synthetic Biology Applications: Conduct structured ethical analyses of the implications of synthetic biology research and development. Students will discuss and evaluate the respect, well-being, autonomy, and fairness of synthetic biology applications, integrating these considerations into their project designs and research proposals.

CBEN422. CHEMICAL ENGINEERING FLOW ASSURANCE. 3.0 Semester Hrs.

Chemical Engineering Flow Assurance will include the principles of the application of thermodynamics and mesocopic and microscopic tools that can be applied to the production of oil field fluids, including mitigation strategies for solids, including gas hydrates, waxes, and asphaltenes. 3 hours lecture; 3 semester hours. Prerequisite: CBEN357.

Course Learning Outcomes

- 1. Demonstrate an understanding of the chemistry and physical properties of oil field production fluids and solids.
- 2. Demonstrate an understanding of the thermodynamics of oil field fluids and solids, including gas hydrates, waxes, and asphaltenes phase equilibria.
- 3. Be able to apply phase equlibrium models to predict the phase equilibria behavior of complex fluids, as well as gas solubility in water/oil systems.
- 4. Demonstrate an understanding of the macroscopic, mesoscopic, and microscopic tools that can be applied to study oil field processing methods, including the control of hydrates, waxes, asphaltenes, scale.
- 5. Demonstrate an understanding of the appropriate chemical treatments and compatibility of the treatment processes for flow assurance.
- 6. Demonstrate an understanding of the key physical chemistry concepts of flow assurance.
- 7. Demonstrate an understanding of the key concepts of industrial gas transportation and storage.

CBEN424. COMPUTER-AIDED PROCESS SIMULATION. 3.0 Semester Hrs.
Advanced concepts in computer-aided process simulation are covered. Topics include optimization, heat exchanger networks, data regression analysis, and separations systems. Use of industry-standard process simulation software (Aspen Plus) is stressed. 3 hours lecture; 3 semester hours. Prerequisite: CBEN314, CBEN357, and CBEN375. Co-requisite: CBEN402 and CBEN418.
Course Learning Outcomes

- Modeling Unit Operations
- Modeling Processes Including Recycle Loops
- Process Optimization

CBEN426. ADVANCED FUNCTIONAL POROUS MATERIALS. 3.0 Semester Hrs.
Nanomaterials synthesis, hierarchically ordered porous materials, functional applications, catalysis, separations, adsorption Prerequisite: CHGN122. Co-requisite: CHGN351.
Course Learning Outcomes

CBEN428. ADVANCED REACTOR DESIGN. 3.0 Semester Hrs.
For traditional industrial chemical processes, the design, optimization and operation of conventional chemical reactors are extremely well developed, drawing upon the principles of chemistry, physics, calculus and economics. CBEN 428/528 course features a survey of conventional and emerging non-conventional reactors to prepare students for career paths in applied academic or industrial research and development environments. Building on these fundamentals, strategies for each reactor's scale-up is addressed, connecting first principles to practical laboratory and reactor simulation approaches to target the information required to deploy the technology. Co-requisites: CBEN418.
Course Learning Outcomes

- Categorize idealized reactor archetypes, their flow patterns, design equations, rate expression forms and non-ideal behaviors
- Identify heterogeneous catalyst limitations and their influence on observable chemical kinetics
- Understand and differentiate among chemical kinetics, transport phenomena, thermodynamics and fluid contacting patterns as four distinct controlling factors within chemical reactors
- Quantitatively apply chemical engineering principles, data analysis and mathematical models to identify and determine performance-controlling phenomena for ideal and non-ideal reactors
- Analyze the geometry, transport limitations, fluid contacting patterns, heat management options, and design and scale-up methodologies for over 16 conventional industrial and non-conventional (e.g., renewably powered) reactors
- Apply the reaction engineering methodologies of #2–5 to critically assess experimental data reported in research literature and patents
- Effectively and concisely communicate engineering assumptions, problem-solving methods, inquiries, findings and resources used

CBEN430. TRANSPORT PHENOMENA. 3.0 Semester Hrs.
This course covers theory and applications of momentum, energy, and mass transfer based on microscopic control volumes. Analytical and numerical solution methods are employed in this course. 3 hours lecture; 3 semester hours. Prerequisite: CBEN307, CBEN314, CBEN357, CBEN375, MATH225.
Course Learning Outcomes

- Write Newton's law of viscosity, Fourier's law of heat conduction, and Fick's law of diffusion. Define flux, gradient, averages, and velocity averages (i.e., bulk quantities).
- Derive microscopic shell balances for the conservation of mass, momentum, energy, and chemical species, including energy sources and chemical reaction. Describe the similarities between conservation equations for momentum, energy and chemical species.
- Apply the generalized equations of change for mass, energy and momentum transport in rectangular, cylindrical and spherical coordinates to describe transport problems.
- Derive boundary conditions for physical problems involving transport of momentum, energy or chemical species. Distinguish between processes that occur at the interface and those that occur within the bulk fluid or material.
- Choose and justify simplifying assumptions to facilitate the solution of a problem describing a physical process. State restrictions that will apply to the solution due to simplifying assumptions.
- Solve limited cases of mass, momentum or energy transport, including unsteady-state that require solutions by ordinary differential equations, separation of variables, and similarity transforms.
- Describe boundary layer development in flow past a flat plate for transport of momentum, and heat or chemical species.
- Describe moving reference frames. Interrelate various forms of Fick's law based on mass or molar average velocity and stationary reference frames.
- Define common dimensionless groups arising in transport problems (Reynolds, Prandtl, Schmidt, Sherwood, and Nusselt numbers) and relate analogous groups.

CBEN431. IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS. 3.0 Semester Hrs.
This course introduces the basic concepts of immunology and their applications in engineering and science. We will discuss the molecular, biochemical and cellular aspects of the immune system including structure and function of the innate and acquired immune systems. Building on this, we will discuss the immune response to infectious agents and the material science of introduced implants and materials such as heart valves, artificial joints, organ transplants and lenses. We will also discuss the role of the immune system in cancer, allergies,

immune deficiencies, vaccination and other applications such as immunoassay and flow cytometry. Prerequisite: CBEN110.

CBEN432. TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS. 3.0 Semester Hrs.

The goal of this course is to develop and analyze models of biological transport and reaction processes. We will apply the principles of mass, momentum, and energy conservation to describe mechanisms of physiology and pathology. We will explore the applications of transport phenomena in the design of drug delivery systems, engineered tissues, and biomedical diagnostics with an emphasis on the barriers to molecular transport in cardiovascular disease and cancer. Prerequisite: CBEN307.

CBEN435. INTERDISCIPLINARY MICROELECTRONICS. 0-3 Semester Hr.

Equivalent with MLGN535,PHGN435,PHGN535,

(II) Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, CBEN, MTGN, or EGGN. Due to lab, space the enrollment is limited to 20 students. 1.5 hours lecture, 4 hours lab; 3 semester hours.

CBEN440. MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Applications of statistical and quantum mechanics to understanding and prediction of equilibrium and transport properties and processes. Relations between microscopic properties of materials and systems to macroscopic behavior. 3 hours lecture; 3 semester hours. Prerequisite: CBEN307, CBEN314, CBEN357, CBEN375, CHGN351 and CHGN353, CHGN221 and CHGN222, MATH225.

CBEN450. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN451. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN454. APPLIED BIOINFORMATICS. 3.0 Semester Hrs.

In this course we will discuss the concepts and tools of bioinformatics. The molecular biology of genomics and proteomics will be presented and the techniques for collecting, storing, retrieving and processing such data will be discussed. Topics include analyzing DNA, RNA and protein sequences, gene recognition, gene expression, protein structure prediction, modeling evolution, utilizing BLAST and other online tools for the exploration of genome, proteome and other available databases. In parallel, there will be an introduction to the PERL programming language. Practical applications to biological research and disease will be presented and students given opportunities to use the tools discussed. 3 hour lecture; 3 semester hours. Prerequisites: General Biology [BIOL110].

CBEN455. INTERNATIONAL GENETIC ENGINEERED MACHINE SEMINAR. 1.0 Semester Hr.

iGEM allows for a hands-on experience in the emerging frontier of synthetic biology and genetic engineering while promoting an entrepreneurial spirit as students engage in teams with all aspects of the engineering design process. CBEN455 is a 1-credit hour seminar course that supports the Mines iGEM students in this process through discussions of previous iGEM projects, initial brainstorming of project ideas, discussion of experimental design, training in lab safety and standard molecular biology protocols and team dynamics. The design process starts with stakeholder engagement, and student identification of a problem they wish to solve using synthetic biology. A team will go through the design build test cycle multiple times in preparation for a culminating public presentation at an international symposium. Projects cover frontiers of science and engineering, such as new biochemical production, new materials, environmental projects (e.g., promoting enzymatic degradation of PET plastics), analysis, and health innovations.

Course Learning Outcomes

- Analysis of previous iGEM projects
- Design new iGEM team projects based off literature reviews
- Employ molecular biology lab techniques to answer experimental questions.
- Create a positive team environment that promotes iGEM project success

CBEN460. BIOCHEMICAL PROCESS ENGINEERING. 3.0 Semester Hrs.

The analysis and design of microbial reactions and biochemical unit operations, including processes used in conjunction with bioreactors, are investigated in this course. Industrial enzyme technologies are developed and explored. A strong focus is given to the basic processes for producing fermentation products and biofuels. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction are presented. 3 hours lecture; 3 semester hours Prerequisite: CBEN201, CBEN358, CHGN428.

CBEN461. BIOCHEMICAL PROCESS ENGINEERING LABORATORY. 1.0 Semester Hr.

This course emphasizes bio-based product preparation, laboratory measurement, and calculation and analysis of bioprocesses including fermentation and bio-solids separations and their application to biochemical engineering. Computer-aided process simulation is incorporated. Prerequisites: CBEN375, CHGN428, CHGN462. Co-requisite: CBEN460, 3 hours laboratory, 1 semester hour.

CBEN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with MEGN469,MTGN469,

Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials-science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 hours lecture; 3 semester hours. Prerequisite: MEGN261 or CBEN357.

CBEN470. INTRODUCTION TO MICROFLUIDICS. 3.0 Semester Hrs.

This course introduces the basic principles and applications of microfluidic systems. Concepts related to microscale fluid mechanics, transport, physics, and biology are presented. To gain familiarity with small-scale systems, students are provided with the opportunity to design, fabricate, and test a simple microfluidic device. Prerequisites: CBEN307 or MEGN351. 3 hours lecture; 3 semester hours.

CBEN472. INTRODUCTION TO ENERGY TECHNOLOGIES. 3.0 Semester Hrs.

In this course the student will gain an understanding about energy technologies including how they work, how they are quantitatively evaluated, what they cost, and what is their benefit or impact on the natural environment. There will be discussions about proposed energy systems and how they might become a part of the existing infrastructure. However, to truly understand the impact of proposed energy systems, the student must also have a grasp on the infrastructure of existing energy systems. 3 lecture hours, 3 credit hours. Prerequisite: CBEN357 Chemical Engineering Thermodynamics (or equivalent).

CBEN480. NATURAL GAS HYDRATES. 3.0 Semester Hrs.
The purpose of this class is to learn about clathrate hydrates, using two of the instructor's books, (1) Clathrate Hydrates of Natural Gases, Third Edition (2008) co-authored by C.A.Koh, and (2) Hydrate Engineering, (2000). Using a basis of these books, and accompanying programs, we have abundant resources to act as professionals who are always learning. 3 hours lecture; 3 semester hours.

CBEN497. SPECIAL SUMMER COURSE. 0-15 Semester Hr.

CBEN498. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN498. SPECIAL TOPICS. 1-6 Semester Hr.

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CBEN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: none, submission of “Independent Study” form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN499. INDEPENDENT STUDY. 1-6 Semester Hr.

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