The School of Science and Engineering

Chemical Engineering (CENG)

Chemical engineering is the world of plastics and high-strength ceramics, of gasoline, natural gas, and fuel cells, of semiconductors and light emitting diodes, of clean air and water, of pharmaceuticals, drug delivery, and scaffolds for artificial organs. It is a world where engineers tinker with molecules through the foundations of chemistry, biology, physics and mathematics to develop new products and chemical processes that enhance our quality of life. This remarkable connection from the molecular scale to the macroscopic scale where one can touch and see the effects of molecular tinkering on products and processes, is truly the hallmark of chemical engineering. The world of chemical engineering fully embraces forefront areas of nanotechnology, biotechnology, and environmental science. Chemical engineers work in virtually all industrial sectors - in the petroleum and chemical industries, in the consumer products industry, in the biotechnology and pharmaceutical industries, in semiconductor manufacturing and microfabrication, in advanced materials and the polymer industries, in the food and natural products industries, and in environmental technology development. Students with chemical engineering backgrounds also go on to successful careers in medicine, law, business and consulting.

The curriculum is based on the foundations of the chemical and biomolecular sciences. Through fundamental courses in thermodynamics, transport processes, reaction engineering and design, students learn how to work with molecules as simple as methane and as complex as proteins, nucleic acids and lipids, and learn how new products and processes are developed. Biomolecular engineering is an increasingly important component of our curriculum, and our faculty are involved in such wonderful new areas as gene delivery systems, cell and tissue engineering, biomimetic materials, and nanobiotechnology.

The Chemical engineering program at Tulane University has a firm basis in classroom fundamentals, coupled with direct practical experience. The following are distinctive aspects of the chemical engineering program at the university.

- We have a small student-to-faculty ratio that allows each student to receive individualized attention. The high level of research activity in the department leads to an environment where individualized learning is coupled with the opportunity to participate in research. Every student has the opportunity to obtain a research experience. Many of our faculty conduct collaborative research with faculty at the other science and engineering departments, and at the medical school. This allows the student to participate in forefront research and to understand the relevance of an education in chemical and biomolecular engineering. We strongly encourage undergraduates to participate in research projects, present their research at scientific conferences and to publish their work in journals.

- The department implements a unique Practice School Program in the senior year, where students work on industrial projects jointly supervised by professional engineers at world-class chemical companies in the region. Students learn to work in teams, acquire excellent communication skills, and learn how to solve real-life technical problems.

- We have a flexible curriculum that allows students to co-specialize in the areas of biomolecular engineering, environmental sciences, materials engineering or business studies.

- The Department has implemented a flexible cooperative work program designed to allow students considering employment after the B.S. degree to gain valuable work experience.

- Based on the events unfolding from the aftermath of hurricane Katrina, the chemical engineering program will reflect educational objectives that are distinctive to Tulane University and to New Orleans. In addition to providing a highly rigorous education in chemical engineering, the Department of Chemical and Biomolecular Engineering will work with university guidance to provide students with opportunities to help rebuild the city and community.

DEPARTMENTAL MISSION

The mission of the Department is to provide the highest quality program to educate students in the principles and applications of chemical and biomolecular engineering. The excellence of the program is ensured by the high regard for teaching, strong research activities and solid industrial ties. The program educates students to take leadership roles in industry, academia and government.

PROGRAM EDUCATIONAL OBJECTIVES

The objectives of Tulane's chemical and biomolecular engineering undergraduate program are to provide our students with the engineering science education and problem-solving skills:

1. to be immediately and fully successful in industry, graduate school, or professional school
2. to successfully pursue their desired career path.
3. to be contributing and fulfilled professionals in their careers.

CURRICULUM

The coursework necessary to graduate with a **B.S. degree in Chemical Engineering** can be grouped into the following categories: 1) the engineering courses, including the core chemical engineering courses and the advanced chemistry courses; 2) the basic science and mathematics sequence, which also satisfy the university's scientific inquiry requirements, 3) the university's cultural knowledge (humanities, fine arts and social science) elective courses, TIDES, public service, and the writing requirement; and 4) the technical elective courses.

The department offers great flexibility in the choice of technical electives. This flexibility provides the student with significant exposure to technical and business fields that are distinct from chemical engineering, but that help develop complementary skills very useful to a chemical engineer's career goals. This is done by developing a "concentrations-oriented" sequence of technical electives in biomolecular engineering, environmental studies, materials engineering, or business studies. Students who wish to obtain advanced degrees in chemical engineering may also take introductory level graduate courses to enhance preparation for graduate school. Students who do not wish to specialize in the concentration-oriented technical elective sequence have a wide variety of courses from which to choose their technical electives.

A typical course sequence follows.

First Year

Fall Semester		*Credits*
CHEM 107, CHEM 117	Chemistry I and Lab	4
PHYS 131	General Physics I and Lab	4
MATH 121	Calculus I	4
TIDE 145	Grand Challenges Sci Engr	1
ENGL 101	Writing	4
		17

Spring Semester		*Credits*
CHEM 108, CHEM 118	General Chemistry II and Lab	4
PHYS 132	General Physics II and Lab	4
MATH 122	Calculus II	4
	Cultural Knowledge 1	3
		15

Second Year

Fall Semester		*Credits*
CENG 211	Material and Energy Balances	3
CENG 212	Thermodynamics I	3
CHEM 241	Organic Chemistry I	3
CHEM 243	Organic Chemistry Lab I	1
MATH 221	Calculus III	4
	Cultural Knowledge 2	3
		17

Spring Semester		*Credits*
CENG 232	Transport Phenomena I	3
CENG 250	Intro to Biotech & Biomolecular Engr	3
CHEM 242	Organic Chemistry II	3
CHEM 244	Organic Chemistry Lab II	1

MATH 224	Introduction to Applied Mathematics	4
	Cultural Knowledge 3	3
		17

Third Year

Fall Semester		*Credits*
CENG 311	Thermodynamics II	3
CENG 323	Numerical Methods for Chemical Engineers	3
CENG 333	Transport Phenomena II	3
	Cultural Knowledge 4	3
	Technical Elective 1	3
		15

Spring Semester		*Credits*
CENG 324	Unit Operations Lab	4
CENG 334	Separation Processes	3
CENG 415	Reactor Design	3
CENG 302	Chemistry and Engineering Science in the Community	2
CHEM	Advanced Chemistry*	3/4
		15/16

Fourth Year

Fall Semester		*Credits*
CENG 431	Chemical Process Design	3
CHEM	Advanced Chemistry*	3/4
	Cultural Knowledge 5	3
	Technical Elective 2	3
	Advanced Technical Elective 3	3
		15/16

Spring Semester		*Credits*
CENG 460/462	Practice School I & II	
	or Cooperative Work Program	6
CENG 450	Process Control	3
	Cultural Knowledge 6	3
	Advanced Technical Elective 4	3
		15

*Advanced Chemistry course can be chosen from Applied Biochemistry (CENG 445/446), Physical Chemistry (CHEM 311, 312), Inorganic Chemistry (CHEM 321) or Biochemistry (CHEM 383, 384). Other courses with permission only. Technical electives are normally engineering, science, or math courses, in consultation with the departmental adviser.

THE CONCENTRATION-ORIENTED CURRICULUM

Technical Electives

In addition to the required core chemical engineering courses, the basic science and mathematics sequence, and the cultural knowledge courses, four technical electives will be required. These technical electives may (but need not) constitute a concentration in one of four areas: biomolecular engineering, environmental studies, materials engineering, and business studies. A concentration consists of four or five courses in the following tracks (note that those concentrations requiring five courses may necessitate an additional course during one semester in the program of study):

1. Biomolecular Engineering

CENG 250 (required course), and four courses chosen from:

CENG 440, CENG 445, CENG 446, CENG 471, CELL 101, CELL 205, CELL 301, CELL 311, BMEN 303/313, BMEN 304/314.

2. Environmental Studies

CENG 413/613, and three courses chosen from Environmental Biology, Environmental Geology, or Environmental Studies. These three courses must be approved by the department.

3. Materials Engineering

ENGR 312, CHEM 321 (also an Adv. Chem. Elective) and two courses chosen from:

CENG 413/613, CENG 455/655, CENG 489, BMEN 323.

4. Business Studies

ACCT 203, ACCT 301, FINC 352, OBHR 331-Organizational behavior, MKTG 382-Marketing management

Note: Additionally if the student also takes ECON 101 (as a Cultural Knowledge requirement), the student qualifies for a minor in business.

Other Technical Electives

Technical electives are normally engineering, science, math, or approved business courses. Students may also petition the department through their adviser or the department chair, to have courses fulfill the technical elective requirement. The student should submit a brief request, in writing, indicating which course is being submitted for approval. The course catalog description of the course and most recent syllabus (available through the department of instruction) must accompany the request. The student will be informed in writing within two weeks of the request whether the course has been approved as a technical elective. It will then be general policy that this course is acceptable as a technical elective, and will be added to the list of approved technical electives. An Advanced Technical Elective is a 300-level or above course that meets the above requirements.

Undergraduate Core Requirements

The following courses are required by the university to obtain a degree:

- Writing (ENGL 101, 4 credits)
- Chemical engineering majors are not required to satisfy the foreign language requirement.
- Scientific Inquiry (9-12 credits) This requirement is satisfied by the basic mathematics and science sequence comprising MATH 121, 122, 221, 224; PHYS 131, 132; and CHEM 107/117, 108/118
- Cultural Knowledge (18 credits): satisfied by 18 credits including at least six credit hours of Humanities/Fine Arts and

at least six credit hours of Social Science

- Public Service (2 credits-3 credits)
- TIDES: satisfied by TIDE 145
- Capstone Experience (3+ credits): satisfied by CENG 431

Certain modifications to the program may be made by:

- Achievement of advanced standing through Advanced Placement Tests.
- Use of advanced placement tests in mathematics and chemistry offered on campus during orientation week.
- Submission of transcripts from other universities for equivalent courses taken prior to entering Tulane University.

Each first-year student is assigned an individual faculty adviser early in the first semester and is expected to consult with this adviser regularly. Each upper class is assigned a faculty member to serve as the adviser. Faculty members keep posted office hours for that purpose and are readily available for conferences.

ROTC courses: ROTC courses, if elected, are taken in addition to the normal courses. ROTC students may receive six technical elective credits for their ROTC courses.

Cooperative Work Program

Students in the CBE program may participate in the department's cooperative work program. This program allows students considering employment after the B.S. degree to gain valuable work experience in the chemical engineering field during their undergraduate career. In the Fall semester of their second year, students are interviewed by employers for three individual work periods (the two summers following the second and third years of study and part-time during the spring semester of the fourth year). To participate, students must commit to work for the same employer during all three sessions. Those who complete all three sessions with satisfactory performance will receive six credits at the conclusion of the fourth year spring semester and do not have to register for Practice School to graduate. Students who stop participating in the program must register for Practice School during the spring semester of their fourth year of study. All exceptions to these guidelines must be decided by the department's undergraduate curriculum committee.

PREMEDICAL CURRICULUM IN CHEMICAL ENGINEERING

A premedical program via the chemical engineering curriculum provides an excellent foundation for medical studies. If the student does not proceed to medical school, there is an opportunity for a professional career in industry.

Premedical students make the following changes:

Technical Electives 1 and 2 can be replaced with biology courses, EEOB 101, EEOB 111 and CELL 101, CELL 111.

Premedical students should also take a second English course as one of their Cultural Knowledge electives. Some medical schools may require it.

MINORS & SECOND MAJORS

A chemical engineering student may also elect to pursue a major or minor in another division of the university. Anyone who is interested should contact the appropriate department chair and work out a program of courses. This should be approved by the department chair and forwarded to the dean's office. When all requirements are met, the transcript will reflect that a major or minor has been completed.

Since many chemical engineering students elect to add a minor in business or a minor or major in mathematics, these programs are as follows.

Business Minor

An undergraduate business minor is awarded for the following coursework.

ECON 101 Microeconomics
ACCT 203 Financial Accounting
And any four of the following:
ACCT 301 Managerial Accounting
FINC 352 Financial Management
OBHR 331 Organization Behavior
PSOM 371 Operations Management
MKTG 382 Marketing Management
Plus:
One additional course from the A. B. Freeman School of Business.

Mathematics Minor

A mathematics minor or major is awarded for the following coursework.

MATH 121, 122, 221 Calculus I, II, III
MATH 224 Introduction to Applied Math or
MATH 217 Discrete Math
MATH 309 Linear Algebra
Plus: One additional course at the 300 level or above.

Mathematics Major

All requirements for the minor
Plus: MATH 305, and two additional courses at the 300 level or above, one of which must be a 400 level course.

Students contemplating either a minor or major in mathematics should consult with the major adviser for science and engineering students in the Department of Mathematics during the spring of the sophomore year.

If a liberal arts degree is desired, then all liberal arts, as well as departmental requirements, must be met.

FACULTY LIST AND COURSE DESCRIPTIONS

Office: Lindy Claiborne Boggs Center, Suite 300

Phone: 504-865-5772

Professors

Daniel De Kee, Ph.D., *University of Montrea*l, Canada 1977. Rheology of natural and synthetic polymers, constitutive equations, transport phenomena and applied mathematics.

Vijay T. John, Department Chair, D.Eng.Sc., *Columbia University, 1982.* Chemical engineering. nanotechnology, biotechnology.

Victor John Law, P.E., Ph.D., *Tulane University, 1963.* Modeling environmental systems, nonlinear optimization and regression, transport phenomena, numerical methods.

Brian S. Mitchell, Ph.D., *University of Wisconsin, Madison, 1991.* Nanostructured hybrid materials; materials processing and characterization.

Kim C. O'Connor, Ph.D., *California Institute of Technology, 1987*. Animal-cell technology, bioengineering and biotechnology, organ/tissue regeneration, recombinant protein expression.

Kyriakos D. Papadopoulos, D.Eng.Sc., *Columbia University, 1982.* Colloid stability, coagulation, transport of multiphase systems through porus media, colloidal interactions.

Assistant Professors

Henry S. Ashbaugh, Ph.D., *University of Delaware, 1998.* Classical thermodynamics and statistical mechanics, molecular simulation, solution thermodynamics, multiscale modeling of self-assembly and nanostructured materials.

W T. Godbey, Ph.D., *Rice University, 2000.* Gene therapy, cellular engineering, molecular aspects of nonviral transfection, biomaterials, tissue engineering.

Professor of Practice

John C. Prindle, Jr., Ph.D., P.E., *University of Wisconsin, Madison, 1989.* Process design, dynamics, and control; applied thermodynamics; applied mathematics.

Professor Emeritus

Richard D. Gonzalez, Ph.D., (Professor Emeritus) *The Johns Hopkins University, 1965.* Synthesis and characterization of supported metal catalysis, fundamental studies in reactor design, in-situ spectroscopic methods, reactions in organized media.

Adjunct Professor

Yunfeng Lu, Ph.D., *University of New Mexico, 1998.*
Nanostructured and microelectronic materials, Sol-Gel processes and organic/inorganic hybrid materials, membrane separations and catalysis, chemical sensors and biosensors.

CORE CHEMICAL ENGINEERING COURSES

Courses numbered in the 100s normally are taken in the first year, 200s in the sophomore year, 300s in the junior year, and 400s in the senior year. Graduate courses are those numbered in the 600s and 700s; 600-level courses may be taken by advanced undergraduates.
The numbers in parentheses next to the course title indicate the course credit. The contact hours, or the actual number of weekly

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hours of lecture, laboratory, and other class work, are indicated after the credit.

CENG 211 Material and Energy Balances (3) Lecture 3.
Basic concepts in mass and energy balances are presented in this introduction to chemical process engineering. Properties of pure materials and relevant equations of state are reviewed in illustrative examples.

CENG 212 Thermodynamics I (3) Lecture 3.
Concepts of energy, equilibrium, and reversibility are presented in the setting of the theoretical development of classical thermodynamics. Energy conversion cycles and elementary fluid mechanics are used to illustrate applied thermodynamics in chemical process technology.

CENG 232 Transport Phenomena I (3) Lecture 3.
Prerequisites: CENG 211, CENG 212, equivalents or approval of instructor. Principles of hydrostatics and fluid mechanics. Emphasis is on mass, energy and momentum balances. Fluid flow through pipes and other types of chemical engineering equipment are considered in detail. The fundamental operations of vector analysis and the development of basic differential equations that govern fluid flow are used to solve representative problems in which viscosity is important.

CENG 250 Introduction to Biotechnology and Biomolecular Engineering (3) Lecture 3.
The major topics in the field of biotechnology are introduced along with 1) related fundamentals in biochemistry, cell biology and molecular biology and 2) engineering applications in the area of material and energy balances, thermodynamics, transport phenomena, kinetics and mathematical modeling. The course emphasizes both an understanding of theory and development of problem solving skills.

CENG 302 Chemistry and Engineering Science in the Community (2) Lecture 2.
Prerequisite: Junior standing. This course satisfies the university's public-service requirement. Topics include public outreach, application of engineering principles to community issues, and educating the community on scientific and engineering issues.

CENG 311 Thermodynamics II (3) Lecture 3.
Basic concepts in physical and chemical equilibria. Systems of variable composition. Chemical reaction equilibria. Thermodynamic analysis of processes. Principles of statistical mechanics. Partition functions.

ENGP 312 Materials Science and Engineering (3) Lecture
Prerequisites: CHEM 107, CHEM 108, PHYS 131, PHYS 132, MATH 221. The structure and properties of engineering materials are considered. Coverage includes basic atomic and microscopic structure, testing methods, phase relationships, and strengthening techniques. Emphasis is placed on common industrial materials. Thermodynamics and kinetics aspects of material science are discussed. Same as BMEN 312 and ENGP 312.

CENG 323 Numerical Methods for Chemical Engineers (3) Lecture 3.
Numerical methods using Matlab with some programming in either Fortran or C++. Numerical differentiation and integration. Solution of linear and nonlinear equations. Numerical solution of ordinary and partial differential equations. Optimization. Use of spreadsheets and graphical presentations. Applications are to design oriented problems.

CENG 324 Unit Operations Lab (4) Laboratory 8
Prerequisites: CENG 333, CENG 334. Bench-scale laboratory experiments in unit operations. Report writing, safety, oral presentations, ethics and group activities are emphasized.

CENG 333 Transport Phenomena II (3) Lecture 3.
Molecular mechanisms of energy transport (heat conduction) and mass transport (diffusion). The development of nonisothermal and multicomponent equations of change for heat and mass transfer. Exact and numerical solutions to steady-state and transient heat and mass transfer problems. Convective heat and mass transfer. Introduction to radiation heat transfer. Heat and mass transfer in boundary layers. Correlations for convective heat and mass transfer. Boiling and condensation. Interphase mass transfer. The analogies between heat, mass, and momentum transfer are emphasized throughout the course.

CENG 334 Separation Processes (3) Lecture 3.
Prerequisites: CENG 211, equivalent, or approval of instructor. Principles of separations processes, including distillation, liquid-

liquid extraction, stripping, gas absorption, and adsorption processes. Single stage and multiple stage processes. Design of plate and packed separations columns. Plate and column efficiencies.

CENG 413 Surface and Colloid Phenomena (3) Lecture 3.
A study of surface and colloid chemistry. Topics include characterization of particles and surfaces, stability of colloidal systems, interactions of charged particles, and electrokinetic phenomena.

CENG 415 Reactor Design (3) Lecture 3.
Prerequisite: MATH 224. The design and analysis of chemical, biological, and polymerization reactor systems are achieved by application of the principles of chemical kinetics and equilibrium coupled with mass and energy transport. Specific areas of study include kinetics, ideal reactors, multiple reactor systems, nonideal flow and mixing, and catalysis.

CENG 431 Chemical Process Design (3) Lecture 3.
Prerequisites: Senior standing or departmental approval. The elements of industrial design and supporting economics are presented in the context of a representative design project. Extension of the student's early background in unit operations through practical design considerations including materials of construction is accomplished. Methods are presented for capital and operating cost estimation, raw materials and utilities pricing, and assembly of investment costs, taxes, environmental and other site requirements. Realistic design constraints are included, e.g., economic factors, safety, reliability aesthetics, ethics, and social impact.

CENG 440 Introduction to Gene Therapy (3) Lecture 3.
A survey into the fundamental aspects of gene delivery and their application to gene therapy. Topics include various gene carriers, carrier/DNA interaction and complex formation, complex interactions with cells and cell structures, targeting, gene therapy applications, host response. A knowledge of cell and molecular biology is not required.

CENG 445 Applied Biochemistry I (3) Lecture 3.
Prerequisite: CHEM 241/243. Biochemistry is the study of the chemistry and chemical processes involved with the molecules that are utilized by living organisms. This two-semester series will provide an in-depth coverage of carbon- and nitrogen-

containing molecules such as proteins and DNA and certain cofactors. In the first semester enzyme kinetics and catalysis will be covered, along with carbohydrates and their metabolism. The metabolic pathways and associated bioenergetics of glycolysis and the TCA cycle will be examined in detail. The material will be related to everyday life, diet, nutrition, and exercise performance.

CENG 446 Applied Biochemistry II (3) Lecture 3.

Prerequisite: CENG 445. This course is a continuation of CENG 445 (please refer to the related course description). Principles taught in CENG 445 will be extended as they are applied to lipids and nitrogen-containing molecules, and the metabolism of each. Example molecules include fats, triglycerides, DNA, amino acids, heme, and urea. The interplay of biochemistry and molecular biology will also be examined.

CENG 450 Chemical Process Control (3) Lecture 3.
Prerequisite: MATH 224. An introduction to linear control theory is presented in which processes are described mathematically through transfer functions and conventional threemode controllers are specified. Frequency and time domain stability studies are made including Bode, Nyquist and root locus methods. Other topics are introduced including cascade control, modal analysis, optimal control, and multivariate system analysis. Automatic control systems are designed for a number of processes.

CENG 455 Sol-Gel Science (3) Lecture 3.
A study of chemistry, physics, and applications of sol-gel processing. Designs and fabrications of functional and nanostructured materials. Recent advances of sol-gel science in nanotechnology, microelectronics, and biomedical engineering.

CENG 460 & 462 Practice School or Cooperative Work Program. (6) Lecture plus Practicum 8.
Prerequisite: Senior standing. Students are placed in groups of three or four and are assigned to a project at a local industrial facility, hospital, or government agency. The project is one of current concern to the organization and may range from a study of an operating process to the development of a new process. The projects are open-ended and the students are expected to apply the principles of good design practice involving realistic constraints such as economics, safety, reliability, aesthetics,

ethics, and social impact. Students normally are assigned to a project which fulfills certain career goals. This internship, under the direction of a faculty member, utilizes engineers and other personnel at the host site. Students are required to submit interim and final written and oral reports.

CENG 471 Biochemical Engineering (3) Lecture 3.
Prerequisite: CENG 250 or equivalent. An advanced course in biochemical engineering. Topics include enzyme-catalyzed and cell-associated reactions, engineering aspects of recombinant DNA technology, cell culture, bioreactors and tissue engineering.

CENG 477 Advancces in Biotechnology (3) Lecture 3.

The objectives of the course are to enhance understanding of the basic principles of biotechnology and to introduce the most current biotechnology research. Topics include gene therapy, microbial pesticides, genetically engineered food, stem-cell technology and tissue engineering.

CENG 482 Undergraduate Independent Studies (2-4).
Under special circumstances, course credit is granted to students undertaking independent research studies. A project adviser should be identified and permission for enrollment filed with the department chair prior to registration.

CENG 489 Polymer Engineering and Science (3) Lecture 3.
Fundamentals of polymer science and engineering, including synthesis, characterization, properties and processing of polymeric materials. An overview of polymer structure, including classification, tacticity, conformation and configuration is given. Synthetic techniques are reviewed, including addition and condensation polymerization and copolymerization. Polymer thermodynamics are described, including an introduction to Flory-Huggins theory, as well as polymer-polymer miscibility and blends. A brief overview of characterization is given, including molecular weight and glass transition temperature determination. Properties are discussed, including mechanical properties of semi-crystalline polymers and elastomers. The time-temperature superposition principle is described, as well as a brief introduction to processing techniques.

CENG 492 Undergraduate Independent Studies (1-4)
Under special circumstances, course credit is granted to students undertaking independent research studies. A project adviser

should be identified and permission for enrollment filled with the department chair prior to registration.

CENG 600 Chemical Engineering Research Seminar (0) Lecture 1.
Students are exposed to the important research findings, presented by invited speakers as well as by professors and advanced PhD candidates of our own department.

CENG 601 Mathematical Methods for Engineers (3) Lecture 3.
Prerequisite: MATH 224. Review of calculus and ordinary differential equations, series solutions and special functions, complex variables, partial differential equations, and integral transforms.

CENG 611 Thermodynamics and Properties of Matter (3) Lecture 3.
Prerequisite: CHEM 311. Molecular thermodynamics of multicomponent systems are reviewed with particular attention to separation processes. Thermal and chemical equilibrium properties are examined for pure and mixed fluids.

CENG 612 Graduate Transport Phenomena (3) Lecture 3.
Prerequisites: CENG 232, CENG 333, CENG 334, and MATH 221, MATH 224 or equivalents. Mathematical formulation and solution of problems involving theoretical concepts in fluid mechanics, heat and mass transfer, thermodynamics and elementary reaction theory. Emphasis is placed upon transient transport processes and the associated partial differential equations.

CENG 613 Surface and Colloid Phenomena (3) Lecture 3.
A study of surface and colloid chemistry. Topics include characterization of particles and surfaces, stability of colloidal systems, interactions of charged particles, and electrokinetic phenomena.

CENG 616 Heterogeneous Catalysis (3) Lecture 3.
A study of the fundamental concepts underlying catalytic processes in the petroleum processing industry and in synthetic fuels research. Topics include molecular theories of adsorption and catalysis, catalyst design and formulation, instrumental methods of catalyst characterization, transport in catalysts, shape-selective catalysis, etc. Applications discussed include catalytic

cracking, reforming, hydrodesulfurization, Fischer-Tropsch synthesis, direct and indirect coal liquefaction, etc.

CENG 625 Applied Numerical Analysis (3) Lecture 3.
Prerequisite: CENG 323 or equivalent, MATH 224. Numerical techniques for the solution of mathematical problems in the engineering analysis of systems are presented for computer implementation. Topics include interpolation, integration, solution of systems of linear and nonlinear algebraic equations, optimization, and regression. A comparison of numerical solution methods for ordinary and partial differential equations is given. Eigenvalue and split boundary problems are included.

CENG 633 Advanced Separations Design (3) Lecture 3.
Prerequisites: CHEM 232, CHEM 333, CHEM 334 or approval of instructor. Design of separations processes based upon newer technologies. Special emphasis is placed upon membrane separations and those processes involving colloidal and surface phenomena.

CENG 640 Introduction to Gene Therapy (3) Lecture 3.
A survey into the fundamental aspects of gene delivery and their application to gene therapy. Topics include various gene carriers, carrier/DNA interaction and complex formation, complex interactions with cells and cell structures, targeting, gene therapy applications, host response. Knowledge of cell and molecular biology is not required.

CENG 642 Advanced Materials Design (3) Lecture 3.
Prerequisites: consent of instructor. Fundamentals of condensed matter are elaborated upon, namely bonding, structure, physical properties, phase equilibria and thermodynamics of solids. Characterization of condensed phases is reviewed. Manipulation of material properties for specific applications is discussed.

CENG 645 Applied Biochemistry (3) Lecture 3.
Prerequisite: CHEM 241/243. Biochemistry is the study of the chemistry and chemical processes involved with the molecules that are utilized by living organisms. This two-semester series will provide an in-depth coverage of carbon- and nitrogen-containing molecules such as proteins and DNA and certain cofactors. In the first semester enzyme kinetics and catalysis will be covered, along with carbohydrates and their metabolism. The metabolic pathways and associated bioenergetics of glycolysis and the TCA cycle will be examined in detail. The material will

be related to everyday life, diet, nutrition, and exercise performance.

CENG 646 Applied Biochemistry II (3) Lecture 3.
Prerequisite: CENG 445. This course is a continuation of CENG 445 (please refer to the related course description). Principles taught in CENG 445 will be extended as they are applied to lipids and nitrogen-containing molecules, and the metabolism of each. Example molecules include fats, triglycerides, DNA, amino acids, heme, and urea. The interplay of biochemistry and molecular biology will also be examined.

CENG 655 Sol-Gel Science (3) Lecture 3.
A study of chemistry, physics, and applications of sol-gel processing. Designs and fabrications of functional and nanostructured materials. Recent advances of sol-gel science in nanotechnology, microelectronics, and biomedical engineering.

CENG 671 Biochemical Engineering (3) Lecture 3.
Prerequisite CENG 250 or equivalent. An advanced course in biochemical engineering. Topics include enzyme-catalyzed and cell-associated reactions, engineering aspects of recombinant DNA technology, cell culture, bioreactors and tissue engineering.

CENG 677 Advances in Biotechnology (3) Lecture 3.
The objectives of the course are to enhance understanding of the basic principles of biotechnology and to introduce the most current biotechnology research. Topics include gene therapy, microbial pesticides, genetically engineered food, stem-cell technology and tissue engineering.

CENG 686 Readings and Research (2-4).

CENG 689 Polymer Engineering and Science (3) Lecture 3.
Fundamentals of polymer science and engineering, including synthesis, characterization, properties and processing of polymeric materials. An overview of polymer structure, including classification, tacticity, conformation and configuration is given. Synthetic techniques are reviewed, including addition and condensation polymerization and copolymerization. Polymer thermodynamics are described, including an introduction to Flory-Huggins theory, as well as polymer-polymer miscibility and blends. A brief overview of characterization is given, including molecular weight and glass transition temperature determination. Properties are discussed, including mechanical

properties of semi-crystalline polymers and elastomers. The time-temperature superposition principle is described, as well as a brief introduction to processing techniques.

CENG 712 Thermodynamics of Macromolecules (3) Lecture 3.
Prerequisite: 611 or equivalent. Thermodynamics is applied to macromolecules. Fundamentals of the thermodynamics of polymers in solution and in the melt. Topics of polymer self-assembly, polymer-surfactant interactions, and polymer nanocomposites are incorporated in the course. Students learn methods of characterization of polymer thermodynamics using spectroscopy, microscopy and scattering techniques.

CENG 715 Advanced Reactor Design (3) Lecture 3.
Coupled reaction and transport phenomena as they are involved in major reactor configurations are studied with attention to data resources and computational capabilities.

CENG 752 Applied Statistical Mechanics (3) Lecture 3.
The course covers the fundamental principles and methods of statistical mechanics. Emphasis is placed on applications to thermodynamics, phase behavior, polymer science and self-assembly phenomena.

CENG 781 Advanced Independent Research (3)
Research studies performed under faculty tutelage by prior arrangement.

CENG 788 Polymer Rheology (3) Lecture 3.
Non-Newtonian phenomena, material functions and generalized Newtonian fluids, rheometry, linear viscoelasticity, multiphase systems and mixing.

CENG 789 Adv Macromolecular Chemistry and Materials (3) Lecture 3.
This course covers various topics on the design, synthesis and applications of polymers and nanocomposites. The goals of this course are to teach the students basic polymer science, in particular, polymer synthesis and characterization, and to expose the students to the current-state-of-art polymer research. The representative topics include basic polymer synthesis and characterization, supramolecular assembly, functional polymers, polymeric nanocomposites, biopolymers, and polymeric devices.

CENG 791-794 Master's Level Research Orientation and Methods (1,1,1,1)

CENG 891-892 Doctoral Level Research Seminar (1,1)

CENG 998 Master's Research

CENG 999 Dissertation Research