Rose-Hulman Institute of Technology Course Catalog

Chemical Engineering

As has been done since we awarded the nation's first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives
Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.

1. Our graduates will attain a promotion and/or responsibilities beyond their entry-level position, or progress toward the completion of an advanced degree.
2. Our graduates will continue to develop professionally.
3. Our graduates will collaborate professionally within or outside of their organizations at a regional, national and/or international level.
4. Our graduates will participate in service to their professions and/or community organizations.

Student Outcomes
Student Outcomes are statements that describe what students are expected to have by the time of graduation.

1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to identify, formulate, and solve engineering problems
3. An ability to design and conduct experiments and analyze and interpret data
4. An ability to design a system or process to meet desired needs within realistic constraints
5. An ability to function on multidisciplinary teams
6. An ability to communicate effectively in presentations and reports
7. An ability to use the techniques, skills, and modern engineering tools (particularly computer-based tools) necessary for engineering practice
8. An understanding of the professional and ethical responsibilities of a chemical engineer
9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
10. The preparation to engage in life-long learning

11. A knowledge of contemporary issues

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degrees of Master of Science in chemical engineering or Master of Chemical Engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required for the Master of Science degree, but not for the Master of Chemical Engineering degree. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET,www.abet.org

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 405 Introduction to MEMS: Fabrication and Applications
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 460 Particle Technology
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 515 Nanomaterials Science and Engineering
- CHE 540 Advanced Process Control

- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics (including biomathematics), or science courses. Students are encouraged to use their electives to focus their studies in a particular subject area.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although it is recommended that a minimum of eight credit hours be focused in one subject area, students are encouraged to focus most or all of the 20 credit hours of electives in a particular subject area. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering, toward a certificate in semiconductor materials and devices, or toward an area of concentration (see below).

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward an approved elective.

Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 320 Fundamentals of Heat and Mass Transfer
- CHE 321 Applications of Heat and Mass Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- BIO110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- BIO210 - Mendelian and Molecular Genetics
- BIO220 - Microbiology
  or
  BIO230 - Cell Biology
- BIO411 - Genetic Engineering
- BIO421 - Applied Microbiology
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary. Students interested in the Biochemical Engineering area minor should consult the CHE Department head and receive prior approval for any equivalent courses to be considered.

AREAS OF CONCENTRATION

Although it is not a requirement, students may pursue a concentration in one or more of the following areas. Students who complete the requirements of a concentration may receive, upon request, a letter from the Department Head that attests to the fact that the requirements have been completed. With proper planning, a student should be able to complete the requirements for an area of concentration without overload.

Advanced Chemical Engineering Analysis

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with prior approval by the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)
- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics
- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 450 Combustion

Industrial and Process Engineering

Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma
- MA 444 Deterministic Models in Operations Research

Engineering Management List

- EMGT524 Production/Operations Management
- EMGT527 Project Management
- EMGT562 Risk Analysis and Management
- EMGT581 Multi-objective Optimization
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Plan of Study

Freshman (A1 Schedule)

Fall

Course	Credit
CHEM 111 General Chemistry I*	4
CLSK 100 College & Life Skills	1
MA 111 Calculus I	5
RH 131 Rhetoric & Composition	4
	Total Credits: 14

Winter

Course	Credit
CHEM 113 General Chemistry II*	4
MA 112 Calculus II	5
PH 111 Physics I	4
HSS Elective	4
	Total Credits: 17

Spring

Course	Credit
CHE 110 Programming & Computation for Chemical Engineers	2
CHEM 115 General Chemistry III	4
EM 103 Introduction to Design	2
MA 113 Calculus III	5
PH 112 Physics II	4
	Total Credits: 17

Sophomore (A1 Schedule)

Fall

Course	Credit
CHE 200 Career Preparation I	0
CHE 201 Conservation Principles & Balances	4
CHEM 251 Organic Chemistry I	3
CHEM 251L Organic Chemistry I Lab	1
MA 211 Differential Equations	4
HSS Elective	4
	Total Credits: 16

Winter

Course	Credit
CHE 202 Basic Chemical Process Calculations	4
CHEM 252 Organic Chemistry II	3
CHEM 252L Organic Chemistry II Lab	1
MA 212Matrix Algebra & Systems of Differential Equations	4
HSS Elective	4
	Total Credits: 16

Spring

Course	Credit
CHE 301 Fluid Mechanics	4
CHE 303 Chemical Engineering Thermodynamics	4
Elective (Approved)	4
HSS Elective	4
	Total Credits: 16

Junior (A1 Schedule)

Fall

Course	Credit
CHE 304 Multi-Component Thermodynamics	4
CHE 320 Fundamentals of Heat and Mass Transfer	4
CHE 315 Materials Science	4
CHEM 225 Analytical Chemistry I	4
	Total Credits: 16

Winter

Course	Credit
CHE 321 Applications of Heat & Mass Transfer	4
CHEM 360 Intro Physical Chemistry	4
MA 223 Engineering Statistics I	4
RH 330 Technical and Professional Communication	4
	Total Credits: 16

Spring

Course	Credit
CHE 404 Kinetics & Reactor Design	4
CHE 411 Chemical Engineering Lab I	3
ECE 206 Elements of Electrical Engineering	4
Elective (Free)	4
	Total Credits: 15

Senior (A1 Schedule)

Fall

Course	Credit
CHE 409 Professional Practice	1
CHE 412 Chemical Engineering Lab II	4
CHE 416 Design I	4
Free Elective(Free)	4
Free Elective(CHE)	4
	Total Credits: 17

Winter

Course	Credit
CHE 413 Chemical Eng. Lab III	4
CHE 417 Design II	4
CHE 440 Process Control	4
HSS Elective	4
	Total Credits: 16

Spring

Course	Credit
CHE 418 Design III	2
HSS Elective	4
HSS Elective	4
Elective(Approved)	4
Elective(CHE)	4
	Total Credits: 18

Freshman (A2 Schedule)

Fall

Course	Credit
CHEM 111 General Chemistry I*	4
CLSK 100 College & Life Skills	1
MA 111 Calculus I	5
RH 131 Rhetoric & Composition	4
	Total Credits: 14

Winter

Course	Credit
CHEM 113 General Chemistry II*	4
MA 112 Calculus II	5
PH 111 Physics I	4
HSS Elective	4

	Total Credits: 17

Spring

Course	Credit
CHE 110 Programming & Computation for Chemical Engineers	2
CHEM 115 General Chemistry III	4
EM 103 Introduction to Design	2
MA 113 Calculus III	5
PH 112 Physics II	4
	Total Credits: 17

Sophomore (A2 Schedule)

Fall

Course	Credit
CHE 200 Career Preparation I	0
CHE 201 Conservation Principles and Balances	4
CHEM 251 Organic Chemistry I	3
CHEM 251L Organic Chemistry I Lab	1
MA 211 Differential Equations	4
HSS Elective	4
	Total Credits: 16

Winter

Course	Credit
CHE 202 Basic Chemical Process Calculations	4
CHEM 252 Organic Chemistry II	3
CHEM 252L Organic Chemistry II Lab	1
MA 212 Matrix Algebra & Systems of Differential Equations	4
HSS Elective	4
	Total Credits: 16

Spring

Course	Credit
MA 223 Engineering Statistics I	4
CHEM 225 Analytical Chemistry I	4
HSS Elective	4
CHE 315 Materials Science	4

	Total Credits: 16

Junior (A2 Schedule)

Fall

Course	Credit
CHE 301 Fluid Mechanics	4
CHE 303 Chemical Engineering Thermodynamics	4
Elective (Approved)	4
RH 330 Technical & Professional Communication	4
	Total Credits: 16

Winter

Course	Credit
CHE 304 Multi-Component Thermodynamics	4
CHE 320 Fundamentals of Heat & Mass Transfer	4
ECE 206 Elements of Electrical Engineering	4
HSS Elective	4
	Total Credits: 16

Spring

Course	Credit
CHE 321 Applications of Heat & Mass Transfer	4
CHE 411 Chemical Engineering Lab I	3
CHEM 360 Intro Physical Chemistry	4
Elective (Free)	4
	Total Credits: 15

Senior (A2 Schedule)

Fall

Course	Credit
CHE 404 Kinetics & Reactor Design	4
CHE 409 Professional Practice	1
CHE 412 Chemical Engineering Lab II	4
CHE 416 Design I	4

Free Elective(Free)	4
	Total Credits: 17

Winter

Course	Credit
CHE 413 Chemical Eng. Lab III	4
CHE 417 Design II	4
CHE 440 Process Control	4
HSS Elective	4
	Total Credits: 16

Spring

Course	Credit
CHE 418 Design III	2
HSS Elective	4
Elective(CHE)	4
Elective(CHE)	4
Elective(Approved)	4
	Total Credits: 18

NOTES

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Chemical Engineering - Course Descriptions

CHE 110 Programming & Computation for Chemical Engineers 2R-0L-2C S
Prerequisites: There are no prerequisites for this course.
Corequisites: There are no corequisites for this course.
An introduction to problem solving and structured programming concepts using spreadsheets and computational software. Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations.

CHE 200 Career Preparation I 1R-0L-0C F
Prerequisites: sophomore standing in Chemical Engineering
Corequisites: There are no corequisites for this course.
Career choices in chemical engineering. Internships and co-ops. Resume preparation. Interview skills

CHE 201 Conservation Principles and Balances 4R-0L-4C F
Prerequisites: MA 113 F,W,S*, and PH 111 F,W*, and CHEM 113 W,S concurrent registration in CHEM 112
Corequisites: There are no corequisites for this course.

An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in the analysis of non-reactive chemical engineering processes will be addressed. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W
Prerequisites: CHE 201 F, and MA 211 F,W,S
Corequisites: There are no corequisites for this course.
The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances. Applications of the principles of conservation of mass and energy to reactive and transient systems will also be addressed.

CHE 301 Fluid Mechanics 4R-0L-4C F,S
Prerequisites: CHE 201 F, and MA 211 F,W,S
Corequisites: There are no corequisites for this course.
Physical properties of fluids, fluid statics, laminar and turbulent flow. Design of pipe networks and pumps. Fluid flow as momentum transport. Flow through porous media. Non-Newtonian fluid flow. Flow past objects and boundary layer concept. Emphasis is placed on general methods of analysis applicable to any fluid.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S
Prerequisites: CHE 202 W, and MA 211 F,W,S
Corequisites: CHE 110 2R-0L-2C S
First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F,W
Prerequisites: CHE 303 F,S, and MA 212 F,W,S
Corequisites: There are no corequisites for this course.
Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Study of phase equilibria involving the use of a process simulator.

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W
Prerequisites: CHE 110 S, and MA 211 F,W,S, and MA 212 F,W,S or concurrent enrollment
Corequisites: There are no corequisites for this course.
The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, toperform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE 315 Materials Science and Engineering 4R-0L-4C F,S
Prerequisites: CHEM 115 F,W,S or consent of instructor
Corequisites: There are no corequisites for this course.

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat & Mass Transfer 4R-0L-4C F,W

Prerequisites: CHE 202 W, and CHE 301 F,S, and MA 211 F,W,S, and MA 212 F,W,S
Corequisites: CHE 304 4R-0L-4C F,W
Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat & Mass Transfer 4R-0L-4C W,S

Prerequisites: CHE 320 F,W, and CHE 304 F,W
Corequisites: There are no corequisites for this course.
Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics & Reactor Design 4R-0L-4C F,S

Prerequisites: CHEM 360 W,S, and CHE 304 F,W
Corequisites: There are no corequisites for this course.
The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication & Applications 3R-3L-4C S

Prerequisites: There are no prerequisites for this course.
Corequisites: Junior or Senior standing
Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F

Prerequisites: Senior standing in Chemical Engineering
Corequisites: There are no corequisites for this course.
Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S

Prerequisites: CHEM 115 F,W, and CHEM 225 F,S, and CHEM 252 W, and CHE 320 F,W, and MA 223 F,W,S, and RH 330 F,W,S
Corequisites: There are no corequisites for this course.

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F
Prerequisites: CHE 321 W,S, and CHE 411 S or consent of instructor
Corequisites: There are no corequisites for this course.
Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W
Prerequisites: CHE 412 F
Corequisites: There are no corequisites for this course.
Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F
Prerequisites: CHE 321 W,S
Corequisites: There are no corequisites for this course.
Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W
Prerequisites: CHE 416 F, and CHE 404 F,S
Corequisites: There are no corequisites for this course.
Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S
Prerequisites: CHE 417 W or consent of instructor
Corequisites: There are no corequisites for this course.
Completion of an open-ended design project that will include written and oral communication of intermediate results and a final written report.

CHE 419 Advanced MEMS: Modeling & Packaging 3R-3L-4C F
Prerequisites: EP 410 S or equivalent (See EP 411/511.)
Corequisites: There are no corequisites for this course.
Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor. Cross-listed with EP 411, and ECE 419.

CHE 420 Consulting Engineering Seminar 2R-0L-2C
Prerequisites: Junior class standing
Corequisites: There are no corequisites for this course.

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers. Cross-listed with CE 420, ECE 466, ME 420, and BE 400.

CHE 440 Process Control 4R-0L-4C W

Prerequisites: CHE 202 W, and MA 211 F,W,S, and MA 212 F,W,S
Corequisites: There are no corequisites for this course.
The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of sensors, transmitters and control elements, stability criteria, and frequency response. Use of control design software is emphasized.

CHE 441 Polymer Engineering 4R-0L-4C F

Prerequisites: CHE 404 F,S*, and CHEM 251 F** *or concurrent registration **or consent of instructor
Corequisites: There are no corequisites for this course.
Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 460 Particle Technology 4R-0L-4C

Prerequisites: MA 212 F,W,S, and CHE 202 W, and CHE 301 F,S
Corequisites: There are no corequisites for this course.
Introduction to the fundamentals of particle technology including particle characterization, transport, sampling, and processing. Students will learn about the basic design and scale-up of some industrial particulate systems (including fluidized beds, mixers, pneumatic conveying systems, cyclone separators, and hoppers) as well as environmental and safety issues related to particulate handling.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W

Prerequisites: EM 301 S or CHE 301 F,S
Corequisites: There are no corequisites for this course.
Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S

Prerequisites: CHE 303 F,S or CHEM 361 F or CE 205 F or ME 301 F,W or consent of instructor
Corequisites: There are no corequisites for this course.
This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C F or S

Prerequisites: CHE 303 F,S
Corequisites: There are no corequisites for this course.
Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, designs to prevent fires and explosions. Informal safety review.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F,W,S
Prerequisites: There are no prerequisites for this course.
Corequisites: There are no corequisites for this course.
Topics of current interest in chemical engineering.

CHE 499 Directed Research Variable Credit F,W,S
Prerequisites: consent of instructor
Corequisites: There are no corequisites for this course.
A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

CHE 502 Transport Phenomena 4R-0L-4C
Prerequisites: CHE 320 F,W
Corequisites: There are no corequisites for this course.
Most of the course focuses on the derivation, simplification, and solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal, laminar flows in both steady and unsteady systems will be covered. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux both in solids and in laminar flows will also be covered. Boundary layer theory will be discussed. Turbulent flow theories may also be addressed.

CHE 504 Advanced Reactor Design 4R-0L-4C W
Prerequisites: CHE 404 F,S
Corequisites: There are no corequisites for this course.
Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication & Applications 3R-3L-4C S
Prerequisites: Junior or Senior class standing
Corequisites: There are no corequisites for this course.
Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, ECE 516, EP 510, and ME 516.

CHE 512 Petrochemical Processes 4R-0L-4C W
Prerequisites: CHE 321 W,S or consent of instructor
Corequisites: There are no corequisites for this course.
Multicomponent separation of petroleum by flash vaporization. Processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas and other fossil fuels. Group projects and presentations on refinery and petrochemical processes. Material balances and economic evaluations of the processes.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C
Prerequisites: CHE 304 F,W
Corequisites: There are no corequisites for this course.
Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic

analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 515 Nanomaterials Science & Engineering 4R-0L-4C
Prerequisites: CHE 315 F,S or ME 328 W
Corequisites: There are no corequisites for this course.
Current research trends and industrial activity in the field of nanotechnology. Contains an overview of nanoscale characterization and production methods and emphasizes the roles that chemical functionality, thermodynamics, and physics play in determining the unique properties of nanoscale materials systems. Independent student reviews of current research literature form an integral part of the course.

CHE 519 Advanced MEMS: Modeling & Packaging 3R-3L-4C F
Prerequisites: EP 410 S or equivalent course
Corequisites: There are no corequisites for this course.
Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 511, ME 519, and ECE 519.

CHE 540 Advanced Process Control 4R-0L-4C
Prerequisites: CHE 440 W and consent of instructor
Corequisites: There are no corequisites for this course.
Control topics beyond those covered in CHE 440. Topics will be selected from among the following: advanced control using cascade, feed forward, nonlinear, and adaptive control; multivariable systems including RGA analysis and decoupling; a major control system design and implementation project using a modern distributed control system.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C
Prerequisites: BIO 110 F,S, and CHEM 330 F, and CHE 404 F,S or ES 201 F,S or consent of instructor
Corequisites: There are no corequisites for this course.
Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C
Prerequisites: BIO 110 F,S, and CHE 321 W,S or ES 201 W,S or consent of instructor
Corequisites: There are no corequisites for this course.
An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F,W,S
Prerequisites: There are no prerequisites for this course.
Corequisites: There are no corequisites for this course.
Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering Variable Credit F,W,S

Prerequisites: consent of instructor
Corequisites: There are no corequisites for this course.
A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F,W,S
Prerequisites: There are no prerequisites for this course.
Corequisites: There are no corequisites for this course.
Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research As assigned F,W,S
Prerequisites: There are no prerequisites for this course.
Corequisites: There are no corequisites for this course.
Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.

CHE CPT Curricular Practical Training 1R-0L-1C
Prerequisites: Consent of department head
Corequisites: There are no corequisites for this course.
Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

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