CHEMICAL & BIOCHEMICAL ENGINEERING

Emphasis area at bachelor of science level in biochemical engineering

Chemical engineering is the branch of engineering which deals with changing the composition, energy content and state of aggregation of materials. As a chemical engineering student, you will consider the fundamental properties and nature of matter (chemistry), the forces that act on matter (physics) and the precise expressions of the relationships between them (mathematics). Extensive use is made of computers in the application of these sciences to engineering problems.

As a chemical engineer, you may study ways in which pure water can be obtained from the sea; design processes to produce fertilizers, rubber, fibers, and fuels; or team up with other engineers and scientists to develop specialized polymeric materials for use in artificial arms, legs and other human organs. You may be instrumental in finding supplemental food sources for man, such as protein from petroleum, wood, or the sea. You might help develop new processes for the application of biochemistry, energy conservation, or environmental control, such as reducing undesirable substances in the air. Or, you might have a hand in the creation of strong lightweight materials to be used in aircraft construction. Your opportunities will be unlimited.

At Missouri S&T, you will have laboratories available which offer training in qualitative and quantitative analysis, basic organic and physical chemistry, physics, unit operations, biochemical engineering, design and automatic process control.

Your studies will give you a broad technical basis with an emphasis on material balances, energy balances, separation processes, rate processes, unit operations, process economics, safety, and design.

Among its facilities, the department features digital data acquisition and control equipment for research and instruction which allows simultaneous utilization of the system by several people. A full complement of hardware exists for input and output of signals to and from process equipment and instrumentation. The campus computer network makes available a wide variety of professional software. Also included is equipment to measure thermodynamic and physical properties, study biochemical engineering processes, polymers, surface phenomena, fluid mechanics, membranes, chemical kinetics and diffusion.

Mission Statement

The chemical and biochemical engineering department:

1. Prepares chemical engineers for successful careers of leadership and innovators in chemical engineering and related fields;
2. Expands the knowledge base of chemical engineering through its scholarly pursuits;
3. Develops technology to serve societal needs; and
4. Benefits the public welfare through service to chemical engineering and related professions.

BSChE Program Educational Objectives:

Within five years of graduation, our students will become successful in their chosen career path by:

1. Making a positive impact as an individual contributor or leader in their industry, business, and community;
2. Working collaboratively to improve the economic and societal environment of their industry sector and community; and
3. Expanding career skills through life-long learning.

Program Student Outcomes

Upon graduation, our students will exhibit the following:

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 judgements, which must consider the impact of engineering solutions on 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

Bachelor of Science Chemical Engineering

The chemical engineering program at Missouri S&T is characterized by its focus on the scientific basics of engineering and its innovative application through attention to problems and needs of the public. The necessary interrelations among the various topics, the engineering disciplines, and the other professions as they naturally come together in the solution of real world problems are emphasized as research, analysis, synthesis, and design are presented and discussed through classroom and laboratory instruction.

For the bachelor of science degree in chemical engineering a minimum of 128 credit hours is required. These requirements are in addition to credit received for algebra, trigonometry and basic ROTC courses. An average of at least two grade points per credit hour must be attained. At least two grade points per credit hour must also be attained in all courses taken in chemical engineering.

Each student's program of study must contain a minimum of 21 credit hours of course work in general education and must be chosen according to the following rules:

1. All students are required to take one American history course, one economics course, one humanities course, and ENGLISH 1120. The history course is to be selected from HISTORY 1200, HISTORY 1300, HISTORY 1310, or POL SCI 1200. The economics course may be either ECON 1100 or ECON 1200. The humanities course must be selected and meets the requirements as specified under "Engineering

Degree Requirements" published in the current undergraduate catalog.

2. Depth requirement. Three credit hours must be taken in humanities or social sciences at the 1000 level or above and must be selected from the approved list. This course must have as a prerequisite one of the humanities or social sciences courses already taken. Foreign language courses numbered 1180 will be considered to satisfy this requirement. Students may receive humanities credit for foreign language courses in their native tongue only if the course is at the 3000 level or above. All courses taken to satisfy the depth requirement must be taken after graduating from high school.
3. The remaining two courses are to be chosen and meets the requirements as specified under "Engineering Degree Requirements" published in the current undergraduate catalog and may include one communications course in addition to ENGLISH 1120.
4. Any specific departmental requirements in the general studies area must be satisfied and meets the requirements as specified under "Engineering Degree Requirements" published in the current undergraduate catalog.
5. Special topics and special problems and honors seminars are allowed only by petition to and approval by the student's department chairman.

Freshman Year

First Semester	Credits	Second Semester	Credits
FR ENG 1100	1	MECH ENG 1720	3
CHEM 1310	4	CHEM 1320	3
CHEM 1319	1	COMP SCI 1500	3
ENGLISH 1120	3	OR	
HISTORY 1200, or 1300, or 1310, or POL SCI 1200	3	COMP SCI 1972 & COMP SCI 1982	
MATH 1214 or 1211[7]	4	MATH 1215[7]	4
CHEM 1100	1	PHYSICS 1135	4
	17		**17**

Sophomore Year

First Semester	Credits	Second Semester	Credits
CHEM ENG 2100[1]	4	CHEM ENG 2110[1]	3
CHEM 2210	3	Science Elective[5]	4
MATH 2222	4	MATH 3304	3
PHYSICS 2135	4	STAT 3113	3
		Humanities and Social Sciences Elective[4]	3
	15		**16**

Junior Year

First Semester	Credits	Second Semester	Credits
CHEM ENG 3101	4	CHEM ENG 3131	3
CHEM ENG 3111	3	CHEM ENG 3141	3
CHEM ENG 3120[1]	3	CHEM ENG 3150	3
ECON 1100 or 1200	3	SP&M S 1185	3
Upper level Humanities or Social Science Elective[4]	3	ENGLISH 3560	3
	16		**15**

Senior Year[3]

First Semester	Credits	Second Semester	Credits
CHEM ENG 4091	3	CHEM ENG 4097[2]	3
CHEM ENG 4101[2]	3	CHEM ENG 4130[2]	3
CHEM ENG 4110	3	CHEM ENG 4311	1
CHEM ENG 4241	3	CHEM ENG 5XXX-Chem Eng Elective[6]	3
CHEM ENG 5XXX-Chem Eng Elective[6]	3	Chem Eng 5xxx --Chem Eng Elective[6]	3
CHEM ENG 4301	1	Chem Eng 5xxx --Chem Eng Elective[6]	3
	16		**16**

Total Credits: 128

Note: The minimum number of hours required for a degree in chemical engineering is 128.

A cumulative grade point average of 2.50 or better and a “C” or better in CHEM 1310, CHEM 1319, CHEM 1320, MATH 1214, MATH 1215 and PHYSICS 1135 are required to be admitted into the chemical engineering major. MATH 1208 or MATH 1210 and MATH 1211 may be substituted for MATH 1214. MATH 1221 may be substituted for MATH 1215.

1 A grade of "C" or better is required in CHEM ENG 2100 & CHEM ENG 2110 in order to enroll in Chem Eng 3120 .

2 Communications emphasized course (See bachelor of science degree, general education communications requirement).

3 Chemical engineering majors are encouraged to take the fundamentals of engineering exam prior to graduation. It is the first step toward becoming a registered professional engineer.

4 Must meet the requirements as specified under "Engineering Degree Requirements" published in the current undergraduate catalog. The prerequisites for the upper level course must be completed with a passing grade.

5 CHEM 2510, or CHEM 4610 and CHEM 4619, or BIO SCI 2213 and BIO SCI 2219, or CHEM 2220 and CHEM 2219, or Bio Sci 3313 and Bio Sci 3319, or CHEM 3420 and CHEM 3459.

6 A minimum of 12 cr. hr. from any Chem Eng 5xxx or Chem Eng 4540 and any class from the approved list published on the Chemical Engineering web site but only 3 cr. hr. of CHEM ENG 4000, CHEM ENG 4099 or Chem Eng 4099H. Students may have no more than three hours from approved out-of-department electives.

7 MATH 1208 or MATH 1210 and MATH 1211 may be substituted for MATH 1214. MATH 1221 may be substituted for MATH 1215.

Chemical Engineering Biochemical Engineering Emphasis

Freshman Year

First Semester	Credits	Second Semester	Credits
FR ENG 1100	1	MECH ENG 1720	3
CHEM 1310	4	COMP SCI 1500	3
CHEM 1319	1	OR	
ENGLISH 1120	3	COMP SCI 1972 & COMP SCI 1982	
HISTORY 1200, or 1300, or 1310, or POL SCI 1200	3	CHEM 1320	3
MATH 1214 or 1211[6]	4	MATH 1215[6]	4
CHEM 1100	1	PHYSICS 1135	4
	17		**17**

Sophomore Year

First Semester	Credits	Second Semester	Credits
CHEM ENG 2100[1]	4	CHEM ENG 2110[1]	3
CHEM 2210	3	STAT 3113	3
MATH 2222	4	Science Elective[5]	4

PHYSICS 2135	4	MATH 3304	3
		ECON 1100 or 1200	3
	15		**16**

Junior Year

First Semester	Credits	Second Semester	Credits
CHEM ENG 3101	4	CHEM ENG 3131	3
CHEM ENG 3111	3	CHEM ENG 3141	3
CHEM ENG 3120[1]	3	CHEM ENG 3150	3
SP&M S 1185	3	Science Elective[5]	4
Science Elective[5]	4	ENGLISH 3560	3
	17		**16**

Senior Year[3]

First Semester	Credits	Second Semester	Credits
CHEM ENG 4091	3	CHEM ENG 4097[2]	3
CHEM ENG 4110	3	CHEM ENG 4210	3
CHEM ENG 5250	3	CHEM ENG 4220	3
CHEM ENG 4201	3	CHEM ENG 4241	3
Upper Level Humanities or Social Sciences Elective[4]	3	Humanities or Social Science Elective[4]	3
CHEM ENG 4301	1	CHEM ENG 4311	1
	16		**16**

Total Credits: 130

Note: The minimum number of hours required for a degree in chemical engineering with an emphasis in biochemical engineering is 130.

A cumulative grade point average of 2.50 or better and a "C" or better in CHEM 1310, CHEM 1319, CHEM 1320, MATH 1214, MATH 1215 and PHYSICS 1135 are required to be admitted into the chemical engineering major.

1. A grade of "C" or better is required in CHEM ENG 2100 & CHEM ENG 2110 in order to enroll in CHEM ENG 3120.
2. Communications emphasized course (See bachelor of science degree, general education communications requirement).
3. Chemical engineering majors are encouraged to take the fundamentals of engineering exam prior to graduation. It is the first step toward becoming a registered professional engineer.
4. Must meet the requirements as specified under "Engineering Degree Requirements" published in the current undergraduate catalog. The prerequisites for the upper level course must be completed with a passing grade.
5. A minimum of 12 credit hours in Science Electives are required. Select three courses from CHEM 2220 CHEM 4610, CHEM 4620, BIO SCI 2213, BIO SCI 3313, and BIO SCI 4323; and a minimum of two laboratory courses from CHEM 2229 or CHEM 2219 CHEM 4619, BIO SCI 2219, BIO SCI 3319, and BIO SCI 4329.
6. MATH 1208 or MATH 1210 and MATH 1211 may be substituted for MATH 1214. MATH 1221 may be substituted for MATH 1215.

Honors in Chemical and Biochemical Engineering

CBE requires the student to complete a three semester long project with 6 or 9 credit hours of CHEM ENG 4099H-Undergraduate Research Honors, three hours counting towards the technical elective and up to 6 towards free electives. CHEM ENG 4099H cannot be taken without a GPA of 3.5. It is necessary to start and finish with the same advisor. The report has to be validated by a committee consisting of at least the project advisor and the CBE honors program advisor. A form has to be sent to the department chair to start and another to complete the process.

Honors projects have no known solutions and in that, the successful completion of the project shows the ability of the candidates to solve problems. The three semesters make the study in-depth. And the report will contribute towards building good technical writing abilities. This report can be shown to all technical people to make a point about the lasting skills that have been achieved along with the B.S. degree.

Muthanna Hikmat Al Dahhan, Curators' Distinguished Professor
DSc Washington University

Baojun Bai, Professor and Lester R. Birbeck Chair
PHD New Mexico Institute of Mining and Technology

Anthony Convertine, Roberta and G. Robert Couch Assistant Professor
PHD University of Southern Mississippi

Daniel Forciniti, Professor
PHD North Carolina State University

Chang-Soo Kim, Professor
PHD Kyungpook National University, Korea

Xinhua Liang, Associate Professor
PHD University of Colorado-Boulder

Douglas K Ludlow, Professor
PHD Arizona State University

Christi Luks, Teaching Professor
PHD University of Tulsa

Parthasakha Neogi, Professor
PHD Carnegie Mellon University

Monday Okoronkwo, Assistant Professor
PHD University of Aberdeen

Fateme Rezaei, Associate Professor
PHD Monash University - Melbourne, Australia

Michael Stephen Schmidt, Adjunct Professor
MS University of Missouri-Rolla

Joseph D Smith, Professor and Laufer Endowed Chair in Energy
PHD Brigham Young University

Jee-Ching Wang, Associate Professor
PHD Pennsylvania State University

David J Westenberg, Professor
PHD University of California-Los Angeles

Chenglin Wu, Assistant Professor
PHD, PHD University of Texas-Austin, Missouri University of Science and Technology

Hu Yang, Department Chair, Professor, Linda and Bipin Doshi Chair
PHD University of Akron

CHEM ENG 2001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a new course.

CHEM ENG 2100 Chemical Engineering Material & Energy Balances (LEC 4.0)
The application of mathematics, physics and chemistry to industrial chemical processes. The use of equations of state, chemical reaction stoichiometry, and the conservation of mass and energy to solve chemical engineering problems. Prerequisites: A grade of "C" or better in Chem 1320 or Geology 3410 and in Math 1215 or Math 1221; preceded or accompanied by Physics 1135.

CHEM ENG 2110 Chemical Engineering Thermodynamics I (LEC 3.0)
Development and application of the laws and fundamental relationships of thermodynamics to industrial chemical processes. Emphasis is placed on the estimation of thermophysical property values for applications in chemical process engineering. Prerequisites: A grade of "C" or better in Math 2222; Preceded or accompanied by Chem Eng 2100.

CHEM ENG 3000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

CHEM ENG 3001 Special Topics (IND 0.0-6.0)
This course is designed to give the department an opportunity to test a new course.

CHEM ENG 3002 Cooperative Engineering Training (IND 0.0-6.0)
On-the-job experience gained through cooperative education with industry, with credit arranged through departmental cooperative adivsor. Grade received depends on quality of reports submitted and work supervisors evaluation.

CHEM ENG 3101 Fundamentals of Transport in Chemical and Biochemical Engineering (LEC 4.0)
This course covers the fundamentals of momentum, energy, and mass transport. Phenomenological mechanisms of molecular transport, fluid static, analysis of a fluid in motion laminar and turbulent flow are covered. The general differential equations for momentum, energy and mass transfer are presented and solved for a variety of chemical engineering problems. Prerequisites: A grade of "C" or better in Math 3304 and Chem Eng 2110.

CHEM ENG 3111 Numerical Computing in Chemical and Biochemical Engineering (LEC 3.0)
Students will add to their programming skills by exploring numerical computational techniques for solving and analyzing algebraic and calculus-based equations and systems of equations that describe chemical engineering processes. Prerequisites: A grade of "C" or better in Math 3304. Comp Sci 1500, or both Comp Sci 1570 and Comp Sci 1580, or both Comp Sci 1971 and Comp Sci 1981, or both Comp Sci 1972 and Comp Sci 1982; preceded or accompanied by Chem Eng 2100.

CHEM ENG 3120 Chemical Engineering Thermodynamics II (LEC 3.0)
Physical, chemical and reaction equilibrium. Study of the thermophysical relationships of multicomponent, multiphase equilibrium. Application of equilibrium relationships to the design and operation of chemical mixers, separators and reactors. Prerequisites: A grade of "C" or better in Chem Eng 2100 and Chem Eng 2110.

CHEM ENG 3131 Separations in Chemical and Biochemical Engineering (LEC 3.0)
Flash and column distillation. McCabe-Thiele method, plate efficiencies. Azeotropes. Batch distillation. Absorption and stripping. Washing and leaching. Prerequisites: Chem Eng 3101, Chem Eng 3111, and Chem Eng 3120.

CHEM ENG 3141 Process Operations in Chemical and Biochemical Engineering (LEC 3.0)
Design and selection of pumps, fans, compressors, valves, and ejectors. Design and selection of heat exchangers, condensers and reboilers. Design of mixing equipment, sterilizers, sedimentation vessels, centrifuges, and filtration and ultrafiltration units. Prerequisites: Chem Eng 3101 and Chem Eng 3120.

CHEM ENG 3150 Chemical Engineering Reactor Design (LEC 3.0)
The study of chemical reaction kinetics and their application to the design and operation of chemical and catalytic reactors. Prerequisites: Preceded or accompanied by both Chem Eng 3111 and Chem Eng 3101.

CHEM ENG 3200 Biochemical Separations (LEC 3.0)
The fundamentals of mass transfer are introduced and applied to various unit operations employed in the separation of chemical and biochemical compounds. Prerequisites: Chem Eng 3120. Chem Eng majors only.

CHEM ENG 3210 Introduction to Biomedical Engineering (LEC 3.0)
This course will provide an introduction to the interdisciplinary field of biomedical engineering. The molecular, cellular, physiological and engineering principles that govern the field will be covered. Applications will include biomaterials, tissue engineering, biomechanics, bioimaging, bioinstrumentation, bio-nanotechnology and artificial organs. Prerequisite: Junior standing or above. (Co-listed with Cer Eng 3110 and Bio Sci 3110).

CHEM ENG 4000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

CHEM ENG 4001 Special Topics (LEC 3.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

CHEM ENG 4091 Chemical Process Design I (LEC 3.0)
Economic analysis of a chemical process including capital requirements, operating costs, earnings, and profits. The economic balance is applied to chemical engineering operations and processes. Optimization and scheduling techniques are applied to process evaluation. Preliminary process design and use of simulation software. Prerequisites: Chem Eng 3131 and Chem Eng 3141; preceded or accompanied by Chem Eng 3150; preceded or accompanied by either English 3560 or English 1160.

CHEM ENG 4097 Chemical Process Design II (LEC 3.0)
Engineering principles involved in the design and layout of chemical process equipment. Material and energy balances, equipment selection and design, and preconstruction cost estimation are performed for a capstone design project. Communication emphasized course. Prerequisites: Chem Eng 3150 and Chem Eng 4091; preceded or accompanied by Chem Eng 4110.

CHEM ENG 4099 Undergraduate Research (IND 0.0-6.0)
Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

CHEM ENG 4101 Chemical Engineering Laboratory I (LAB 2.0 and LEC 1.0)
Experiments associated with unit operations involving fluid flow and heat transfer. Principles of data and uncertainty analysis are introduced with emphasis on model building. Communication skills are stressed. This is a communication emphasized course. Prerequisites: Stat 3113 and Chem Eng 3141; Preceded or accompanied by ChemEng 4110.

CHEM ENG 4110 Chemical Engineering Process Dynamics And Control (LEC 3.0)
Study of the dynamics of chemical processes and the instruments and software used to measure and control temperature, pressure, liquid level, flow, and composition. Generally offered fall semester only. Prerequisites: Chem Eng 3150, Chem Eng 3131 and Chem Eng 3141.

CHEM ENG 4130 Chemical Engineering Laboratory II (LAB 2.0 and LEC 1.0)
Experiments illustrating the unit operations of continuous and staged separation. Experimental design methods are extended to include the principles of regression and model building. Communication skills are stressed. This is a communication emphasized course. Prerequisites: Stat 3113, Chem Eng 3141 and Chem Eng 3131; preceded or accompanied by Chem Eng 3150 and either English 3560 or English 1160.

CHEM ENG 4140 Chemical Process Safety (LEC 3.0)
The identification and quantification of risks involved in the processing of hazardous and/or toxic materials are studied. Prerequisite: Preceded or accompanied by Chem Eng 3150.

CHEM ENG 4150 Chemical Process Flowsheeting (LAB 1.0 and LEC 2.0)
The development, implementation, and evaluation of methods for determining the mathematical model of a chemical process, ordering the equations in the mathematical model, and solving the model. Prerequisite: Math 3304 or graduate standing.

CHEM ENG 4200 Biochemical Separations Laboratory (LAB 2.0)
Introduction to the unit operations employed in the separation of chemicals and biochemicals. The experiments illustrate the staged and continuous separation systems that are involved. This is a communications emphasized course. Prerequisite: Chem Eng 3200.

CHEM ENG 4201 Biochemical Separations and Control Laboratory (LAB 2.0 and LEC 1.0)
Introduction to the unit operations employed in the separation of chemicals and biochemicals. The experiments illustrate the staged and continuous separation systems that are involved. Application of concepts of industrial process dynamics and control. Communications emphasized. Prerequisites: Stat 3113; Preceded or accompanied by Chem Eng 5250.

CHEM ENG 4210 Biochemical Reactors (LEC 3.0)
Application of chemical engineering principles to biochemical reactors. Emphasis on cells as chemical reactors, enzyme catalysis and disposable technology. Prerequisite: Chem Eng 3150 or graduate standing.

CHEM ENG 4220 Biochemical Reactor Laboratory (LAB 2.0 and LEC 1.0)
Introduction to the unit operations involved with the production of biochemicals. The experiments emphasize the isolation of proteins and enzymes from tissue and bacteria cells. This is a communications emphasized course. Prerequisites: Stat 3113; Preceded or accompanied by Chem Eng 4210.

CHEM ENG 4241 Process Safety in the Chemical and Biochemical Industries (LEC 3.0)
This course covers risk assessment, hazardous and/or toxic materials containment, environmental impact, safety regulations, and other safety issues relevant to chemical and biochemical industries. Prerequisites: Preceded or accompanied by Chem Eng 3150.

CHEM ENG 4301 Chemical Process Materials (LEC 1.0)
Seminar to highlight the classification, properties, selection, and processing of engineering materials that may include polymers, electronic materials, biomaterials, and nanomaterials. Students will research related topics for presentation and discussion. Prerequisites: Physics 1135.

CHEM ENG 4310 Interdisciplinary Problems In Manufacturing Automation (LAB 1.0 and LEC 2.0)
The course will cover material necessary to design a product and the fixtures required to manufacture the product. Participants will gain experience with CAD/CAM software while carrying out an actual manufacturing design project. (Co-listed with Mech Eng 5644, Eng Mgt 5315).

CHEM ENG 4311 Professional Practice And Ethics (LEC 1.0)
Preparation for post-graduate activities including resume writing and job searching. Professional attitudes, practice, licensure, and ethics in the chemical engineering profession. Discussions led by visiting industrialists and other invited speakers. Discussion of professional development including professional and graduate programs. Generally offered fall. Prerequisite: Senior standing.

CHEM ENG 5000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required. Prerequisite: Consent of Instructor Required.

CHEM ENG 5001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

CHEM ENG 5010 Seminar (RSD 0.0-6.0)
Discussion of current topics.

CHEM ENG 5040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/ comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

CHEM ENG 5100 Intermediate Transport Phenomena (LEC 3.0)
The similarities of flow of momentum, heat and mass transfer and the applications of these underlying principles are stressed. Course is primarily for seniors and beginning graduate students. Prerequisite: Chem Eng 3101 or graduate standing.

CHEM ENG 5110 Intermediate Chemical Reactor Design (LEC 3.0)
A study of homogeneous and heterogeneous catalyzed and noncatalyzed reaction kinetics for flow and batch chemical reactors. Application to reactor design is stressed. Prerequisite: Chem Eng 3150 or graduate standing.

CHEM ENG 5120 Interfacial Phenomena In Chemical Engineering (LEC 3.0)
The course deals with the effects of surfaces on transport phenomena and on the role of surface active agents. Topics include fundamentals of thermodynamics, momentum, heat and mass transfer at interfaces and of surfactants. Some applications are included. Prerequisite: Chem Eng 3131 or graduate standing.

CHEM ENG 5130 Risk Assessment and Reduction (LEC 3.0)
Safe, secure manufacturing facilities protect the health of employees and the public, preserve the environment, and increase profitability. Methods for systematically identifying hazards and estimating risk improve the safety performance and security of manufacturing facilities. Prerequisite: Senior or Graduate Standing. (Co-listed with Eng Mgt 4312).

CHEM ENG 5150 Intermediate Process Computing (LAB 1.0 and LEC 2.0)
Analysis of chemical processes from model development to solution. Emphasis on numerical computational techniques and tools appropriate for ordinary and partial differential equation solution. Prerequisite: Graduate standing.

CHEM ENG 5161 Intermediate Molecular Engineering (LEC 3.0)
Molecular aspects of chemical thermodynamics, transport processes, reaction dynamics, and statistical and quantum mechanics, and their treatments in molecular-based modeling and simulation approaches. Prerequisites: Chem Eng 3120 or graduate standing.

CHEM ENG 5170 Physical Property Estimation (LEC 3.0)
Study of techniques for estimating and correlating thermodynamic and transport properties of gases and liquids. Prerequisite: Chem Eng 3131 or graduate standing.

CHEM ENG 5190 Plantwide Process Control (LEC 3.0)
Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Multiloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: Chem Eng 4110 or Elec Eng 3320 or Elec Eng 3340 or graduate standing. (Co-listed with Elec Eng 5350).

CHEM ENG 5200 Biomaterials I (LEC 3.0)
This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisite: Senior undergraduate standing. (Co-listed with Bio Sci 5210, MS&E 5310).

CHEM ENG 5210 Intermediate Biochemical Reactors (LEC 3.0)
Application of chemical engineering principles to biochemical reactors. Emphasis on cells as chemical reactors, enzyme catalysis and production of monoclonal antibodies. Projects on special topics and presentations related to the course materials will be included. Prerequisite: Preceded or accompanied by Chem Eng 3150 or graduate standing.

CHEM ENG 5220 Intermediate Engineering Thermodynamics (LEC 3.0)
Review thermodynamic principles for pure fluids and mixtures. Emphasis on applications for the chemical industry and use of fundamental relations and equations of state. Prerequisite: Chem Eng 3120 or graduate standing.

CHEM ENG 5250 Isolation and Purification of Biologicals (LEC 3.0)
Isolation and purification of biologicals with emphasis on biopharmaceuticals. Principles and applications of chromatography, lyophilization, and product formulation. Use of ultrafiltration and diafiltration in the processing of protein products. Disposable technology. Prerequisites: Preceded or accompanied by Chem Eng 3131 and Chem Eng 3141.

CHEM ENG 5300 Principles Of Engineering Materials (LEC 3.0)
Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Physics 4523, Met Eng 5810, Cer Eng 5810).

CHEM ENG 5305 Hazardous Materials Management (LEC 3.0)
Major themes: hazard indentification and characterization; safety, health and environmental management; and the protection of safety, health and environment. Students will have an understanding of work place and environmental hazards in order to be able to facilitate their management and control. The course will include an intensive 30 hour hands-on workshop Prerequisite: Chem Eng 3131 or graduate standing.

CHEM ENG 5310 Structure and Properties of Polymers (LEC 3.0)
A study of the parameters affecting structure and properties of polymers. Syntheses, mechanisms, and kinetic factors are emphasized from the standpoint of structural properties. Prerequisite: Chem Eng 3131 or graduate standing.

CHEM ENG 5315 Corrosion and Its Prevention (LEC 3.0)
A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: A grade of "C" or better in either Chem Eng 2110 or Cer Eng 3230. (Co-listed with Met Eng 5310).

CHEM ENG 5320 Introduction to Nanomaterials (LEC 3.0)
Introduction to the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties,synthesis, processing, and applications of nanomaterials. Example nanomaterials include nanoparticles, nanotubes, and nanowires. Prerequisite: Chem Eng 2300, or Met Eng 1210 or Chem 1320.

CHEM ENG 5325 Carbon Capture Process Engineering (LEC 3.0)
An introduction to the process technologies and material design associated with capturing carbon in industrial operations to reduce carbon emission, reutilizing captured carbon in oil and chemical process industries, and extracting carbon from the atmosphere to mitigate green-house effect and climate change. Prerequisites: Chem Eng 3150 or graduate standing.

CHEM ENG 5330 Alternative Fuels (LEC 3.0)
Global energy outlook and available resources are discussed. Alternative energy options and their technologies are covered. Associated environmental concerns and technology are assessed. Special emphases are placed on renewable energies, transportation fuels, energy efficiencies, and clean technologies. Prerequisite: Chem Eng 3131 or graduate standing.

CHEM ENG 5340 Principles of Environmental Monitoring (LEC 3.0)
This course introduces the fundamentals of particle technology, including particle characterization, transport, sampling, and processing. In addition, students will learn about the basic design of some industrial particulate systems and environmental and safety issues related to particulate handling. Prerequisites: Chem Eng 3101 or graduate standing.

CHEM ENG 5350 Environmental Chemodynamics (LEC 3.0)
Interphase transport of chemicals and energy in the environment. Application of the process oriented aspects of chemical engineering and science to situations found in the environment. Prerequisite: Chem Eng 3131 or graduate standing.

CHEM ENG 5355 Process Control System Safety, Security and Alarms (LEC 3.0)
Lifecycle approach for industrial automation in the context of IEC 61511 (safety) and IEC 62443 (IACS cybersecurity) standards. Functional safety and cybersecurity fundamentals for risk analysis, safety/cybersecurity requirements, inherently safer/secure design techniques, SIL/SL verification, operations, real-world cybersecurity attacks, alarm management. Prerequisites: Elec Eng 3320, Elec Eng 3340, or Chem Eng 4110. (Co-listed with Elec Eng 5355).

CHEM ENG 5810 Introduction to Polymeric Materials (LEC 3.0)
A basic study of the organic chemistry of natural and synthetic high polymers, their inherent properties and their uses in plastic, fiber, rubber, resin, food, paper and soap industries. Credit may not be given for both Chem 5810 and Chem 4810. Prerequisites: Chem 1320. (Co-listed with Chem 5810 and MS&E 5810).