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) 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. Variable credit. Approval of department.
Research in analytical, inorganic, organic, and physical chemistry.

CHINESE

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

CIVIL AND ENVIRONMENTAL ENGINEERING

(Name change effective July 1, 1985. Formerly the Department of Civil and Sanitary Engineering.)

College of Engineering

Civil Engineering   C E

251.   Elementary Surveying
    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, Spring. 4(4-0) CEM 141A, or CEM 151, MTH 112, CPS 112 or CPS 251.
Hydrology; ground water and surface water supply systems; wastewater treatment, methods of pollution control for solid waste, air, and noise.

305.   Structural Analysis I
    Fall, Winter. 3(3-0) MMM 211.
Stability and determinacy; linearity. Plane trusses; shear and bending in beams and frames. Virtual work calculation of forces and displacements in statically-determinate plane structures.

306.   Structural Analysis II
    Winter, Spring. 3(3-0) C E 305.
Beam-columns. Flexibility method for plane structures. Kinematic indeterminacy. Stiffness method for plane structures. Moment distribution method. Design loading of structures.

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
    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. 4(3-2) MTH 310.
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. 4(4-0) MTH 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 E 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 contruction 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 E 306, C E 390.

Miscellaneous topics in displacement calculation by virtual work. Matrix formulation of the general principles of framed structural analysis. Exhaustive study of the flexibility and stiffness methods.

405. *Structural Design in Steel*

Fall, Winter. 4(4-0) C E 306 or concurrently, C E 390.

Beams, columns, tension and compression members, connections. Elastic, plastic and ultimate strength concepts.

406. *Structural Design in Concrete*

Winter, Spring. 4(4-0) C E 306, C E 308, C E 390.

Reinforced concrete beams, columns, slabs, footings and retaining walls. Elastic theory and ultimate strength concepts. Prestressed theory and design.

407. *Structural Design Concepts*

Spring. 3(3-0) C E 405, C E 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 E 400, CPS 112.

Continuation of C E 400. Matrix analysis of framed structures with extensive use of computer programs.

418. *Foundation Engineering*

Fall, Spring. 3(3-0) C E 312, C E 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 E 312, C E 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 E 280, C E 321, C E 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 E 321 or M E 333, C E 390 or M E 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 E 321 or M E 333, C E 390 or M E 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 E 346, STT 351 or approval of department.

Driver and vehicle characteristics affecting traffic flow; traffic flow density, headway and speed measurements; signing and signal control for efficient intersection operation, parking characteristics and capacity analysis.

442. *Airport Planning and Design*

Fall, Spring. 4(3-2) C E 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 E 346 or C E 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(3-3) C E 308, C E 347.

Design concepts of roadways, facilities, drainage and pavement design. Maintenance, construction and supervision methods and procedures.

471. *Scheduling Construction Activities*

Winter. 3 credits. Approval of department.

Techniques for coordinating and controlling construction projects. Scheduling under the constraints of deadlines, uncertain time estimates and limited resources. Computer programs and data files for effective management.

481. *Water and Wastewater Analysis*

Fall. 4(3-3) C E 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.

483. *Water and Wastewater Treatment*

Winter. 4(3-2) C E 280, C E 321 or concurrently, C E 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.

485. *Environmental Health Engineering*

Spring. 4(3-2) MPH 200, C E 280, C E 321 or concurrently, STT 351.

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 reenroll 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, Summer. 1 to 4 credits. May reenroll 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.

801. *Structural Modeling and Experimental Methods*

Fall. 3(2-3) C E 406, MMM 405 or approval of department.

Experimental methods in structural analysis and design. Model, materials, fabrication, loading and instrumentation. Experimental stress analysis.

802. *Structural Dynamics I*

Fall. 3(3-0) C E 405, C E 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 approach to blast and earthquake resistant structures; dynamic behavior of bridges and other topics.

803. Fiber Reinforced Concrete
Fall. 3(2-2) C E 406 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 400, 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.
Behavior, analysis and design of pretensioned and posttensioned concrete structures. Flexural, shear, bond and anchorage zone design. Cracking and losses. Partial prestressing strength, serviceability and structural efficiency of beams, slabs, tension and compression members. Frameworks and bridges.

807. Random Vibration of Structural and Mechanical Systems
Spring of odd-numbered years. 3(3-0) C E 802 or M E 823, STT 351 or STT 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, aerodynamic and ocean wave loadings); response of single and multiple degree-of-freedom systems to random excitation; designing against failure; nonstationary and nonlinear problems.

809. 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(3-0) MMM 211; C E 312.
Engineering classification of rocks. Behavior of rocks under compressive, tensile and shear loads. Failure criteria. Design of openings in rock. Modes and mechanics of failure of rock slopes.

815. Principles of Highway and Airport Soils
Fall. 4(4-0) C E 418 or approval of department.
Foundation 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 of deep 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; compactions, blending, admixture, grouting, electrosmosis, vibroflotation, 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.
Physical properties of porous media. Equations of flow in saturated media. Flow nets and numerical analysis. Groundwater resource evaluation. Geotechnical problems. Conformal mapping.

823. Hydrology II
Winter of even-numbered years. 3(3-0) C E 421, C E 422, STT 351 or approval of department.
Use of regression and correlation analysis in hydrology. Groundwater recession. Unit hydrograph theory. Hydrologic river and watershed routing. Watershed models for rural and urban environments.

824. Coastal Engineering
Fall of even-numbered years. 3(3-0) C E 422 or approval of department.
Linear wave theory. Effects of shoaling, retraction, 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 equation; 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 826 or approval of department.
Continuation of C E 826 showing adaptation of theory to describe transport in environments selected from the following: rivers, lakes, estuaries, groundwater, the atmosphere, nearfield 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; method of 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 loads, stresses in flexible pavements, stresses in rigid pavements, pavement behaviors 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, STT 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. Offline 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 exisiting 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, STT 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 Decisions**

Spring of even-numbered years. 3(3-0) C E 346 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 design 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 849 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 849. To receive credit C E 849 and C E 850 must be completed satisfactorily except by prior arrangement with instructor.

Continuation of C E 849.

880. **Special Problems in Civil Engineering**

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

Research problems of limited scope not pertaining to thesis accomplished under C E 899 or C E 999.

890. **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.

899. **Master's Thesis Research**

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

905. **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.

906. **Advanced Structural Steel Design**

Spring. 3(3-0) C E 406.

Analysis and design of multiple-story building frames, continuous trusses and rigid-frame girder bridges in structural steel. Plastic design.

909. **Elastic Thin Shells**

Spring. 4(4-0) C E 804 or MMM 815 or approval of department; MTH 421. Interdepartmental with the Department of Metallurgy, Mechanics, and Materials Science.

Elements of differential geometry, membrane theory of shells, Pucher's stress function, deformation and bending of shells of revolution and shallow shells.

912. **Theory of Plates**

Winter. 4(4-0) C E 804 or MMM 815 or approval of department; MTH 422. Interdepartmental with and administered by the Department of Metallurgy, Mechanics, and Materials Science.

Bending of thin elastic plates with various shapes and boundary conditions; application of energy principles and approximate methods of solution; thick plates, large deflection theory; sandwich plates.

915. **Earth Structure**

Spring. 3(3-0) C E 817 or approval of department.

Embankments, earth dams, natural and cut slopes, stability of circular and composite slip surfaces; performance of embankments on soft foundations; seepage through earth dams; instrumentation for field performance evaluation.

916. **Soil Dynamics**

Winter. 4(4-0) C E 817 or approval of department.

Characteristics of ground motions during earthquakes; dynamic soil properties; liquefaction and settlement under transient and repeated loadings; foundation design for vibratory loads; wave propagation in soil media.

921. **Porous Media Flow II**

Winter of odd-numbered years. 3(3-0) C E 809, C E 821.

Mathematical formulations for unsteady groundwater flows and convection/dispersion phenomena. Emphasis placed upon finite-difference and finite-element solution techniques, computer based analysis of field data, and design applications.

941. **Urban Public Transport: Issues and Technology**

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

Planning and operating urban transportation systems; system technology. Regional and rapid rail systems, light rail, buses, paratransit, transportation system management.

999. **Doctoral Dissertation Research**

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

Environmental Engineering ENE

800. **Environmental Engineering Seminar**

(S E 800.) Fall, Winter, Spring. 1(1-0) May reenroll for a maximum of 3 credits. Graduate major in C E or ENE.

Current research, reports, and literature reviews.

801. **Dynamics of Environmental Systems**

Fall. 4(4-0) CEM 361, C E 481.

Thermodynamics, kinetics, and mass transfer of environmental transformations. Environmental modeling, systems analysis, reactor theory, and process design. Applications to air, water and soil pollution, waste treatment, and hazardous waste management.

802. **Physical Chemical Processes of Environmental Engineering**

(S E 802.) Winter. 5(4-3) C E 483.

Analysis of physical and chemical principles which form the basis of air and water pollution control and solid waste disposal; process dynamics, sedimentation, coagulation, filtration, adsorption, absorption, oxidation.

804. **Biological Processes of Environmental Engineering**

(S E 804.) Winter. 4(4-0) MPH 200, ENE 802.

Aerobic and anaerobic degradation of liquid and solid wastes. Biochemical reactions; activated sludge and trickling filter kinetics; sludge digestion and composting.

805. **Biological Waste Treatment Laboratory**

(S E 805.) Spring. 1(0-3) ENE 804.

Treatability studies to develop parameters for design of biological waste treatment systems; reactor kinetics; oxygen uptake; sludge settling rate; biomass production.

816. **Hazardous and Indusrial Waste Management**

(S E 816.) Fall. 3(3-0) Approval of department.

RCRA; waste and process survey, sampling and analysis; treatability studies; process modification; advanced treatment processes; case studies; field trips to industrial sites required.

822. **Air Resource Management**

(S E 822.) Spring of even-numbered years. 4(4-0) ENE 802.

Characteristics of air contaminants and noise; sources and source inventory; microclimitology and pollutant transport; pollutant effects, introduction to sampling and control.

832. **Solid Waste Management**

(S E 832.) Spring of odd-numbered years. 4(4-0) C E 485 or approval of department.

Generation rates; storage; collection; transfer and transport; processing; resource recovery; landfill; siting; design; operation; closure and monitoring; hazardous waste.

880. **Special Problems in Environmental Engineering**

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

Solution of environmental engineering problems, of limited scope not pertaining to thesis.

899. **Master's Thesis Research**

(S E 899.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

916. **Advanced Environmental Control**

(S E 916.) Spring. 4(1-9) ENE 804.

Design of advanced methods for control of environmental pollutants.

999. **Doctoral Dissertation Research**

(S E 999.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.