809. *Chemical Process Design*

Summer. 4(3-2) B.S. with a major in chemistry, biochemistry, or a closely allied area. CHE 806 and CHE 807. Not open to students with B.S. in chemical engineering for graduate credit.

Integrated design of complete processes. Flowsheets. Instrumentation. Optimization of equipment design. Energy consumption. Operating cost. Capital investment. Product loss. Product quality. Economic evaluation of chemical and microbiological processes.

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*

Winter. 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.

825. *Theory, Applicability and Engineering of Radioisotopes*

Winter of even-numbered years. 3(3-0) PHY 498 or PHY 430 or approval of department.

Principles of utilization of radioisotopes in research and production problems for engineering and science majors. Fundamentals and preparation techniques of radioisotopes. Selection, specification, measurement and disposal for typical technical 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. *Distillation, Absorption, and Extraction–Ideal Stages*

Fall. 3(3-0) CHE 307. May precede or follow CHE 832.

Stagewise calculations in distillation, absorption, and extraction processes. Computer techniques. Liquid-gas and liquid-liquid equilibria. Batch, continuous, binary and multi-component calculations.

832. *Distillation, Absorption and Extraction–Phase Contractors*

Winter. 3(3-0) CHE 307. May precede or follow CHE 831.

Mass transfer in distillation, absorption, and extraction processes. Continuous and stagewise phase contactors. Column hydrodynamics and plate efficiency.

835. *Nonlinear Optimization Models*

(SYS 828.) Winter, Summer. 4(4-0) Students may not receive credit for both SYS 835 and MGT 835. CHE 465 or MGT 834 or knowledge of linear programming. Interdepartmental with Systems Science and the Department of Management. Jointly administered by Systems Science and the Department of Management.

Nonlinear optimization-examples and applications. Khun-Tucker Theory. Saddle point optimality conditions. Algorithms for problems with constraints. Unconstrained optimization; introduction to search methods.

841. *Advanced Transport Phenomena*

Spring. 3(3-0) MTH 215, B S. in engineering or physical science.

Use of equations of change in solving engineering problems. Boundary layer and penetration theories of interphase transport. Potential flow. Theories of turbulence from statistical standpoint.

847. *Physical Chemistry of Macromolecules*

Winter of odd-numbered years. 3(3-0) CHE 446 or approval of department. Interdepartmental with the Department of Chemistry.

Thermodynamics—phase equilibria of polymer solutions; configuration and conformation of chain molecules; characterization of polymer molecular weight and distribution; theoretical and experimental results for dilute solution viscosity and diffusivity; polyelectrolytes.

881. *Seminar*

Fall, Winter, Spring, Summer. 1(0-2) May reenroll for a maximum of 3 credits allowed toward M.S. degree and 6 credits toward Ph.D. degree.

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. Variable credit. Approval of department.

899. *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.

927. *Flow of Heat II*

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

Fundamentals of radiant heat transfer. Computer techniques in the design of radiant and convective heat transfer equipment.

999. *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: 130 and 141, 131 and 141, 142 and 153, 132 and 241 or 351, 242 and 352, 383 and 461, 361 and 384, 394 and 472.

With department approval, students with credit in CEM 141-161 may enroll in CEM 181-184H. Those with credit in CEM 152 may enroll in CEM 182H and those with credit in CEM 153 may enroll in CEM 183H. However, students with credit in an Honors Chemistry course may not receive credit in the corresponding non-Honors Chemistry course.

130. *Introductory Chemistry I*

Fall, Winter, Spring, Summer. 4 credits--Self-instructional only. MTH 108 or MTH 111 or concurrently.

General discussion of principles. Atomic and molecular structure and spectra; stoichiometry; gases, liquids, solids, solutions, and changes of state. Laboratory experiments via film, TV tape or live demonstration.

131. *Introductory Chemistry II*

Fall, Winter, Spring, Summer. 3 credit--Self-instructional only. CEM 130; CEM 161 concurrently.

Continuation of CEM 130. Chemical kinetics and equilibrium; ionic equilibrium; acids and bases.

132. *Introductory Chemistry: Carbon Compounds*

Fall, Spring, Summer. 3(3-2) CEM 131 or CEM 141; CEM 161.

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

141. *Principles of Chemistry I*

Fall, Winter. 4(4-0) MTH 108 or MTH 111 or concurrently; 1 year high school chemistry; CEM 161 concurrently.

Atomic and molecular structure, chemical kinetics and equilibrium; acids and bases. The solid state.

142. *Introductory Chemistry III*

Fall, Spring. 3(3-0) CEM 131 or CEM 141.

Reactions and behavior of inorganic compounds.

152. *Principles of Chemistry II*

Winter, Spring. 3(3-0) CEM 131 or CEM 141; MTH 112 or concurrently. Grade of C or better in CEM 131 or CEM 141 recommended.

Thermochemistry and applications of themochemical principles; equilibrium and electrochemistry.

153. *Introductory Inorganic Chemistry*

Fall, Spring. 3(3-0) CEM 152.

Descriptive inorganic chemistry with further discussion of bonding; introduction to radiochemistry.

161. Introductory Chemistry Laboratory

Fall, Winter, Spring, Summer. 1(0-3) CEM 131 or CEM 141 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 131 or CEM 141; CEM 161.

Laboratory work in quantitative chemistry.

163. Introductory Inorganic Laboratory

Spring 2(0-6) CEM 162.

Qualitative analysis and inorganic preparations.

181H. Honors Chemistry I--Principles

Fall. 4(4-0) An A average in high school chemistry, physics and mathermatics; 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 131 or CEM 141; CEM 161.

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, Summer. 1(0-2) 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 132 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.

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, 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 132 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

Winter, Summer. 3(4-0) CEM 132 or CEM 241 or CEM 351; MTH 113.

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

Spring. 3(4-0) CEM 383 and CEM 384.

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

394. Spectroscopy Laboratory

Spring. 2(1-3) CEM 384 or CEM 461.

Laboratory work in electronic, vibrational, and rotational spectroscopy, mass spectrometry, nuclear and electron spin resonance, dipole moments and magnetic susceptibility.

400H. Honors Work

Fall, Winter, Spring, Summer. Variable credit. 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, Summer. 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. 2 to 8 credits.

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 the Department of 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 the Department of Physics.

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

446. *Polymerization*

Fall. 3(3-0) One year organic chemistry, elementary physical chemistry. Interdepartmental with the Department of Chemical Engineering.

Formation and characterization of polymers of high molecular weight will be emphasized.

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*

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

Structure, bonding and reactivity patterns of inorganic compounds, with emphasis on metallic elements and coordination chemistry in aqueous and nonaqueous media; concepts in symmetry, pseudo-rotation and other reaction mechanisms.

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.

830. *Nuclear and Radiochemistry*

Winter. 3(3-0) Approval of department

Chemistry of production, isolation and identification of radionuclides and their uses in chemical research.

833. *Analytical Spectroscopy*

Winter of odd-numbered years. 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 of even-numbered years. 3(2-4) 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. 2(1-3) to 4(2-6) May reenroll for a maximum of 8 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.

847. *Physical Chemistry of Macromolecules*

Winter of odd-numbered years. 3(3-0) CEM 446 or approval of department. Interdepartmental with and administered by the Department of Chemical Engineering.

Thermodynamics—phase equilibria of polymer solutions; configuration and conformation of chain molecules; characterization of polymer molecular weight and distribution; theoretical and experimental results for dilute solution viscosity and diffusivity; polyelectrolytes.

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 carbocations, carbanions, free radicals, carbenes, arynes and other reactive intermediates, and concerted reactions are included.

861. *Structure of Organic Compounds*

(851.) 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*

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

The strategy and methods of organic synthesis will be discussed.

863. *Physical Organic Chemistry*

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

Experimental techniques and theoretical principles used to determine organic reaction mechanisms will be discussed. These include kinetics, dependence of reactivity on solvent and structure, and orbital symmetry restrictions.

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 descritption 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. Variable credit. May reenroll for a maximum of 12 credits. Approval of department.

899. 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(1-0) 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(1-0) May reenroll for a maximum of 3 credits.
Discussions of recent advances and reports by graduate students on research problems.

985. Statistical Thermodynamics
Winter of even-numbered years. 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. Research
Fall, Winter, Spring, Summer. Varible credit. Approval of department.
Research in analytical, inorganic, organic, and physical chemistry.

CHINESE

See Linguistics and Oriental and African Languages.

CIVIL AND SANITARY ENGINEERING

College of Engineering

Civil Engineering — C E

251. Elementary Surveying
Fall, Spring. 4(3-3) Trigonometry, EGR 160 or EGR 267. 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) Trigonometry.
Instruments, theory of measurements, error analysis, stadia, horizontal and vertical curves, U.S. Public Land System, observation for meridian.

280. Introduction to Environmental Engineering
(382.) 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
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.

311. Urban Utilities
Winter. 3(3-0)
Capacities, limitations and cost of public and semi-public utilities as they relate to the planning and design of the urban environment. Topics include transportation, water supply, storm drainage, sewage collection and treatment, solid waste and municipal finance.

312. Soil Mechanics I
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.

342. Survey of Transportation Systems
Fall. 4(4-0) Juniors; not open to majors.
Survey of engineering aspects of all forms of transportation with emphasis on highway transportation including highway systems, planning, economic and financial aspects, geometrics and traffic studies.

346. Transportation
Fall, Winter, Summer. 3(3-0) MTH 214.
Planning, design and evaluation of transportation systems. Operational characteristics of transportation modes, traffic flow and techniques for system selection.

347. Transportation Facilities
Winter. 4(3-3) C E 251 or C E 252.
Geometric design of highway and airport facilities as these considerations affect capacity, traffic control and economics of transport systems. Financing and administration of transport systems.

353. Surveying II
Spring. 4(3-3) C E 251 or C E 252.
Continuation of C E 252 including photogrammetric methods, astronomical observations for latitude, longitude and meridian. Introduction to geodetic methods.