Chemical Engineering Program (CENG)

Student Affairs: 182 Engineering Building II, Warren College

AFFILIATED FACULTY

Professors

P. C. Chau, Ph.D., *MAE, Co-Director*
J.E. Crowell, Ph.D., *Chemistry*
J. A. Frangos, Ph.D., *Bioengineering*
C. H. Gibson, Ph.D., *MAE*
D. A. Gough, Ph.D., *Bioengineering*
M. Krstic, Ph.D., *MAE*
A. C. Kummel, Ph.D., *Chemistry*
J. Lasheras, Ph.D., *MAE*
P. F. Linden, Ph.D., *MAE*
J. McKittrick, Ph.D., *MAE*
D. R. Miller, Ph.D., *MAE*
B. O. Palsson, Ph.D., *Bioengineering*
C. Pozrikidis, Ph.D., *MAE*
K. Seshadri, Ph.D., *MAE*
J. B. Talbot, Ph.D., *MAE, Program Director*
F. A. Williams, Ph.D., *MAE*

Professor Emeritus

S. Middleman, Ph.D., *MAE*

Associate Professors

C.P. Caulfield, Ph.D., *MAE*
R. K. Herz, Ph.D., *MAE*

Assistant Professors

R. deCallafon, Ph.D., *MAE*
G. A. Huber, Ph.D., *Bioengineering*

Professional Research Staff

J. L. White, Ph.D., *MAE*

Program Mission and Objectives

The Chemical Engineering Program has affiliated faculty from the Department of Mechanical and Aerospace Engineering, Department of Chemistry and Biochemistry, and the Department of Bioengineering. The program is administered by the Department of Mechanical and Aerospace Engineering. The curricula at both the undergraduate and graduate levels are designed to support and foster chemical engineering as a profession that interfaces engineering and all aspects of basic sciences (physics, chemistry, and biology).

The mission of the Chemical Engineering Program is to provide the next generation of chemical engineers with an excellent and innovative chemical engineering education. The primary goals are:

- To provide chemical engineering students with a strong technical education and communication skills that will enable them to have successful careers in a wide range of industrial and professional environments.
- To prepare chemical engineering students for rapidly changing technological environments with the core knowledge central to multidisciplinary development and personal improvement throughout their professional careers.
- To instill in chemical engineering students a strong sense of humanistic values and professionalism such that they can conduct ethically and knowledgeably regarding technological impact in societal issues.

The curriculum is designed to prepare chemical engineering graduates for further education and personal development through their entire professional career. We strive to accomplish these goals by providing a rigorous and demanding curriculum that incorporates lectures, discussions, laboratory and project development experiences in basic sciences, mathematics, engineering sciences, and design as well as the humanities and social sciences. The main objectives are:

1. To enable students to understand and apply scientific principles and engineering and computational tools to analyze and solve problems of importance to society.
2. To enable students to apply appropriate experimental and statistical techniques in engineering analysis and applications.
3. To enable students to incorporate engineering economics and information from multiple disciplines in the analysis, synthesis, and design of engineering systems under realistic settings.
4. To enable students to acquire effective technical writing and oral communication skills necessary for successful participation on teams and in leadership positions.
5. To enable students to acquire the basic knowledge of chemical and process safety.
6. To instill in our students an understanding of their professional and ethical responsibilities.

Unless otherwise stated, the requirements and policies follow those of the Department of Mechanical and Aerospace Engineering. Only features unique to Chemical Engineering are provided in this section.

The Undergraduate Program

The B.S. program in Chemical Engineering is accredited by the Engineering Accreditation Commission of the Accreditation Board of Engineering and Technology (ABET/EAC). The curriculum is tailored to provide breadth and flexibility by taking advantage of the strength of basic sciences and other engineering disciplines at UCSD. The intention is to graduate chemical engineers who are multidisciplinary and can work in a broad spectrum of industries rather than solely traditional chemical and petrochemical industries.

Areas of specialization are available whereby a graduate can be in a position for a career in environmental technology, microelectronic device fabrication, materials and polymer processing, pharmaceutical and biotechnology, biomedical engineering, energy and thermal systems, control and system engineering, and so forth.

For students who aspire to pursue a graduate degree and a career in research and development, the units in an area of specialization can be allocated to more fundamental science and engineering courses. These students are also encouraged to perform independent projects in one of the faculty research laboratories or groups.

Whether the career goal is industry, or graduate or professional school, the curriculum has a strong emphasis on developing problem-solving skills and the ability to think and learn independently. The capstone courses in this respect are the two senior design courses and the two very unique senior process laboratory courses where the environment is not unlike product development in either an industrial or academic setting. In each process development lab, students work in groups of three, on one project where they carry through the entire stages of project planning, experimental design and setup, execution, analysis, modification and improvement, and final project evaluation.

Major Requirements

For policies in general education requirements, professional licensing, academic advising, and application for admission to the major, please refer to the section under Mechanical and Aerospace Engineering.

To receive a B.S. in Chemical Engineering, students must complete 194 units for graduation, which includes 44 units of general education (HSS) requirements of their Colleges and the ABET requirements in the arts, humanities, and social sciences. The balance consists of basic sciences (53 units), chemistry core (24 units), chemical engineering core (32 units), process laboratory and design (16 units), general engineering (12 units), and an area of specialization (12 units). Beyond the 53 units of basic sciences, the science and engineering courses total to 96 units. A one-unit introductory seminar (CENG1) is required of all incoming freshmen. The specific breakdown is as follows:

Basic sciences (53 units): This lower-division requirement includes 24 units of mathematics (Math. 20A-F), 14 units of physics (Phys. 2A-C, 2CL), and 15 units of chemistry (Chem. 6A-C, 6BL).

Chemistry core (24 units): This requirement must include two physical and one organic chemistry courses (Chem. 131, 132, 140A). Three additional advanced chemistry courses must be chosen among biochemistry, physical, organic, and inorganic chemistries. Two courses must be selected among Chem. 133, 135, 140B or 141B, 114A-B, 120A-B, and the third must be a laboratory course selected among Chem. 105, 106, and 143A.

Chemical engineering core (32 units): This requirement covers chemical process modeling, solution thermodynamics, transport phenomena, chemical reaction engineering, process control, and unit operations (CENG 100, 101A-C, 102, 113, 120, 122).

Process laboratory and design (16 units): This requirement is crucial to fulfill the ABET design content (CENG 124A-B, 176A-B).

General engineering (12 units): This requirement covers basics in computer programming, probability and statistics, and instrumentation. The computer programming requirement can be satisfied with a course in either Fortran (MAE 10), C (MAE 9), or Java (CSE 8B or 11). If you have no programming experience, you need CSE 8A before 8B, but no credit is given for 8A alone. Probability and statistics can be satisfied with ECE 109 or a course with equivalent content. Instrumentation is satisfied with MAE 170.

Electives in an area of specialization (12 units): Electives are intended to broaden and enhance professional goals. They may be chosen to achieve either breadth or depth in one's education. These electives must be upper-division courses in either science or engineering. Suggestions are listed below. To ensure that your selections have proper engineering content, you must have faculty approval before you take these electives.

Biotechnology/Biochemical Engineering: Both Chem. 114A-B (or BIBC 100,102) must be taken as part of the advanced chemistry requirement. These two classes are prerequisites to the following courses: BIMM 100, BIMM 120, BIBC 110, Chem. 115, BE 160A-B-C.

Electronic Materials: Chem. 133 must be taken as part of the advanced chemistry requirement. This course is a prerequisite to the following courses: ECE 103, 134, 135A, 136, 136L.

Engineering Mechanics : MAE 130A-B, 131A, 160.

Engineering Science : MAE 105, 107, 140; Chem. 135, 136; Phys. 152 (requires Chem. 133).

Environmental Engineering: Chem. 149A-B, 173; MAE 120, 121, 122, 124.

Materials Science: Chem. 133 must be taken as part of the advanced chemistry requirement. This course is a prerequisite to the following courses: Chem. 107; Phys. 152; ECE 137; MS 201A-B-C, 205A, 227.

Process Control: ECE 101, 171A-B or MAE 141A-B.

Thermal Engineering and Systems: MAE 118A-B-C, 110B, 113.

Independent Research: CENG 199 as equivalent to a senior thesis can be approved as equivalent to two elective courses (8 units). Consult department Student Affairs Office for details.

CHEMICAL ENGINEERING (ABET ACCREDITED PROGRAM)

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 21C
	Phys. 2A	Phys. 2B
Chem. 6A	Chem. 6B	Chem. 6C
MAE 9[1]	CENG 1	
HSS[2]	HSS	HSS
SOPHOMORE YEAR		
Math. 21D	Math. 20F	Math. 20E
		Phys. 2C/2CL
Chem. 131	Chem. 132	Chem. 140A[3] or Chem 141A
	CENG 100	CENG 102
HSS	HSS	HSS
JUNIOR YEAR		
CENG 103A	CENG 103B	CENG 103C
	CENG 113	
Adv. Chem.[5]	Adv. Chem.	Adv. Chem.
MAE 170		ECE 109
HSS	HSS	HSS
SENIOR YEAR		
CENG 120[4]	CENG 124A	CENG 124B
CENG 122	CENG 176A	CENG 176B
AS[6]	AS	AS
HSS	HSS[7]	HSS

[1] MAE 9 can be replaced by MAE 10, CSE 8B or 11.

[2] Humanities and social sciences (HSS).

[3] Chem. 141A is offered only in the fall quarter. Chem133, 105, or 106 may fit in the spring quarter schedule.

[4] If a student chooses process control as the area of specialization, CENG 120 can be replaced by a relevant course within the approved set of courses for specialization in process control.

[5] Two advanced chemistry electives must be selected among Chem. 133, 135, 140B or 141B, 114A-B, and 120 A-B, and the third laboratory elective must be selected among Chem. 105, 106, and 143A. Students who choose Chem 105 must take Chem 6CL.

[6] The electives in an area of specialization (AS) must be upper-division or graduate courses in engineering, natural sciences or mathematics based on the pre-approved sequences. Otherwise, the selections must receive prior approval of the department to meet ABET standards.

[7] If students do not require these additional HSS courses to meet their College requirements, they may substitute an unrestricted elective in order to meet the minimum 194 unit graduation requirement. The twelfth HSS course is intended only for students who have additional College requirements to fulfill. To meet ABET requirements, students must have a total of twenty-four units in the arts, humanities, and social sciences, not including subjects such as accounting, industrial management, finance or personnel administration.

Transfer Students

The Chemical Engineering curriculum is designed to integrate four years of college educational experience. It is not easy for transfer

students to complete the major requirements in only two additional years beyond their junior college work. However, if transfer students seek a College for which they already satisfy the general education requirements, have taken the lower-division science and mathematics, and have completed the organic chemistry requirement, then the rigorous first-year schedule below will permit them to graduate in two years. Other students should consult their adviser for a transition program compatible with their junior college preparation.

FALL	WINTER	SPRING
JUNIOR YEAR		
Chem. 131	Chem. 132	Adv. Chem.
	CENG 100	CENG 102
CENG 103A	CENG 103B	CENG 103C
MAE 170	CENG 113	ECE 109[1]

[1] Transfer students can petition with an equivalent course in probability and statistics if it is available at a junior college.

Integrated BS/MS Requirements

An integrated co-terminal program leading to a bachelor of science and a master of science degree in chemical engineering is offered to a student with junior standing who has an upper-division GPA of 3.5 or better and a 3.0 overall UCSD GPA. Details of the program are available from the MAE Graduate Student Affairs Office.

Program Accreditation

The B.S. program in chemical engineering is accredited by the Accreditation Board of Engineering and Technology (ABET/EAC).

Graduate Program

The Chemical Engineering Program offers graduate instruction leading to the **M.S. and Ph.D. degrees in engineering sciences** with a designated specialization in chemical engineering.

Admission is in accordance with the general requirements of the graduate division, which requires at least a B.S. in some branch of engineering, sciences, or mathematics; an overall GPA of 3.0; and three letters of recommendation from individuals who can attest to the academic or professional competence and to the depth of their interest in pursuing graduate study.

In addition, all applicants are required to submit GRE General Test Scores. A minimum score of 550 on the Test of English as a Foreign Language (TOEFL) is required of all international applicants whose native language is not English. Students who score below 600 on the TOEFL are strongly encouraged to enroll in an English as a second language program before beginning graduate work. UCSD Extension offers an excellent English language program during the summers as well as the academic year.

Applicants are judged competitively. Based on the candidate's background, qualifications, and goals, admission to the program is in one of three categories: M.S. only, M.S., or Ph.D. Admission to the M.S. only category is reserved for students for whom the M.S. degree is likely to be the terminal graduate degree. The M.S. designation is reserved for students currently interested in obtaining an M.S. degree but who at a later time may wish to continue in the doctoral degree program. Admission to the Ph.D. program is reserved for qualified students whose final aim is a doctoral degree.

Non-matriculated students are welcome to seek enrollment in graduate level courses via UC Extension's concurrent registration program, but an extension student's enrollment in a graduate course must be approved by the instructor.

Master's Degree Program

The M.S. program is intended to extend and broaden an undergraduate education with fundamental knowledge in different fields. The degree may be terminal, or obtained on the way to the Ph.D. The degree is offered under both the Thesis Plan I and the Comprehensive Examination Plan II.

M.S. Time Limit Policy: Full-time M.S. students are permitted seven quarters in which to complete all requirements. While there is no written time limit for part-time students, the department has the right to intervene and set individual deadlines if it becomes necessary.

Course requirements: All M.S. students must complete a total of 48 units which include a core of *five* courses (20 units) chosen among fluid dynamics (CENG 210A, MAE 210B), heat and mass transfer (CENG 221AB), kinetics (CENG 252), and mathematics. To maintain a certain balance in the core, no more than two mathematics courses should be chosen among the choices of applied mathematics (MAE 294AB or Math. 210AB), and numerical mathematics (MAE 290AB or Math. 270AB).

No more than three courses (12 units) of upper-division courses may be applied toward the total course work requirement. No more than a total of 8 units of CENG 296 and 298 may be applied toward the course work requirement. Units in seminars (CENG 259) may not be applied toward the degree requirement.

Thesis Plan I: Completion of the research thesis (CENG 299) fulfills 12 units toward the total graduation requirement. The balance is made up of the five core courses (20 units) and additional four elective courses (16 units) subject to the restrictions described above.

Comprehensive Examination Plan II: This plan involves course work only and culminates in an oral comprehensive examination based on topics selected from the core courses. In addition to the five core courses (20 units), one must choose an additional seven electives (28 units) subject to the restrictions of CENG 259, 296, and 298 described above. Sample electives are listed in the table below. A student should consult their academic adviser to choose an appropriate course schedule, including alternatives in bioengineering, electrical and computer engineering, materials science, basic sciences, and mathematics.

FALL	WINTER	SPRING
CORE SELECTIONS		
CENG 210A	CENG 221A	CENG 221B
	MAE 210B	CENG 252
MAE 290A or 294A	MAE 290B or 294B	
SUGGESTED ELECTIVES		
MS 201A	MS 201B	MS 201C
MAE 211	MAE 212	MAE 213
Math. 270A	Math. 270B	Math. 270C
Chem. 211	Chem. 212	Chem. 213

Change of Degree: Upon completion of the requirements for the M.S. degree, students admitted as M.S. *only* or M.S. candidates are not automatically eligible for admission to the Ph.D. program.

M.S. *only* and M.S. candidates who subsequently wish to pursue a doctorate must submit an application for a change in status to their examining committee. The application, if approved by the committee, must be signed by a faculty member who expects to serve as the student's Ph.D. adviser. The student must also submit a general petition for graduate students to effect the change of status. If the student elects the comprehensive examination plan for the M.S. degree, the examining committee may recommend that the comprehensive examination may replace the preliminary qualifying examination expected of Ph.D. students.

Doctoral Degree Program

The Ph.D. program is intended to prepare students for a variety of careers in research and teaching. The emphasis is on research. In general, there are no formal course requirements. All students, in consultation with their advisers, develop appropriate course programs that will prepare them for the Preliminary Qualifying Examination and for their dissertation research. These programs must be planned to meet the time limits established to advance to candidacy and to complete the requirements of the degree.

All Ph.D. students are required to pass three examinations. The first is a Preliminary Qualifying Examination which should be taken within three to four quarters of full-time graduate study. The second is the Ph.D. Qualifying Examination. The last is the Dissertation Defense.

Preliminary Qualifying Examination: The examination is intended to determine a candidate's basic understanding of engineering fundamentals and the candidate's ability to pursue successfully a research project at a level appropriate for the doctorate. The scope of the examination is based on topics selected from the core curriculum as listed under the M.S. degree program. A candidate is expected to demonstrate knowledge equivalent to these courses and formal enrollment record is not a prerequisite. The format is an oral examination administered by a committee of three faculty members in the Chemical Engineering Program. The candidate should present to the committee, prior to the examination, the five core courses that will constitute the basis of the examination.

Depth Requirement: A candidate must have the ability to perform in-depth analysis in the dissertation topic. A candidate should consult with the thesis adviser to develop a proper course program if it is deemed necessary. Depending on an individual's background and the nature of the research problem, a candidate should either complete a set of a minimum of four courses or demonstrate to the thesis adviser the equivalent knowledge and ability.

Ph.D. Qualifying Examination: Prior to taking this examination, the candidate must have completed the departmental qualifying examination, obtained a faculty research adviser, and must have made initial progress on a chosen dissertation project. At the time of application for advancement to candidacy, a doctoral committee responsible for the remainder of the student's graduate program is appointed by the Graduate Council under the policy listed in the Graduate Studies section of the General Catalog. The committee conducts the Ph.D. Qualifying Examination, during which the student must demonstrate the ability to engage in thesis research. The process involves the presentation of a plan for the thesis research project. The committee may ask questions directly or indirectly related to the project and general questions that it determines to be relevant. Upon successful completion of the examination, subject to the UCSD time limit policy, the student is advanced to candidacy and is awarded the candidate in Philosophy degree (see "Graduate Studies" section in this Catalog).

Teaching Experience: Prior to the dissertation defense, the candidate must serve at least once as a teaching assistant with the responsibility to hold a problem-solving section one hour a week.

Dissertation Defense: This is the final Ph.D. examination. Upon completion of the dissertation research project, the candidate writes a dissertation that must be successfully defended in an oral examination and public presentation conducted by the doctoral committee. A complete copy of the student's dissertation must be submitted to each member of the doctoral committee four weeks before the defense. It is understood that this copy of the dissertation given to committee members will not be the final copy, and that the committee members may request changes in the text at the time of the defense. This examination may not be conducted earlier than three quarters after the date of advancement to doctoral candidacy. Acceptance of the dissertation by the Office of Graduate Studies and Research and the University Librarian represents the final step in completion of all requirements for the Ph.D. degree.

Ph.D. Time Limit Policy: Pre-candidacy status is limited to four years. Doctoral students are eligible for university support for six years. The defense and submission of the doctoral dissertation must be within seven years.

Annual Evaluation: In the spring of each year, the faculty adviser evaluates each doctoral student's overall performance in course work, research, and prospects for financial support for future years. A written assessment is given to the student after the evaluation. If a student's work is found to be inadequate, the faculty may determine that the student cannot continue in the graduate program.

COURSES

All students enrolled in CENG courses or admitted to the CENG program (including pre-majors) are expected to meet prerequisite and performance standards, i.e., students may not enroll in any CENG courses or courses in another department which are required for the major prior to having satisfied prerequisite courses with a C– or better. (The program does not consider D or F grades as adequate preparation for subsequent material.) Additional details are given under the program outline, course descriptions, and admission procedures for the Jacobs School of Engineering in this catalog.

LOWER-DIVISION

1. The Scope of Chemical Engineering (1)
Demonstrations and discussions of basic knowledge and the opportunities in chemical engineering for professional development. Introduction to campus library and computer resources. Use of personal software tools such as spreadsheeting and student edition of MATLAB. *Prerequisites: none. (P/NP grading only.)*

UPPER-DIVISION

CENG 100. Process Modeling and Computation in Chemical Engineering (4)
(Formerly AMES 153) Introduction to elementary numerical methods with applications to chemical engineering problems using a variety of problem solving strategies. Error analysis. Concepts of mathematical modeling, material and energy balances and probability and statistics with applications to design problems. *Prerequisites: admission to the chemical engineering or bioengineering major only and grades of C– or better in MAE 9 or 10, and Chem. 6C.*

CENG 101A. Introductory Fluid Mechanics (4)
(Formerly CENG 103A) Kinematics and equation of motion; hydrostatics; Bernoulli's equation; viscous flows; turbulence, pipe flow; boundary layers and drag in external flows; applications to chemical engineering, bioengineering, and structural engineering. Students may not receive credit for both MAE 101A and CENG 103A. *Prerequisites: admission to the major and grades of C– or better in Phys. 2A and Math. 21D or 20D-E.*

CENG 101B. Heat Transfer (4)
(Formerly CENG 103C) Conduction, convection, radiation heat transfer; design of heat exchangers. Students may not receive credit for both MAE 101C and CENG 103C. *Prerequisites: admission to the major and a grade of C– or better in CENG 103A-B.*

CENG 101C. Mass Transfer (4)
(Formerly CENG 103B) Diffusive and convective mass transfer in solids, liquids, and gases; steady and unsteady state; mass transfer coefficients; applications to chemical engineering and bioengineering. *Prerequisites: admission to the major and grade of C– or better in CENG 103A.*

CENG 102. Chemical Engineering Thermodynamics (4)
(Formerly AMES 111) Thermodynamic behavior of pure substances and mixtures. Properties of solutions, phase equilibria. Thermodynamic cycles. Chemical equilibria for homogeneous and heterogeneous systems. *Prerequisites: grade of C– or better in CENG 100 and Chem. 131*. Enrollment restricted to chemical engineering premajors and majors only.

CENG 113. Chemical Reaction Engineering (4)
(Formerly AMES 113A-B) Principles of chemical reactor analysis and design. Experimental determination of rate equations, design of batch and continuous reactors, optimization of selectivity in multiple reactions, consideration of thermal effects and residence time distribution. Introduction to multi-phase reactors. *Prerequisites: grade of C– or better in CENG 100 and Chem. 6B*. (Chem. 132 may be taken concurrently)

CENG 120. Chemical Process Dynamics and Control (4)
(Formerly AMES 140) Examination of dynamic linear and linearized models of chemical processes. Stability analysis. Design of PID controllers. Selection of control and manipulated variables. Root locus, Bode and Nyquist plots. Cascade, feed- forward and ratio controls. *Prerequisites: admission to the major and grades of C– or better in Math. 21D or Math. 20D.* (Students may not receive credit for both MAE 141A and CENG 120).

CENG 122. Separation Processes (4)
(Formerly AMES 112) Principles of analysis and design of systems for separation of components from a mixture. Topics will include staged operations (distillation, liquid-liquid extraction), and continuous operations (gas absorption, membrane separation) under equilibrium and nonequilibrium conditions. *Prerequisites: admission to the major and grades of C– or better in CENG 102 and CENG 103 or CENG 101C.*

CENG 124A. Chemical Plant and Process Design I (4)
(Formerly AMES 114A: Principles of chemical process design and economics. Process flow diagrams and cost estimation. Computer-aided design and analysis. Representation of the structure of complex, interconnected chemical processes with recycle streams. Ethics and professionalism. Health, safety, and the environmental issues. *Prerequisites: admission to chemical engineering major and grades of C– or better in CENG 122.*

CENG 124B Chemical Plant and Process Design II (4)
(Formerly AMES 114B: Engineering and economic analysis of integrated chemical processes, equipment, and systems. Cost estimation, heat and mass transfer equipment design and costs. Comprehensive integrated plant design. Optimal design. Profitability. *Prerequisites: admission to chemical engineering major and grade of C– or better in CENG 124A.*

CENG 176A. Chemical Engineering Process Laboratory I
(Formerly AMES 176A) Laboratory projects in the areas of applied chemical research and unit operations. Emphasis on applications of engineering concepts and fundamentals to solution of practical and research problems. *Prerequisites: admission to the major and grades of C– or better in CENG 122 and MAE 170.*

CENG 176B. Chemical Engineering Process Laboratory II
(Formerly AMES 176B) Training in planning research projects, execution of experimental work and articulation (both oral and written) of the research plan and results in the areas of applied chemical technology and engineering operations related to mass, momentum, and heat transfer. *Prerequisites: admission to the major and grade of C– or better in CENG 176A.*

CENG 199. Independent Study for Undergraduates (4-4)
Independent reading or research on a problem by special arrangement with a faculty member. *Prerequisite: consent of instructor.* (P/NP Only).

CHEMICAL ENGINEERING GRADUATE COURSES

CENG 205. Graduate Seminar in Chemical Engineering (1)
Each graduate student in CENG is expected to attend one seminar per quarter, of his or her choice, dealing with current topics in chemical engineering. Topics will vary. *Prerequisites: none.*

CENG 210A. Fluid Mechanics I (4)
Basic conservation laws, flow kinematics. The Navier-Stokes equations and some of its exact solutions, nondimensional parameters and different flow regimes, vorticity dynamics. Cross-listed with MAE 210A. *Prerequisites: MAE 101AB and MAE 110A or consent of instructor.*

CENG 221A Heat Transfer (4)
Conduction, convection, and radiation heat transfer development of energy conservation equations. Analytical and numerical solutions to heat transport problems. Specific topics and applications vary. Cross-listed with MAE 221A. *Prerequisites: MAE 101ABC or CENG 103ABC or consent of instructor.*

CENG 221B Mass Transfer (4)
Fundamentals of diffusive and convective mass transfer and mass transfer with chemical reaction. Development of mass conservation equations. Analytical and numerical solutions to mass transport problems. Specific topics and applications will vary. Cross-listed with MAE 221B. *Prerequisites: MAE 101ABC or CENG 103ABC or consent of instructor.*

CENG 251. Thermodynamics (4)
Principles of thermodynamics of single and multicomponent systems. Phase equilibria. Estimation, calculation, and correlation of properties of liquids and gases. *Prerequisite: consent of instructor.*

CENG 252. Chemical Reaction Engineering (4)
Analysis of chemical rate processes; complex kinetic systms. Chemical reactor properties in steady state and transient operations; optimal design policies. The interaction of chemical and physical transport processes in affecting reactor design and operating characteristics. Uniqueness/multiplicity and stability in reactor systems. Applications of the heterogeneous reactor systems. *Prerequisite: consent of instructor.*

CENG 253. Heterogeneous Catalysis (4)
Physics and chemistry of heterogeneous catalysis. Adsorption/desorption kinetics, chemical bonding, isotherms, kinetic models, selection of catalysts, poisoning, experimental techniques. *Prerequisite: consent of instructor.*

CENG 254. Biochemical Engineering Fundamentals (4)
Introduction to microbiology as relevant to the main topic, biological reactor analysis. Fermentation and enzyme technology. *Prerequisite: consent of instructor.*

CENG 255. Electrochemical Engineering (4)
Fundamentals of electyrochemistry and electrochemical engineering. Structure of the double layer, cell potential and electrochemical thermodynamics, charge transfer kinetics, electrochemical transport phenomena, and introduction to colloidal chemistry. Applications such as corrosion prevention, electroplating, reacgtor design, batteries and fuel cells. *Prerequisite: consent of instructor.*

CENG 258. Special Topics in Chemical Engineering (4)
Directed studies in chemical engineering using topics not covered in regular course offerings. *Prerequisites: consent of instructor.*

CENG 259. Seminar in Chemical Engineering (4)
Presentations on research progress by graduate students and by visitors from industrial and academic research laboratories. (May be repeated for credt. S/U grades only). *Prerequisite: consent of instructor.*

CENG 296. Independent Study in Chemical Engineering (4)
Independent reading or research on a problem as arranged by a faculty member. Must be taken for a letter grade only. *Prerequisite: consent of instructor.*

CENG 299. Graduate Research in Chemical Engineering (1-12)
S/U grades only. *Prerequisite: consent of instructor.*