927. Flow of Heat II  
Fall of even-numbered years. 3(3-0)  
Department. 
Fundamentals of radiant heat transfer. Computer techniques in the design of radiant and convective heat transfer equipment.

942. Transport Properties  
Spring of odd-numbered years. 3(3-0)  
Department. 

965. Special Topics in Optimal Process Theory  
Spring of odd-numbered years. 3(3-0)  
SYS 285 or approval of department. Interdepartmental with Systems Science.  
Continuation of 282 and special topics from the literature in nonlinear, stochastic, and dynamic programming.

999. Research  
5(5-0)  
EGR 999.  
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 152, 132 and 241 or 351, 311 and 411, 383 and 461, 361 and 384, 394 and 472.

130. Introductory Chemistry I  
Fall, Winter, Summer. 4(3-3)  
MTH 122 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  
Winter, Spring, Summer. 3(3-0)  
161 concurrently. 
Continuation of 130. Chemical kinetics and equilibrium; ionic equilibrium; acids and bases.

132. Introductory Chemistry: Carbon Compounds  
Fall, Spring, Summer. 3(3-2)  
131 or 141: 161. 
Chemistry of carbon compounds, introducing the alphabetic 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 111 or concurrently; satisfactory grade on placement examination, 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)  
131 or 141. 
Reactions and behavior of inorganic compounds.

152. Principles of Chemistry II  
Winter, Spring. 3(3-0)  
131 or 141; MTH 112 or concurrently. Grade of C or better in 131 or 141 recommended. 
Thermochemistry and applications of thermochemical principles; equilibrium and electrochemistry.

153. Introductory Inorganic Chemistry  
Fall, Spring. 3(3-0)  
131 or 141 concurrently. 
Descriptive inorganic chemistry with further discussion of bonding; introduction to radiochemistry.

161. Introductory Chemistry Laboratory  
Fall, Winter, Spring, Summer. 1(0-3)  
131 or 141 concurrently. 
Laboratory work in chemistry including quantitative physical or analytical experiments and chemical syntheses.

162. Quantitative Analysis  
Fall, Winter, Spring, Summer. 2(0-8)  
101 or 141 or 161. 
Laboratory work in quantitative chemistry.

163. Introductory Inorganic Laboratory  
Spring. 2(0-8)  
162. 
Qualitative analysis and inorganic preparations.

241. Organic Chemistry  
Fall, Winter, Summer. 4(4-0)  
131 or 141 concurrently. 
Common classes of organic compounds with emphasis on nomenclature, structural principles, reactions and reaction mechanisms.

242. Organic Chemistry  
Winter, Spring. 4(4-0)  
241. 
Continuation of 241 with emphasis on polyfunctional compounds, particularly groups of compounds having biological significance.

243. Organic Chemistry Laboratory  
Fall, Winter, Summer. 1(0-3)  
241 or concurrently. 
Introduction to standard organic laboratory techniques.

244. Organic Chemistry Laboratory  
Winter, Spring, Summer. 1(0-3)  
241. 
Laboratory work in organic chemistry.

245. Organic Chemistry  
Spring. 3(3-0)  
242. 
Special topics in organic chemistry. Reactions of technical and biological interest, stereochemistry, reaction mechanisms, etc.

311. Inorganic Chemistry  
Fall, Summer. 4(4-0)  
384 or 461 or concurrently; approval of department. 
The chemistry of selected non-metals and metals. Electrical coordination chemistry and solid-base theory. Bonding in inorganic compounds. The periodic law and table.

333. Instrumental Methods  
Spring. 4(2-0)  
132 or 241 or 351; 162. 
Principles, applications of separation and instrumental analysis. Atomic emission, absorption, fluorescence spectroscopy; IR, visible, UV spectrophotometry; molecular fluorescence; gas and other chromatography; electroanalytical chemistry, electrochemistry, radiochemistry.

351. Organic Chemistry  
Fall. 3(4-0)  
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)  
351. 
Continuation of 351.

353. Organic Chemistry  
Spring. 3(4-0)  
352. 
Continuation of 352.

354. Organic Chemistry Laboratory  
Winter. 2(0-8)  
242. 
A laboratory course in modern techniques of organic chemistry, including qualitative organic analysis.

355. Organic Chemistry Laboratory  
Spring. 2(0-8)  
352, 354. 
Continuation of 354.

356. Organic Chemistry Laboratory  
Fall. 2(0-8)  
355. 
Continuation of 355.

361. Chemical Thermodynamics  
Fall, Spring. 3(4-0)  
One year general chemistry; one year general physics; MTH 215. Interdepartmental and jointly administered with the Chemical Engineering Department. 

362. Analytical-Physical Chemistry I  
Winter. 3(4-0)  
381. 
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)  
362. 
Chemical kinetics. Homogeneous kinetics, reaction mechanisms, temperature dependence of reaction rates, transport processes, heterogeneous kinetics, electrode kinetics, X-ray diffraction, crystal structure.

372. Analytical-Physical Chemistry Laboratory I  
Winter. 2(1-3)  
160; 383 or 361. 
Measurement techniques. Temperature measurement and control, pressure, calorimetry, pH, acid-base titrations, cell potentials, treatment of data.

373. Analytical-Physical Chemistry Laboratory II  
Spring. 2(1-3)  
372. 
Infrared spectrometry. Electrode potentials, chromatography, spectrophotometry, electrolytic conductance, solution kinetics.

383. Physical Chemistry: Introductory  
Fall, Summer. 3(4-0)  
132 or 241 or 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 coligative properties.
384. Physical Chemistry: Introductory Chemistry
   Winter, Summer. 3(4-0) 132 or 241
   or 351; MTH 115.
   Atomic and molecular structure. Atomic and
   molecular orbitals and chemical bonding. Rotational,
   vibrational and electronic spectra. nuclear magnetic
   resonances and electron spin resonance.

385. Physical Chemistry: Introductory Physics
   Spring. 3(4-0) 383 and 384.
   Electrochemistry and electromotive force. Chemical
   kinetics, Macromolecules and biochemical systems.
   Nuclear chemistry.

394. Spectroscopy Laboratory Theory
   Spring. 2(1-3) 384 or 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. Systematic Inorganic Chemistry
   Winter, Summer. 4(4-0) 461.
   Systematic study of the chemistry of representa­
   tive metallic and non-metallic elements. Coordina­
   tion chemistry and an introduction to acidic
   base theory and non-aqueous solvent systems.

414. Laboratory Work in Inorganic Chemistry
   Spring, Summer. 3(3-6) Seniors.
   Use of synthetic and analytical techniques com­
   monly employed in modern research to prepare
   and characterize inorganic compounds.

419. Problems and Reports
   Fall. Winter, Spring, Summer. 2 to 8 credits.

430. Introduction to Radioactivity and Radiosotope Techniques
   Fall. Summer. 3(2-3) One year each
   of general college chemistry and physics and
   161; 162 recommended. Physics majors can­
   not apply course towards graduation requirements.
   Interdepartmental with and administered by the
   Physics Department.
   Elementary nuclear properties and processes with
   emphasis on radioactivity, its measurement, and
   its interaction with matter. Special attention is
   given to experimental techniques and applica­
   tions of radiosotopes to problems in chemi­
   stry, the life sciences and industry.

446. Polymerization
   Fall. 3(3-0) One year organic chemis­
   try, elementary physical chemistry. Interdepart­
   mental with the Chemical Engineering De­
   partment.
   Formation and characterization of polymers of high
   molecular weight will be emphasized.

461. Theoretical Chemistry I
   Fall. 3(4-0) One year general chemis­
   try; one year general physics; MTH 215.
   Quantum chemistry. Wave properties, postula­
   tives of quantum mechanics, hydrogen atom,
   helium atom, orbital theories, ionic bonds, simple
   molecules, valence bond and molecular-orbital theo­
   ries, complex molecules, introduction to
   spectra.
880. **Atomic and Molecular Structure**  
Fall. 3(3-0) 452 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) 880.  
Rates and mechanisms of chemical reactions, reaction rate theory, kinetic theory of gases, photochemistry.

890. **Problems and Reports**  
Fall, Winter, Spring, Summer. Variable credit. May re-enroll for a maximum of 12 credits. Approval of department.

899. **Research**  
Fall, Winter, Spring, Summer. Variable credit. May re-enroll for a maximum of 12 credits. Approval of department. Research in inorganic, analytical, organic, and physical chemistry.

908. **Seminar**  
Summer. 2 credits. Approval of department.  
Topics are selected from current active research areas.

913. **Selected Topics in Inorganic Chemistry**  
Fall, Spring. 3(3-0) May re-enroll 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 non-aqueous solvents.

918. **Seminar in Inorganic Chemistry**  
Fall, Winter, Spring. 0 or 1(1-0)  
Discussions of recent advances and reports by graduate students on research problems.

924. **Selected Topics in Analytical Chemistry**  
Fall, Winter, Spring. 2(2-0) May re-enroll for a maximum of 6 credits if different topic is taken.  
Among topics which may be discussed are: advances in electro-analytical chemistry or spectrophotometry; non-aqueous solvents in analytical chemistry; theory of acid-base and complexation phenomena; electronic structure and application to chemical problems.

938. **Seminar in Analytical Chemistry**  
Fall, Winter, Spring. 0 or 1(1-0)  
Discussions of recent advances and reports by graduate students on research problems.

956. **Selected Topics in Organic Chemistry**  
Fall, Winter. 2(2-0) or 3(3-0) May re-enroll 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.

959. **Seminar in Organic Chemistry**  
Fall, Winter, Spring. 0 or 1(1-0)  
Discussions of recent advances and reports by graduate students on research problems.

985. **Statistical Thermodynamics**  
Fall of odd-numbered years, Winter and Spring of even-numbered years. 3(3-0) May re-enroll for a maximum of 9 credits if different topic is taken. Approval of department.  
Definition of partition function; translational, rotational, vibrational and electronic partition functions and their calculation and application to thermodynamic problems; application of statistical mechanics to thermodynamic calculations.

987. **Selected Topics in Physical Chemistry**  
Fall. 3(3-0) May re-enroll for a maximum of 6 credits if different topic is taken. Approval of department.  
Mathematical preparation for quantum chemistry. Selected topics as: kinetics and photochemistry, macromolecules and liquid crystals, physical chemistry, molecular spectroscopy, X-rays and crystal structure, statistical thermodynamics.

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

999. **Quantum Chemistry**  
Fall, Winter, Spring. 3(3-0) May re-enroll for a maximum of 9 credits if different topic is taken. Approval of department.  
Principles of quantum chemistry and their application to chemical problems. Electronic structure of molecules and its correlation with the chemical and physical properties of substances. Emission and absorption of radiation.

998. **Selected Topics in Physical Chemistry**  
Winter. 3(3-0) May re-enroll 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 thermodynamics.

999. **Seminar in Physical Chemistry**  
Fall, Winter, Spring. 0 or 1(1-0)  
Discussions of recent advances and reports by graduate students on research problems.

999. **Research**  
Fall, Winter, Spring, Summer. Variable 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**

**251. Elementary Surveying**  
Fall, Spring. 4(3-3)  
Trigonometry, EGR 160 or 267. Not open to majors.

Use of the tape, compass, level, and transit with simple maps, traverse closures and area computations. Projection, 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 Survey, observation for meridian.

**255. Structural Mechanics I**  
Winter, Spring. 4(3-0)  
MM 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.

**258. Engineering Materials I**  
Winter, Spring. 4(3-3)  
MM 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)  
MM 211.  
Properties of soil and particulate materials, physics of clay water systems, effective stress and consolidation theory, soil strength theory, and introduction to problems of design and construction.

**321. Hydrodynamics**  
Winter, Spring. 5(3-3)  
MM 206.  
Fundamentals of flow of real fluid, fluid prop­erties, kinematics, continuity, laminar and turbulent flow, for­m drag, stream lines, potential flow, pipe and open channel flow.

**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, geometries and traffic studies.

**346. Transportation**  
(448) Fall. 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**  
(447) Winter. 4(3-3)  
215 or 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**  
Fall, Spring. 4(3-3)  
251 or 252.  
Combination of 252 including photogrammetric methods, astronomy, surveying for latitude, longitude and meridian. Introduction to geo­detic methods.