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 developed and illustrated. Spectroscopic data will be developed and employed in a description of atomic and molecular structure.

863. Chemical Kinetics
Spring. 3(3-0) CEM 860.
Rates and mechanisms of chemical reactions, reaction rate theory, kinetic theory of gases, photochemistry.

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

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.

957. 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.

958. Statistical Thermodynamics
Winter, Spring. 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. Approval of department.

959. Selected Topics in Physical Chemistry
Fall. 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 in quantum mechanics and thermodynamics. Time correlation functions and spectroscopic line shapes, light scattering, and magnetic relaxation. Transport properties of fluids and gasses.

960. Selected Topics in Physical Chemistry
Winter. 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. Approval of department.
Mechanical considerations for quantum chemistry. Selected topics in quantum mechanics and thermodynamics. Time correlation functions and spectroscopic line shapes, light scattering, and magnetic relaxation. Transport properties of fluids and gasses.

961. 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.

962. 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.

963. Doctoral Dissertation Research
Fall, Winter, Spring. Variable credit. Approval of department.
Research in analytical, inorganic, organic, and physical chemistry.

CHINESE
See Linguistics and Germanic, Slavic, Asian and African Languages.
346. Transportation  
Winter, Spring, Summer. 4(4-0) C 308
113.
Planning, design, and evaluation of transportation systems; highway, street, and intersection capacity; basic elements of geometric design.

347. Geometric Design of Highways  
Fall, Winter. 4(3-3) C 346 or concurrently.
Geometric design of streets and highways as related to capacity, construction costs, and safety. State and national design standards and practice.

370. Cost and Optimization Engineering  
Fall, Winter. 3(3-0) MTH 113
Formulation of engineering decisions governed by current and future costs and returns. Comparison and optimization of alternative engineering projects, products, and processes.

372. Construction Estimating  
Fall, Spring. 3(3-0) Juniors.
Cost studies of construction activities with emphasis on labor productivity and operating characteristics of equipment under various site conditions. Interpretation of drawings and specifications.

374. Legal Aspects of Engineering  
Spring. 3(3-0) Juniors.
The professional engineer's relationship with the legal aspects of engineering. Special emphasis on contract documents.

390. Civil Engineering Analysis  
Fall, Spring. 3(3-0) MTH 310, CPS 112.
Analysis of civil engineering problems by numerical methods. Use of microcomputers to analyze problems. Technical reports to present methods and computed results.

392. Civil Engineering Fundamentals for Planners  
Winter. 4(4-0) Junior Urban Planning and Landscape Architecture majors.
Site planning; utility systems; subdivision review including street design, grading, density, and costs; transportation planning; and project evaluation.

400. Structural Mechanics I  
Fall. 4(4-0) C 306, C 330.

405. Structural Design in Steel  
Fall, Winter. 4(4-0) C 306 or concurrently. C 350.
Beams, columns, tension and compression members, connections. Elastic, plastic and ultimate strength concepts.

406. Structural Design in Concrete  
Winter, Spring. 4(4-0) C 306, C 308, C 330.

407. Structural Design Concepts  
Spring. 3(3-0) C 405, C 406.
Develop and expand design concepts through study, investigation and project design of various structural systems. Criteria for material selection and creative design of unusual structural systems pursued.

410. Structural Mechanics II  
Winter. 4(4-0) C 400, CPS 112.
Continuation of C 400. Matrix analysis of framed structures with extensive use of computer programs.

418. Foundation Engineering  
Fall, Spring. 3(3-0) C 312, C 390.
Bearing capacity and settlement of shallow foundations; analysis and design of single piles and pile groups; stress distribution in soil masses; site investigation, data evaluation for field and laboratory tests.

419. Stability of Soil Masses  
Winter. 3(3-0) C 212, C 390.
Stability of natural and cut slopes; design of embankments and fills; soil placement and compaction; seepage through soil masses; slope stabilization techniques; lateral earth pressures, retaining walls, and braced excavations.

421. Hydrology I  
Fall. 4(3-2) C 280, C 331, C 390.
Engineering hydrology; frequency and precipitation analysis; streamflow analysis and the unit hydrograph; flood prediction; rainfall-runoff correlations; urban hydrology.

422. Open Channel Flow I  
Winter. 3(2-2) C 280 or M 333, C 390 or M 351.
Fundamentals of free surface flow; steady uniform and nonuniform concepts; energy and momentum principles; subcritical and supercritical regimes; gradually and rapidly varied flows; design applications; laboratory assignments.

423. Closed Conduit Hydraulics  
Spring. 3(2-2) C 280 or M 333, C 390 or M 351.
Steady flow in piping; numerical analysis of pipe networks: theory of turbomachinery; fluid measurements; design of water supply systems; introduction to unsteady flow; laboratory assignments.

441. Highway Operations  
Fall. 3(3-0) C 346, STT 351 or approval of department.
Driver and vehicle characteristics affecting traffic flow; traffic flow density; headway and speed measurements; signaling and signal control for efficient intersection operation, parking characteristics and capacity analysis.

442. Airport Planning and Design  
Fall, Spring. 4(3-2) C 346.
The planning and design of the components of the airport system including ground access facilities, aircraft characteristics, the air traffic control system; airport configuration; capacity analysis; management systems.

448. Transportation Planning  
Winter. 3(3-0) C 346 or C 392; STT 351 or approval of department.
Urban transportation facilities needs and programs. Design of transportation models for urban highways and public transit including trip generation, trip distribution, mode split and traffic assignment. Transport agencies function and services.

449. Highway Engineering  
Spring. 4(3-2) C 308, C 347.
Design concepts of roadways, facilities, drainage and pavement design. Maintenance, construction and supervision methods and procedures.

451. Water and Wastewater Analysis  
Fall. 4(3-3) C 280, STT 351.
Quantitative analysis bacteriologic and chemical characteristics of water and wastewater; principles of softening, iron removal, coagulation and chlorination; laboratory examination of water and wastewater including turbidity, solids, coliforms, chlorine, etc.

453. Water and Wastewater Treatment  
Winter. 4(3-2) C 280, C 321 or concurrently, C 390.
Water treatment theory and design including sedimentation, coagulation, softening, iron removal and chlorination; wastewater treatment theory and design including grit chambers, activated sludge, trickling filter, and anaerobic digesters.

455. Environmental Health Engineering  
Spring. 4(3-3) MTH 200, C 280, C 321 or concurrently, C 390.
Design of small water, waste water and solid waste facilities. Epidemiology of communicable disease transmission by air, water, food and arthropods. Engineering measures to control disease spread.

494. Civil Engineering Design Project  
Fall, Winter. Spring. 3(2-2) May receive for a maximum of 6 credits. Seniors, approval of department.
Planning, specifications and design of a civil engineering project or facility.

499. Civil Engineering Projects  
Fall, Winter, Spring. 1 to 4 credits. May receive for a maximum of 6 credits. Approval of department.
Original civil engineering problem of specific interest to the student and a faculty member. Student's proposal describing problem required prior to approval.

491. Structural Modeling and Experimental Methods  
Fall. 3(2-3) C 406, MMM 405 or approval of department.

802. Structural Dynamics I  
Fall. 3(3-0) C 406, C 406, or approval of department.
Basic concepts in structural dynamics; dynamic loading on structures due to blasts and earthquakes; dynamic properties of structures; methods of analysis; design approaches to blast and earthquake resistant structures; dynamic behavior of bridges and other topics.
803. Fiber Reinforced Concrete
Fall. 3(2-2) C E 496 or approval of department.
Concepts and advantages of fiber reinforced concrete. Fiber types, mix design, and manufacturing techniques. Mechanical, physical and chemical properties. Constitutive modeling, design techniques and applications.

804. Advanced Structural Theory I
Winter. 4(4-0) C E 406, or approval of department.
Energy principles and their application in the analysis of elastic structures, Advanced force and displacement methods and their matrix formulation. Introduction to finite element methods.

805. Advanced Reinforced Concrete
Winter. 3(3-0) C E 406.
Analysis and design of two-way slabs, floor systems, deep beams, shear walls and footings. Limit state, yield line and deflection analysis. Continuity, tall buildings and seismic design. Torsion.

806. Prestressed Concrete Design
Spring. 3(3-0) C E 406.

807. Random Vibration of Structural and Mechanical Systems
Spring of odd-numbered years. 3(3-0) C E 802 or M E 823, ST T 251 or ST T 441, or approval of department. Interdepartmental with the departments of Mechanical Engineering, and Metallurgy, Mechanics, and Materials Science.
Probabilistic modeling of random excitations (e.g. earthquake, suction, ocean wave and wind loads); response of single and multiple degree-of-freedom systems to random excitation; designing against failure; nonstationary and nonlinear problems.

808. Finite Element Method
Fall, Winter, Spring. 4(4-0) Approval of department. Interdepartmental with the departments of Metallurgy, Mechanics, and Materials Science and Agricultural Engineering. Administered by the Department of Metallurgy, Mechanics, and Materials Science.
Theory and application of the finite element method to the solution of continuum type problems in heat transfer, fluid mechanics and stress analysis.

812. Rock Mechanics
Fall of odd-numbered years. 3(2-0) M M M 211; C E 312.

815. Principles of Highway and Airport Soils
Fall. 4(4-0) C E 418 or approval of department.
Foundational problems as related to highways and airports, relation of subsoil conditions to design and construction, analytical review of laboratory and field results.

817. Mechanical Properties of Soils
Fall. 4(3-3) C E 418, C E 419 or approval of department.
Mechanical properties of soil including stress-strain behavior, conditions of failure and shear strength; consolidation theory and permeability; Laboratory determination of soil properties including interpretation of experimental data for use in practice.

818. Advanced Soil Mechanics
Winter. 4(4-0) C E 418, C E 419; or approval of department.
Foundations and earth retaining structures; bearing capacity, lateral resistance and settlement analysis; design of foundations; earth pressures on braced excavations and sheet pile walls; design of caissons and cofferdams.

819. Soil Stabilization in Geotechnical Engineering
Winter. 3(3-0) C E 418 or approval of department.
Techniques to improve the performance of soil in engineering applications; comparisons, blending, admixture, grouting, electroosmosis, vibration, compaction piles, thermal treatment, load bearing and hydraulic fills, precompression, reinforced earth.

820. Geotechnical Engineering for Cold Regions
Spring. 3(3-0) C E 418, C E 419 or approval of department.
Physical and thermal properties of ice and frozen soils; ground thermal regime; mechanical properties of frozen ground; thaw consolidation problems; foundation design; slope stability problems; and artificial freezing for construction.

821. Porous Media Flow I
Fall. 3(3-0) C E 422 or approval of department.

823. Hydrology II
Winter of even-numbered years. 3(3-0) C E 431, C E 432, ST T 351 or approval of department.

824. Coastal Engineering
Fall of even-numbered years. 3(3-0) C E 423 or approval of department.
Linear wave theory. Effects of shoaling, refraction, diffraction, Wind generated waves. Wave runup and overtopping. Wave forces on structures. The beach and longshore sediment transport.

826. Environmental Fluid Mechanics I
Winter of even-numbered years. 3(3-0) C E 422 or approval of department.
Fundamentals: the convective-diffusion equations; solution methods; analytical solutions; simplified solutions, numerical modeling. Molecular diffusion; momentum, mass and heat transport; turbulent diffusion; the effects of stratification.

827. Environmental Fluid Mechanics II
Winter of odd-numbered years. 3(3-0) C E 426 or approval of department.
Continuation of C E 426 showing adaptation of theory to describe transport in environments selected from the following: rivers, lakes, estuaries, groundwaters, the atmosphere, near field regions. Physical modeling.

828. Open Channel Flow II
Spring. 3(3-0) C E 422 or M E 333 or approval of department.
Advanced topics in steady flow analysis. Unsteady flow phenomena and characteristics; propagation of discontinuities; gradually- and rapidly-varied unsteady flow analysis; computer based design applications.

829. Fluid Transients
Fall. 3(3-0) M E 333 or approval of department. Interdepartmental with the Department of Mechanical Engineering.
Application of unsteady flow concepts and wave mechanics to hydraulic engineering; method of characteristics, surges and waterhammer in piping systems, resonance phenomena.

830. Intermediate Fluid Mechanics
Fall. 3(3-0) M E 332 or C E 321. Interdepartmental with and administered by the Department of Mechanical Engineering.
Deformable control volumes, Navier-Stokes equations, dimensionless variables, vorticity and circulation, turbulent flow, inviscid flow, and boundary layer theory.

840. Pavement Design
Spring of even-numbered years. 3(3-0) C E 449 or approval of department.
Pavement types and wheel load stresses in flexible pavements, stresses in rigid pavements, pavement behavior under loadings, climate effects on pavement performance, evaluating subsoil strengths, subgrades, and pavement design criteria.

841. Optimization of Urban Traffic Flow
(SYS 841.) Fall of even-numbered years. 3(3-0) C E 346, ST T 351 or approval of department. Interdepartmental with Systems Science.
Traffic flow models used in design of computerized traffic control systems. Optimal freeway ramp metering algorithms. Off line and online optimization of traffic signal timing.

842. Pavement Rehabilitation
Spring of odd-numbered years. 4(4-0) C E 449 or approval of department.
Strengthening existing pavements, pavement overlay design criteria, epoxy and polyester resin repair and rehabilitation, evaluation of resurfacing practices for bituminous and cement pavements.

843. Traffic Engineering Characteristics
Winter. 3(3-0) C E 346, ST T 351 or approval of department.
Safety analyses, flow and capacity characteristics, statistical properties of traffic, queuing characteristics at intersections, delay characteristics and analyses.

844. Highway and Traffic Safety
Spring of odd-numbered years. 3(3-0) C E 843.
Highway safety improvement programs; identification of hazardous locations; selection and evaluation of countermeasures; programming improvements.
845. Environmental Impacts of Transportation Facility Design

Spring of even-numbered years. 3(3-0) C E 349 or C E 392, C E 448, or approval of department.

The context in which current transportation planning and design decisions are made: legislation; socio-economic effects; air, noise, and water pollution. Preparation of environmental impact statements.

846. Statewide Transportation Planning

Fall of odd-numbered years. 3(3-0) C E 346 or approval of department.

Highway inventory, road use studies and programming, analysis of highway costs, economic considerations in location and design.

847. Advanced Geometric Design of Highways

Winter of even-numbered years. 3(3-0) C E 347.

Advanced geometric designs of highways and freeways, including the redesign of existing systems with development and evaluation of geometric alternatives.

848. Travel Demand Forecasting

Fall of even-numbered years. 3(3-0) C E 448.

Advanced topics in travel demand: disaggregate and behavioral models, error analysis, and model sensitivity.

849. Design of Research Programs I

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

To receive credit C E 489 and C E 850 must be completed satisfactorily except by prior arrangement with instructor.

Two-term sequence to design a major research program not thesis related, e.g., response to a request for a proposal. Includes experiment design, detailed literature review and synthesis.

850. Design of Research Programs II

Summer. 2(2-0) C E 489. To receive credit C E 489 and C E 850 must be completed satisfactorily except by prior arrangement with instructor.

Continuation of C E 489.

851. Special Problems in Civil Engineering

Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 12 credits in C E 860 and S E 880 combined. Approval of department.

Research problems of limited scope not pertaining to thesis assigned under C E 899 or C E 900.

852. Special Topics in Civil Engineering

Fall, Winter, Spring, Summer. 2 to 4 credits. May reenroll for a maximum of 9 credits. Approval of department.

Selected topics in new or developing areas of civil engineering.

853. Master's Thesis Research

Fall, Winter, Spring. Summer. Variable credit. Approval of department.

854. Advanced Theory and Design of Reinforced Concrete II

Spring. 3(3-0) C E 805.

Continuation of C E 805 with application of theory to analysis and design of tanks, rigid frames, and shells.