451. Process Systems Control
Winter. 3(3-0) CHE 307, CHE 428.
Foundation of control theory for chemical processes. Integration of present and developing practice with modern theory.

460. Problems and Reports
Fall, Winter, Spring, Summer. 1 to 9 credits. Seniors, approval of department.
Library and laboratory investigations of problems relating to departmental research.

461. Process Selection and Optimization
Winter. 5(5-0) CHE 307, CHE 428.
Application of chemical engineering principles in design calculations. Selection of the optimum design for equipment, functional units, and for the overall process. Influence of design on capital investment, operating cost, product loss, and product quality.

462. Process Design
Spring. 3(1-6) CHE 461.
Integrated design of the complete chemical engineering process. Process engineering, project engineering, instrumentation, and layout.

465. Process Optimization Methods
Fall. 3(3-0) MTH 310. Interdepartmental with Systems Science.
Methods for determining optimum design and operating policies of systems of varying complexity. Includes classical methods, mathematical programming and modern methods.

470. Theory of Nuclear Reactors
Winter. 3(3-0) PHY 289 and MTH 215 or approval of department.
Theory and design of nuclear research and power reactors. Nuclear transformation, fission, and energy conversion. Derivation of chain reaction design criteria, and calculation of flux-power distribution. Analysis of reactor safety, reliability and economics.

481. Transport Phenomena
Spring. 3(3-0) CHE 307, CHE 381.
Fundamental treatment of momentum, energy and mass transport. Use of partial differential equations and equations of change for chemical engineering applications. Analogies among the phenomena, dimensional analysis, and boundary layer theory.

801. Advanced Chemical Engineering Calculations I
Fall. 3(3-0) CHE 307.
Chemical engineering applications of advanced mathematical methods. Formulation and solution of mathematical equations which describe physical problems. Computer solutions.

802. Advanced Chemical Engineering Calculations II
Winter. 3(3-0) CHE 801.
Continuation of CHE 801.

806. Thermodynamics and Kinetics in Chemical Engineering
Summer. 5(7-0) B.S. with a major in chemistry, biochemistry, or a closely allied area. Mathematics through calculus. College level physics. General physical, and organic chemistry. Not open to students with B.S. in chemical engineering for graduate credit.
Mass and energy balances in batch continuous and open systems. Process thermodynamics. Cryogenics. Properties of substances and mixtures. Phase equilibria. Chemical reaction equilibrium. Chemical reactor kinetics. Process design orientation.

807. Transfer and Separation Processes
Summer. 5(7-0) B.S. with a major in chemistry, biochemistry, or a closely allied area. Mathematics through calculus. College level physics. General physical, and organic chemistry. Not open to students with B.S. in chemical engineering for graduate credit.
Momentum, energy, and mass transfer. Laminar and turbulent flow. Fluid friction. Dimensional analysis. Heat through stationary and flowing materials. Interchangers. Condensation. Boiling. Binary and multicomponent distillation, absorption, extraction.

811. Advanced Chemical Engineering Thermodynamics I
Fall. 3(3-0) CHE 311, CHE 411. CEM 361.
Advanced treatment of the laws of thermodynamics. Cryogenic processes. Corresponding state and higher parameters in computing properties of chemical compounds and solutions.

817. Advanced Chemical Reaction Engineering I
Spring. 3(3-0) CHE 428.
Treatment of absorption and catalysis and their application to catalytic reactors. Heat, momentum, and mass-transfer in fixed-bed and fluidized-bed reactors. Noncatalytic heterogeneous reactions. Homogeneous chain reactions and free radical mechanisms. Computer applications to solution of complex kinetic problems.

826. Flow of Heat I
Spring. 3(3-0) CHE 307.
Steady and unsteady state heat transfer. Conduction and convection in flow and non-flow systems.

831. Advanced Distillation
Winter. 3(3-0) CHE 307, CHE 451 or concurrently.
Stagewise calculation in distillation processes. Computer techniques. Batch, continuous, binary and multi-component calculations. Tray hydrodynamics and efficiency. Process control and energy integration.

832. Advanced Absorption and Extraction
Spring. 3(3-0) CHE 307, CHE 451 or concurrently.
Mass transfer in absorption and extraction processes. Continuous and stagewise phase contactors. Column hydrodynamics and plate efficiency. Design and control principles.

850. Fluid Flow and Rheology
Fall. 3(3-0) CHE 481 or approval of department.
Application of fluid dynamics to chemical engineering systems. Balance principles for fluids; Newtonian and non-Newtonian behavior; theory and practice of laminar and turbulent flows; stability.

851. Mass Transfer
Winter. 3(3-0) CHE 850.
Formulation of component material balances; Fick's first and second laws; convective mass transfer; multicomponent fluxes; boundary layer theory and interfacial mass transfer for laminar and turbulent flows.

881. Seminar
Fall, Winter, Spring. 1(0-2) May reenroll for a maximum of 6 credits.
Detailed library investigation of one or more specialized aspects of chemical engineering, such as recent theoretical developments in one of the unit operations; presentations of these studies to a seminar group. Participation generally required each term of residence.

886. Selected Topics in Chemical Engineering
Fall, Winter, Spring, Summer. 3(3-0) May reenroll for a maximum of 9 credits if a different topic is taken.
A newly developing area of chemical engineering selected by the department for offering each term. Information on the specific topic to be covered should be obtained from the department office before registration.

888. Research Survey
Fall, Winter, Spring, Summer. 1 to 3 credits. May reenroll for a maximum of 3 credits.
Literature search, problem analysis, and layout of a complete research program.

893. Special Problems
Fall, Winter, Spring, Summer. 3(3-0) May reenroll for a maximum of 9 credits. Approval of department.

899. Master's Thesis Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

912. Advanced Chemical Engineering Thermodynamics II
Spring of even-numbered years. 3(3-0) Approval of department.
Relation of thermodynamics to quantum theory and statistical mechanics. Computation of chemical engineering thermodynamic data from spectral measurements. Irreversible thermodynamics.

918. Advanced Chemical Reaction Engineering II
Fall of odd-numbered years. 3(3-0) Approval of department.
Quantitative treatment of current literature in chemical kinetics and reaction engineering.

999. Doctoral Dissertation Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

CHEMISTRY CEM

College of Natural Science

Credit cannot be earned in more than one course of each of the following groups: 141A and 141B and 151, 143, 241, and 351; 142 and 153; 242 and 352; 243 and 354; 244 and 355; 245 and 353; 361 and 383; 363 and 385; 384 and 461.

With department approval, students with advanced placement credit in CEM 151 and 161 may enroll in CEM 181H and 184H. Those with advanced placement credit in CEM 152 may enroll in CEM 182H, and those with advanced placement credit in CEM 153 may enroll in CEM 183H. CEM 181H-182H-183H is a more advanced treatment of material in CEM 151-152-153. CEM 184H-185H-186H is a more advanced treatment of material in CEM 161-162-163. Students with credit in an honors chemistry course may not enroll in the corresponding nonhonors course.

139. Selected Topics in Introductory Chemistry
Fall, Winter, Spring, Summer. 1 to 3 credits. May reenroll for a maximum of 7 credits. Previous college chemistry, approval of department.
Self-instructional units from CEM 140, CEM 141A, CEM 141B (or equivalent) selected and approved by the department for individual students with special needs.

140. Introductory Chemistry

Fall, Winter, Spring, Summer. 2 credits. Self-scheduled instruction only. MTH 108 or MTH 111 or concurrently.

Chemical symbols, formulas, equations, stoichiometry, structure of atoms, bonding, states of matter, solutions.

141A. Chemical Principles

(141.) Fall, Winter, Spring, Summer. Fall 4(4-0); Winter, Spring, Summer: 4 credits. Self-scheduled instruction only. MTH 108 or MTH 111 or concurrently; CEM 140 or satisfactory chemistry placement test score.

Chemical principles for students in the physical sciences and engineering.

141B. Chemical Principles

Fall, Winter, Spring, Summer. Fall 4(4-0); Winter, Spring, Summer: 4 credits. Self-scheduled instruction only. MTH 108 or MTH 111 or concurrently; CEM 140 or satisfactory chemistry placement test score.

Chemical principles for students in biological, health-related, and agricultural disciplines.

142. Descriptive Inorganic Chemistry

Winter, Spring. 3(3-0) CEM 141A or CEM 141B or CEM 152.

Reactions and behavior of inorganic compounds illustrated in part by industrial and environmental applications.

143. Introductory Organic Chemistry

(132.) Fall, Spring, Summer. 4(3-3) CEM 141A or CEM 141B or CEM 152.

Chemistry of carbon compounds, introducing the aliphatic and aromatic hydrocarbon series. Some typical compounds are prepared and their behavior studied.

151. Principles of Chemistry I

Fall, Winter. 4(4-0) MTH 108 or MTH 111 or concurrently; CEM 140 or satisfactory chemistry placement test score.

First of a 3-term sequence for science majors, chemical engineering students, and others desiring a comprehensive general chemistry sequence. Atomic and molecular structure; stoichiometry; solids, liquids, and gases; solutions.

152. Principles of Chemistry II

Winter, Spring. 3(3-0) MTH 112 or concurrently; CEM 151 or CEM 141A or CEM 141B or CEM 181H.

Continuation of CEM 151. Chemical thermodynamics; kinetics, acids, bases, and aqueous equilibria; electrochemistry.

153. Introductory Inorganic Chemistry

Fall, Spring. 3(3-0) CEM 152 or CEM 182H.

Continuation of CEM 152. Descriptive inorganic chemistry with further discussion of bonding.

161. Introductory Chemistry Laboratory

Fall, Winter, Spring, Summer. 1(0-3) CEM 140 or CEM 141A or CEM 141B or CEM 151 or concurrently.

Laboratory work in chemistry, including quantitative physiochemical or analytical experiments and chemical synthesis.

162. Quantitative Analysis

Fall, Winter, Spring, Summer. 3(1-6) CEM 141A or CEM 141B or CEM 151 or CEM 181H; CEM 161 or CEM 184H.

Laboratory work in quantitative chemistry.

163. Introductory Inorganic Laboratory

Spring. 2(0-6) CEM 142 or CEM 153 or concurrently; CEM 161.

Qualitative analysis and inorganic preparations.

181H. Honors Chemistry I—Principles

Fall. 4(4-0) An A average in high school chemistry, physics and mathematics; MTH 112 or MTH 122 concurrently. Results of examination during orientation; approval of department.

Subatomic, atomic and molecular structure; quantum theory and bonding; experimental methods of structure determination; states of matter; nuclear chemistry.

182H. Honors Chemistry II—Principles

Winter. 4(4-0) CEM 181H with grade of 3.0 or better and/or approval of department. MTH 113 or MTH 123 concurrently.

Kinetic theory of gases, thermodynamics, chemical equilibrium, electrochemistry, chemical kinetics, properties of solutions, macromolecular chemistry.

183H. Honors Chemistry III—Inorganic Chemistry

Spring. 3(3-0) CEM 182H with grade of 3.0 or better and/or approval of department.

Descriptive inorganic chemistry by periodic groups of elements. Nomenclature, bonding, sterochemistry, and reactions of compounds of the representative and transition elements.

184H. Honors Chemistry Laboratory I

Fall. 1(0-3) CEM 181H concurrently; approval of department.

Techniques of measurement; errors and significant figures; experiments related to atomic and molecular structure.

185H. Honors Chemistry Laboratory II

Winter. 2(0-6) CEM 184H; CEM 182H concurrently; approval of department.

Experiments related to gas behavior, thermodynamics, electro-chemistry, chemical kinetics and properties of solutions.

186H. Honors Chemistry Laboratory III

Spring. 2(0-6) Approval of department.

Introductory independent laboratory work in chemistry.

241. Organic Chemistry

Fall, Winter, Summer. 4(4-0) CEM 141A or CEM 141B or CEM 152 or CEM 181H; CEM 161 or CEM 184H.

Common classes of organic compounds with emphasis on nomenclature, structural principles, reactions and reaction mechanisms.

242. Organic Chemistry

Winter, Spring, Summer. 4(4-0) CEM 241.

Continuation of CEM 241 with emphasis on polyfunctional compounds, particularly groups of compounds having biological significance.

243. Organic Chemistry Laboratory

Fall, Winter: 1(0-2) Summer: 1(0-3). CEM 241 or concurrently.

Introduction to standard organic laboratory techniques.

244. Organic Chemistry Laboratory

Winter, Spring, Summer. 1(0-3) CEM 241, CEM 243, CEM 242 concurrently.

Organic preparations and qualitative analysis.

245. Organic Chemistry

Fall, Spring. 4(4-0) CEM 242.

Selected topics of organic chemistry, especially compounds of biological interest, discussed with emphasis on mechanisms and stereochemistry. Topics include polymers, amino acids, proteins, sugars, terpenes, steroids, and alkaloids.

333. Instrumental Methods

Spring. 4(2-6) CEM 143 or CEM 241 or CEM 351; CEM 162.

Principles, applications of separation and instrumental analysis. Atomic emission, absorption, fluoresence spectrometry; UV, visible, IR spectrophotometry; molecular fluoresence; gas and other chromotography; electro-analytical chemistry; electrophoresis; radiochemistry.

351. Organic Chemistry

Fall. 3(4-0) CEM 152 or CEM 182H.

A comprehensive introduction to the fundamentals of organic chemistry designed for chemistry majors but open to others who desire a rigorous, modern treatment of the subject.

352. Organic Chemistry

Winter. 3(4-0) CEM 351.

Continuation of CEM 351.

353. Organic Chemistry

Spring. 3(4-0) CEM 352.

Continuation of CEM 352.

354. Organic Chemistry Laboratory

Winter. 2(0-6) CEM 162 or CEM 185H; CEM 351.

A laboratory course in modern techniques of organic chemistry, including qualitative organic analysis.

355. Organic Chemistry Laboratory

Spring. 2(0-6) CEM 352, CEM 354.

Continuation of CEM 354.

356. Organic Chemistry Laboratory

Fall. 2(0-6) CEM 355.

Continuation of CEM 355.

361. Chemical Thermodynamics

Fall. 3(4-0) One year general chemistry; one year general physics; MTH 215.

Thermodynamics. Properties of gases. Laws of thermodynamics, properties of ideal and non-ideal solutions, thermodynamics of chemical reactions, activities in non-ionic systems.

362. Analytical-Physical Chemistry I

Winter . 3(4-0) CEM 361.

Applications of thermodynamics. Activity coefficients, ionic solutions, cell potentials, ionic equilibria including acid-base, complexation, solubility and redox equilibria, phase equilibria, distillation, extraction, chromatography.

363. Analytical-Physical Chemistry II

Spring. 3(4-0) CEM 362.

Chemical kinetics. Homogeneous kinetics, reaction mechanisms, temperature dependence of reaction rates, transport process, heterogeneous kinetics, electrode kinetics, X-ray diffraction, crystal structure.

372. Analytical-Physical Chemistry Laboratory I

Winter. 2(1-3) CEM 162; CEM 383, or CEM 361.

Measurement techniques. Temperature measurement and control, pressure, caloimetry, pH, acid-base titrations, cell potentials, treatment of data.

373. Analytical-Physical Chemistry Laboratory II

Spring. 2(1-3) CEM 372.

Instrumental measurements. Electrode potentials, chromatography, spectrophotometry, electrolytic conductance, solution kinetics.

383. Physical Chemistry: Introductory

Fall, Summer. 3(4-0) CEM 143 or CEM 241 or CEM 351; MTH 113.

Classical and chemical thermodynamics. Introduction to the laws and their applications in treating chemical reactions, pure substances, ideal and non-ideal mixtures, and colligative properties.

384. Physical Chemistry: Introductory

Spring. 3(4-0) CEM 383.

Atomic and molecular structure. Atomic and molecular orbitals and chemical bonding. Rotational, vibrational and electronic spectra, nuclear magnetic resonance and electron spin resonance.

385. Physical Chemistry: Introductory

Winter. 3(4-0) CEM 383.

Electrochemistry and electromotive force. Chemical kinetics. Macromolecules and biochemical systems. Nuclear chemistry.

400H. Honors Work

Fall, Winter, Spring, Summer. 1 to 3 credits. May reenroll for a maximum of 18 credits. Seniors, approval of department.

Assigned reading and investigation in chemistry under the supervision of the staff. The program will include some creative work.

411. Inorganic Chemistry I

Fall. 3(3-0) CEM 385 or CEM 363.

Principles of structure and bonding in inorganic chemistry, crystal symmetry, coordination chemistry, solvent systems, hydrogen bonding and selected examples from the chemistry of various elements.

412. Inorganic Chemistry II

Winter. 3(3-0) CEM 411.

Inorganic chemistry viewed in a variety of examples of reactions, structure, mechanisms, etc., from representative main group elements and transition elements.

419. Problems and Reports

Fall, Winter, Spring, Summer. 1 to 8 credits. May reenroll for a maximum of 8 credits. Approval of department.

430. Introduction to Radioactivity and Radioisotope Techniques

Spring, Summer. 2(3-0) or 3(3-0) One year each of general college chemistry and physics. Interdepartmental with and administered by Physics.

First 7 weeks. Elementary nuclear processes and properties with emphasis on radioactivity, its measurement, and its interaction with matter. Effects of radiation on chemical and biological systems. Applications of nuclear technology, safety and environmental factors.

Last 3 weeks. Fundamentals of nuclear models, reactions and decay mechanisms. Basic principles of nuclear reactors and accelerators.

431. Laboratory for Radioactivity and Radioisotope Techniques

Spring, Summer. 1(0-3) CEM 161, PHY 430, concurrently. CEM 162 recommended. Interdepartmental with and administered by Physics.

Introduction to nuclear instrumentation. Experimental techniques for application of radioisotopes to problems in chemistry, the life sciences, and industry.

461. Theoretical Chemistry I

Fall. 3(4-0) One year general chemistry; one year general physics; MTH 215.

Quantum chemistry. Wave properties, postulates of quantum mechanics, hyrdodgen atom, helium atom, orbital theories, ionic bonds, simple molecules, valence-bond and molecular-orbital theories, complex molecules, introduction to spectra.

462. Theoretical Chemistry II

Winter. 3(4-0) CEM 361, CEM 461.

Spectroscopy and molecular structure. Electronic, infrared, Raman, and microwave spectroscopy, magnetic susceptibility and magnetic resonance, statistical mechanics, statistical thermodynamics, kinetic theory of gases, absolute rate theory.

471. Analytical-Physical Chemistry Laboratory III

Fall. 2(0-6) CEM 363, CEM 373.

Kinetics, operational amplifiers, polarography, coulometry, electrochemical kinetics, stopped-flow kinetics, digital measurements, neutron activation.

472. Analytical-Physical Chemistry Laboratory IV

Winter. 2(0-6) CEM 461, CEM 471.

Molecular properties. Mass spectrometry, nuclear and electron spin resonance spectroscopy, infrared spectroscopy, dipole moments, magnetic susceptibility, gaseous decomposition kinetics.

484. Modern Physical Chemistry

Spring. 3(3-0) May reenroll for a maximum of 6 credits if a different topic is taken. CEM 462.

Topics may be selected from the following: physical properties and structure, molecular structure, spectroscopy, theory of solutions.

499. Seminar on Chemical Physics

Fall, Winter, Spring. 1(1-0) May reenroll for a maximum of 3 credits. One year of analytical-physical chemistry. MTH 215; PHY 428.

Literature of chemical physics through oral reports on selected journal articles in the area.

810. Advanced Inorganic Chemistry

Fall. 3(3-0) Approval of department.

Structure, bonding, and reactivity patterns of inorganic compounds, with emphasis on nonmetallic elements and reactions in nonaqueous media.

811. Symmetry, Group and MO Theory

Winter. 3(3-0) Approval of department.

Applications of group and molecular orbital theory to chemical bonding, structure and reactions.

813. Advanced Inorganic Chemistry—Metals

Spring. 3(3-0) CEM 811.

Continuation of CEM 811 with emphasis on the structure and chemistry of the metals.

833. Analytical Spectroscopy

Spring. 3(3-0) Approval of department.

834. Advanced Analytical Chemistry

Fall. 3(3-0) Approval of department.

Consideration of principles and equilibria pertaining to aqueous and non-aqueous neutralization, redox and complexation reactions and the various separation techniques employed in analyses.

835. Spectrochemical Methods of Analysis

Winter. 3(3-0) or 4(3-4) Approval of department.

Principles and applications of atomic absorption, emission, fluorescence; arc and spark emission spectroscopy; UV, visible, IR spectrophotometry; spectrophotometric titrations, reaction rate methods; molecular fluorescence, phosphorescence spectrometry; other optical spectrometric methods

836. Separations

Spring of odd-numbered years. 3(3-0) Approval of department.

Physical and chemical methods of separation.

837. Electroanalytical Chemistry

Spring of even-numbered years. 3(3-0) Approval of department.

Theory and applications of modern electroanalytical chemistry to chemical and biomedical problems. Coulometry, electrometric titrations, ion-selective voltammetry; electrochemical synthesis and preparation of species for spectroscopy; trace analysis.

838. Scientific Instrumentation

Fall, Spring, Summer. 3(1-6) May reenroll for a maximum of 9 credits. Approval of department.

Scientific measurements. Principles and applications of servo systems, operational amplifiers, linear and digital solid state devices, analog, digital and hybrid instrumentation systems, and minicomputers for scientific measurements.

844. Structural Elucidation by Instrumental Methods

Fall. 3(3-0) Approval of department.

A practical instrumental analysis course with the major emphasis on the interpretation of data rather than a detailed description of the instrumentation. The fundamental principles behind the various measurements will be discussed in a general way, and important instrumental limitations will be noted.

860. Organic Reactions: A Mechanistic Approach

Fall. 3(3-0) CEM 353; CEM 462 or approval of department.

Organic reactions are presented in a mechanistic framework. Reactions which proceed via carboncations, carbanions, free radicals, carbenes, arynes and other reactive intermediates, and concerted reactions are included.

861. Structure of Organic Compounds

Winter. 3(3-0) CEM 860 or approval of department.

Structural and stereochemical principles will be developed and illustrated. Spectroscopic data will be used to illustrate the principles and to determine structure, with an emphasis on nuclear magnetic resonance spectroscopy.

862. Advanced Synthetic Organic Chemistry
Spring. 3(3-0) CEM 860 or approval of department.
The strategy and methods of organic synthesis will be discussed.

880. Atomic and Molecular Structure
Fall. 3(3-0) CEM 462 or approval of department.
Basic concepts of non-relativistic quantum mechanics will be developed and employed in a description of atomic and molecular structure.

881. Thermodynamics
Winter. 3(3-0) Approval of department.
Laws of thermodynamics and their application to pure substances and solutions.

883. Chemical Kinetics
Spring. 3(3-0) CEM 880.
Rates and mechanisms of chemical reactions, reaction rate theory, kinetic theory of gases, photochemistry.

890. Graduate Problems and Reports
Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 12 credits. Approval of department.

899. Master's Thesis Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.
Research in inorganic, analytical, organic, and physical chemistry.

913. Selected Topics in Inorganic Chemistry
Fall, Spring, 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken.
Rare earth elements, recent advances in the chemistry of metals or nonmetals, high-temperature chemistry. Coordination chemistry and nonaqueous solvents.

918. Seminar in Inorganic Chemistry
Fall, Winter, Spring. 1(2-0) May reenroll for a maximum of 3 credits.
Discussions of recent advances and reports by graduate students on research problems.

924. Selected Topics in Analytical Chemistry
Fall, Winter, Spring. 3(3-0) or 2(2-0) May reenroll for a maximum of 9 credits if different topic is taken.
Among topics which may be discussed are: advances in electroanalytical chemistry or spectroscopy; nonaqueous solvents; complexation equilibria; surface chemistry; analytical chemistry of polymers.

938. Seminar in Analytical Chemistry
Fall, Winter, Spring. 1(1-0) May reenroll for a maximum of 3 credits.
Discussions of recent advances and reports by graduate students on research problems.

956. Selected Topics in Organic Chemistry
Fall, Winter, Spring. 2(2-0) or 3(3-0) May reenroll for a maximum of 12 credits if different topic is taken. Approval of department.
Topics may be selected from heterocyclic chemistry, natural products, free radicals, carbonium ions, organic sulfur or nitrogen compounds, acidity functions, isotope effects, photochemistry and others.

958. Seminar in Organic Chemistry
Fall, Winter, Spring. 1(2-0) May reenroll for a maximum of 3 credits.
Discussions of recent advances and reports by graduate students on research problems.

985. Statistical Thermodynamics
Winter, Spring. 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. Approval of department.
Partition functions, spectroscopic measurements and thermodynamic applications. Nonequilibrium statistical mechanics and thermodynamics. Time correlation functions and spectroscopic lineshapes, light scattering, and magnetic relaxation. Transport properties of fluids and gases.

987. Selected Topics in Physical Chemistry
Fall, Winter. 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. Approval of department.
Mathematical preparation for quantum chemistry. Selected topics as: kinetics and photochemistry, macromolecular and surface chemistry, molecular spectroscopy, electro and magnetic properties of matter, application of statistical mechanics to chemical problems.

988. Selected Topics in Physical Chemistry
Winter, Spring. 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. Approval of department.
Topics may be chosen from analysis and interpretation of the spectra of molecules, advanced molecular structure, magnetic resonance, spectroscopy, X-rays and crystal structure, statistical mechanics.

991. Selected Topics in Quantum Chemistry
Fall, Winter. 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. Approval of department.
Principles of quantum mechanics and application to chemical problems. Selected topics from spectroscopy, properties of atoms and molecules in electric and magnetic fields, and theories of molecular electronic structure.

998. Seminar in Physical Chemistry
Fall, Winter, Spring. 1(1-0) May reenroll for a maximum of 3 credits.
Discussions of recent advances and reports by graduate students on research problems.

999. Doctoral Dissertation Research
Fall, Winter, Spring, Summer. Varible credit. Approval of department.
Research in analytical, inorganic, organic, and physical chemistry.

CHINESE

See Linguistics and Germanic, Slavic, Asian and African Languages.

CIVIL AND SANITARY ENGINEERING

College of Engineering

Civil Engineering C E

251. Elementary Surveying
Fall, Spring. 4(3-3) Not open to majors.
Use of the tape, compass, level, and transit with simple maps; traverse closure and area computations. Profile, cross section and stadia surveys, U.S. land system.

252. Surveying I
Fall, Spring. 5(4-3) Engineering majors or approval of department.
Instruments, theory of measurements, error analysis, stadia, horizontal and vertical curves, U.S. Public Land System, observation for meridian.

280. Introduction to Environmental Engineering
Fall, Winter, Spring. 4(4-0) CEM 141, or CEM 131, MTH 112, CPS 120.
Hydrology; ground water and surface water supply systems; wastewater treatment, methods of pollution control for solid waste, air, and noise.

305. Structural Mechanics I
Winter, Spring. 4(4-0) MMM 211.
Stability and determinacy of structures. Two and three dimensional determinate structures. Indeterminate structural analysis by displacement and force methods based upon equilibrium, compatibility and load-deformation relations.

308. Engineering Materials I
Fall, Winter, Spring. 4(3-3) MMM 211 or concurrently.
Structure; composition; physical, mechanical and rheological properties of non-metallic construction materials. Emphasis on aggregates, asphalt, inorganic cements, concrete, and wood.

312. Soil Mechanics I
Winter, Spring, Summer. 4(3-3) MMM 211.
Engineering properties of soils and their measurement. Effective stress concept; permeability; fluid flow in soils; stress-strain behavior; soil strength; compaction and consolidation of soils; field exploration and design problems.

321. Introductory Fluid Mechanics
Fall, Winter, Spring. 5(4-2) MMM 306.
Fluid properties; hydrostatics; control volume aproach to conservation of mass, momentum and energy; dimensional analysis and dynamic similitude; fluid resistance; pipe and open channel flows; boundary layer concepts.

346. Transportation
Winter, Spring, Summer. 3(3-0) MTH 113.
Planning, design and evaluation of transportation systems. Operational characteristics of transportation modes, traffic flow and techniques for system selection.

347. Transportation Facilities
Fall, Winter. 4(3-3) C E 252.
Geometric design of highways and airports as these considerations affect capacity, contruction costs, financing and safety.