

Graduate School Announcement, 2009-2010

Department of Civil and Environmental Engineering

Chair

Michael A. Celia

Director of Graduate Studies

Peter R. Jaffé

Professor

David P. Billington

Michael A. Celia

Peter R. Jaffé

Jean-Hervé Prévost

Ignacio Rodriguez-Iturbe

George W. Scherer

James A. Smith

Erik H. VanMarcke

Eric F. Wood

Associate Professor

Denise L. Mauzerall, also Woodrow Wilson School

Catherine A. Peters

Assistant Professor

Sigrid Adriaenssens

Elie Bou-Zeid

Kelly Caylor

Maria Garlock

Branko Glisic

Mark Zondlo

Associated Faculty

Ilhan Aksay, Chemical Engineering

Lars O. Hedin, Ecology and Evolutionary Biology

Michael G. Littman, Mechanical and Aerospace Engineering

François M. M. Morel, Geosciences

Guy J. Nordenson, Architecture

Tullis C. Onstott, Geosciences

Jorge L. Sarmiento, Geosciences

The Department of Civil and Environmental Engineering offers programs of graduate study and research in the following two areas: Mechanics, Materials, and Structures (MMS); and Environmental Engineering and Water Resources (EEWR).

The department offers three degree programs of study: Doctor of Philosophy (Ph.D.), Master of Science in Engineering (M.S.E.), and Master of Engineering (M.Eng.). Students must be admitted to one of these three degree programs.

The student-faculty ratio in the department is kept small to allow for productive working relationships between students and their advisers. The department maintains an atmosphere in which close interaction between students and faculty is the norm, whereby students benefit from the background, experience, and knowledge their advisers have gained in solving important engineering problems.

A bachelor's degree in engineering or science, completed with superior standing, is normally required for admission to the graduate program. As well, applicants are required to submit the results of the Graduate Record Examination (GRE). An international student coming from a non-English-speaking country and whose bachelor's degree is not from an American university is required to submit the results of the Test of English as a Foreign Language (TOEFL). The application for admission must be submitted through the office of the Graduate School of Princeton University. Reenrollment to subsequent years of study is granted by the Dean of the Graduate School on the recommendation of the department, and depends upon the student's demonstrated capabilities in course work and research.

Master of Engineering

An M.Eng. degree is offered to those students who are interested in the applied aspects of engineering and who wish to prepare for professional practice and consulting. The department offers two such programs: the M.Eng. in structural engineering, and the M.Eng. in environmental engineering and water resources. In each case, the student fulfills the requirements by successfully completing eight one-term courses selected from a list of relevant courses. A thesis is not required, and financial support is normally not offered. The M.Eng. degree is usually completed in one academic year of full-time study.

The M.Eng. in structural engineering focuses on the applied aspects of structural engineering. Two of the leading civil engineering design companies in the world are actively involved in the program by teaching design-oriented courses and by supervising design/research projects. The program also provides the opportunity for formal study in nontechnical areas such as corporate finance, public policy, and regulatory issues.

Master of Science in Engineering

The M.S.E. program has a strong research focus, reflected in the requirement of a master's thesis. The course requirements are fulfilled by successfully completing 10 one-term courses, two of which are required research courses, CEE 509 and CEE 510. The M.S.E. is usually completed within two academic years of full-time study. Financial support in the form of a research or a teaching assistantship is available for students enrolled in this program.

By the second term of study, a committee consisting of the adviser and one additional faculty member is formed to guide and supervise the candidate in his or her research. Candidates must prepare and submit an acceptable thesis as well as present an open seminar on their research.

Doctor of Philosophy

Study leading to the degree of doctor of philosophy is offered in two areas: environmental engineering and water resources; and materials, mechanics, and structures. When a student enters the department, an adviser is assigned from the appropriate program, in the student's area of interest. The plan of study for the first year is arranged by the student, in consultation with the adviser and the department's director of graduate studies. A typical plan consists of eight courses, one being CEE 509, which is a required research course. Near the end of the first year, a student who wishes to continue as a Ph.D. candidate declares this intention to the department.

Students are expected to complete the general examination successfully within the first two years of their Ph.D. studies. Students are not normally readmitted to a third year (fifth term) of graduate study unless they have successfully completed the general examination. In no case are students admitted to a fourth year (seventh term) of graduate study unless they have passed the general examination. The specific requirements for the examination are different in the two programs, and students should consult the department for details about the examination requirements.

Upon completion of the general examination, the student must have in place a research committee consisting of the adviser and two or more additional members. The research committee meets with the candidate at least once per year to supervise his or her research.

Two to three years is usually necessary for completion of a suitable dissertation after completion of the general examination. Upon completion and acceptance of the dissertation by the department, the candidate is admitted to the final public oral examination, in which the dissertation is presented and defended by the candidate.

Teaching experience is considered to be a significant part of the graduate education. It is recommended that Ph.D. candidates assist with course instruction for at least one term.

English Proficiency Requirements

All international students who are not native speakers of English and who are candidates for the Ph.D. in civil and environmental engineering are required to pass the Princeton Oral Proficiency Test (POPT). Students who do not pass the POPT by January of their second year of enrollment will have their reenrollment decision (for year three) deferred until the results of the May examination are available. Students who do not pass the POPT by May of their second year of enrollment are not reenrolled to a third year of Ph.D. study, although they may switch to the M.S.E. track. Students are not appointed as an assistant in instruction until they have passed the POPT. Students are required to enroll in the term-time English Language Program (ELP), offered by the McGraw Center for Teaching and Learning, for each term of enrollment until they pass the POPT.

M.Eng. and M.S.E. students are not required to pass the POPT. However, unless exempted prior to the initial date of enrollment, such students are still required to enroll in the term-time ELP at

the McGraw Center for Teaching and Learning until they pass the POPT or complete all degree requirements.

Fellowships and Assistantships

All first-year Ph.D. students are supported on University fellowships, consisting of full tuition and fees, and a competitive stipend.

The department has been able to support all continuing doctoral students and most M.S.E. students through a combination of fellowships, research assistantships, and teaching assistantships. In addition to this basic support, students usually continue to work on their research projects during the two summer months, during which additional funding is provided.

Upon arrival at Princeton, each student is assigned to an ongoing research project under the supervision of a faculty member, whose interests seem compatible with those of the student as presented in the student's career statement. At the end of the first year, a student may request reassignment to a different project, and the department will make every attempt to accommodate such a request within the budgets and needs of the various research areas.

The workloads associated with the assistantships are such that they do not interfere with a full-time graduate program. In fact, duties required by a research assistantship generally form the basis for the student's thesis.

Equipment and Facilities

The equipment and facilities that are common to all departments of the School of Engineering and Applied Science include the Engineering School Library, a central machine shop, and an instrumentation center. Departmental computer facilities include many different state-of-the-art scientific workstations from multiple manufacturers, and access to parallel computing systems.

The department has state-of-the-art laboratory facilities that are equipped to conduct research in the biodegradation of hazardous wastes; building materials (cement, concrete, steel, and stone); geophysics; hydraulics; mechanics; porous media; soil mechanics; structural engineering; and water quality. Equipment for field work is also available in these laboratories.

Courses

CEE 507 Master's Project I

Staff

Under the direction of a faculty member, each student carries out a master's project and presents the results. Master's Project I is usually taken during the fall semester of the M.Eng. degree.

CEE 508 Master's Project II

Staff

A continuation of CEE 507, each student carries out a master's project, writes a report, and presents the results. Master's Project II is usually taken during the spring semester of the M.Eng. degree.

CEE 509 Directed Research

Staff

Under the direction of a faculty member, each student carries out research and presents the results. Directed research is normally taken during the first year of study.

CEE 510 Research Seminar

Staff

A continuation of CEE 509, each student writes a report and presents research results. Doctoral candidates must complete this course one semester prior to taking the general examination.

Areas of Concentration and Related Courses

The following areas of concentration are described in the context of research and instruction at Princeton. The student's choice of an area and the route he or she wishes to follow determine the makeup of his or her study and research.

Mechanics, Materials, and Structures. Current research work in earthquake engineering, structural engineering, and computational mechanics includes the analysis and design of structures in seismically active areas; synthesis of earthquake ground motion; soil liquefaction and its effect on structures; linear and nonlinear finite-element methods; use of parallel computing in structural engineering; nonlinear dynamic analysis of structures; probabilistic mechanics and structural reliability; stochastic finite-element methods; vulnerability of buildings to progressive collapse; improvement of related codes and standards; response of structures to extreme loads (impact/blast/fire); sensors for structural-condition assessment; methods of multihazard risk assessment and management; numerical modeling of fire-structure interactions; fluid-structure interactions; soil-structure interactions; cavitating flows; and dynamic/explosive impact on structures.

Current research work in materials includes the determination of the bulk mechanical and transport properties of porous materials; anomalous behavior of liquids in nanoporous materials; mechanisms responsible for deterioration of concrete and other building materials, particularly by crystallization of salt and ice; and the structure and properties of gels. Computational materials research includes numerical simulation of crack growth and propagation in layered and polycrystalline structures and topology optimization of materials microstructure. Students can participate in the Princeton Institute for the Science and Technology of Materials (PRISM), which provides special courses, experimental facilities, and interdisciplinary interactions necessary for research in modern materials science and engineering.

A project on sequestration of carbon dioxide in saline aquifers involves numerical simulation of transport of injected CO₂ in deep aquifers and deterioration of cement in existing oil wells by the acidic brine. The work is done in collaboration with colleagues in the Program in Environmental Engineering and Water Resources (EEWR) who are studying geochemical interactions, the contamination of drinking water, and other related problems.

Current research in the history of technology includes a program of study on the transfer of technology from Europe to the United States, focused on structural engineering (NSF); research on bridge design that links techniques and aesthetics; research on the structuring of major American river basins, with an emphasis on the design, construction, and environmental consequences of large-scale federal dams; and research on major engineering innovations in the United States between 1876 and 1939.

Courses

CEE 511 Design of Large-Scale Structures: Buildings

Staff

Focusing on the structural design of buildings, this course is open to students from engineering and architecture. Structural design is considered from concept development to the completion of detailed design; alternative systems, materials, and the like are debated, as are some fundamentals of structural engineering. Gravity, earthquakes, and wind analyses make use of both computer and manual calculations. For a range of building types, from museums to high-rise, class time is replete with PowerPoint presentations. A visit to the offices of a consulting engineer is offered (in order to meet young engineers and discuss office organization, continuing education, etc.), but is not mandatory. Teams of two or three students select alternative concepts of a specific project for detailed investigation. While drawings of the as-built building are provided as a reference, each team develops its own design, presenting it in a project book. For one hour before each class, the instructor is available for private consultation.

CEE 512 Design of Large-Scale Structures: Bridges

Staff

The design of bridges is considered from the conceptual phase up to the final design phase. The course addresses the following issues: bridge types, design codes, computer modeling of bridges, seismic analysis and design, seismic retrofit design, inspection, maintenance and rehabilitation of bridges, movable bridges, bridge aerodynamics, and organization of a typical engineering firm, and marketing for engineering work. Several computer codes for analysis and design of bridges are used in this course.

CEE 513 Introduction to Finite-Element Methods

Staff

Basic concepts of matrix structural analysis. Direct stiffness method. Axial force member. Beam bending member. Formation of element stiffness matrix. Assembling of global stiffness matrix. Introduction of boundary conditions. Solution of linear algebraic equations. Special analysis procedures. The finite-element method. Introduction. Basic formulation. Plane stress and plane strain problems. Plate bending problems. The use of structural analysis and finite-element computer codes is emphasized throughout the course.

CEE 514 Structural Dynamics and Earthquake Engineering

Jean-Hervé Prévost

Analysis of forces and deformations in structures under dynamic loads. Idealization as discrete parameter systems. Single and multiple degrees of freedom. Response analysis under free vibration, harmonic, periodic, impulsive, and general dynamic loads. Time and frequency domains. Distributed parameter systems. Earthquake phenomena from the engineering point of view. Faulting and seismic waves. Measurement of strong ground motion. Influence of geology. The concept of response spectra, structural response to earthquakes, and design criteria.

CEE 515 Geotechnical Engineering

Staff

Introduction to geotechnical/foundation engineering, subsurface material types and their properties, character of natural deposits, techniques of subsurface investigation, stability of

slopes, earth retaining structures, types of foundation and methods of construction, design of shallow foundations (footings and raft/mat foundations), design of deep foundations (piles and caissons), ground improvement techniques, use of computers in geotechnical engineering.

CEE 521 Continuum Mechanics

Peter C. Y. Lee

Index notation and Cartesian tensors; stress and kinematics of a continuum; field equations from the fundamental principles of conservation of mass, balance of linear and angular momenta, and conservation of energy; constitutive equations for linear elastic solid and ideal fluid; reduction of the three-dimensional equations of linear elasticity to those for the plane stress and plane strain theories; application to torsion, bending, and two-dimensional problems of elastostatics.

CEE 522 Random Vibration Theory and Applications to Earthquake and Wind Engineering

Erik H. VanMarcke

A review of probability theory. The course explores random processes: correlation functions, stationary random processes, ergodic theorem, and power spectral density function. Input-output relation of linear one-degree-of-freedom systems, multi-degree-of-freedom systems, and continuous systems are also studied. Simulation of stochastic processes, fields, and waves; Monte Carlo simulation; response to nonstationary and non-Gaussian random loads; response of nonlinear systems; and earthquake and wind engineering applications are emphasized throughout the course.

CEE 523 Mechanics of Dissipative Media

Jean-Hervé Prévost

The development of constitutive equations for nonlinear, anisotropic viscoelastic, and plastic media. The course gives an analysis of plastic yielding, fatigue under cyclic loading, and failure. It examines limit-analysis techniques; elastoplastic rate equations; finite deformation of plastic bodies; uniqueness and stability of incremental solutions; and loss of ellipticity, bifurcation phenomena, and emergence of shear bands.

CEE 524 Random Heterogeneous Materials (see MSE 515)

CEE 525 Applied Numerical Methods

Yin Lu (Julie) Young

The course introduces students to a broad spectrum of numerical methods for the analysis of typical mathematics, physics, or engineering problems. Topics covered include error analysis, interpolation, and polynomial approximation; numerical differentiation and integration; ordinary differential equations; and partial differential equations.

CEE 531 Elastodynamics

Peter C. Y. Lee

A review of the equations of the 3-D theory of linear elasticity. The course explores uniqueness of solutions and boundary conditions; reduction to wave equations; propagation, reflection, and refraction of waves; Rayleigh and Love surface waves in semi-infinite solids; Rayleigh-Lamb waves in plates; various approximate 2-D and 1-D equations of motion for plates, beams, and

rods, and an examination of their accuracy in dispersions and applicable ranges of frequencies; and methods to extend the approximate equations to higher frequencies and to anisotropic or piezoelectric materials.

CEE 532 Advanced Finite-Element Methods

Jean-Hervé Prévost

Special techniques for solving classes of linear and nonlinear elliptic, parabolic, and hyperbolic and eigenvalue problems encountered in structures and mechanics. The course explores implicit, explicit, and implicit-explicit elements and subdomain strategies in transient analysis; stability, consistency, and accuracy of integration procedures; error estimates; approximation properties; and computer implementation. Prerequisite: a working knowledge of a computer language.

CEE 533 Seminar in Advanced Elasticity

Peter C. Y. Lee

The governing equations of the 3-D theory of linear elasticity; compatibility conditions and uniqueness theorem of solutions; the tensor stress functions and Boussinesq-Papkovich displacement potentials; applications to the 3-D static-boundary value problems; orthogonal curvilinear coordinates; and the theory of thin elastic shells are studied.

CEE 539, 540 Special Topics in MMS (Mechanics, Materials, and Structure)

Staff

Advanced topics in mechanics, materials, and structures, or the investigation of problems of current interest are explored.

CEE 548 Risk Assessment and Management

Erik H. VanMarcke

Fundamentals of integrated risk assessment and risk-based decision analysis; stochastic modeling of natural and man-made hazards; evaluation of failure chances and consequences; decision criteria and acceptable risk; methods of risk assessment based on event trees, fault trees, system reliability, and stochastic processes in space and time: risk-based regulation, liability, and insurance. Students gain practical experience from case studies involving energy-related technologies, the environment, civil infrastructure, and financial risk. There is a mixture of lectures and weekly precepts.

CEE 558 Random Fields and Random Media

Erik H. VanMarcke

A synthesis of methods to describe, analyze, and where appropriate, predict and control random fields or distributed disordered systems. Second-order analysis of space-time processes, spectral parameters, level excursions, and extremes, and simulation and parameter estimation. A range of practical applications in engineering, the sciences, and finance are studied.

CEE 567 Advanced Design and Behavior, and Steel Structures

Maria Garlock

Advanced topics in the design and analysis of steel structures are considered, including plastic analysis, ductile lateral systems, behavior and design for fire, and local and global stability issues.

Pertinent Courses in Allied Departments, Schools, and Institutes

Chemical Engineering

501 Fluid Mechanics
522, 523 Colloidal Dispersions I and II
524 Introduction to Statistical Mechanics
531 Synthesis and Processing of Ceramic Matrix Composites
532 Interfacial Science and Engineering
544 Solid-State Properties of Polymers

Geosciences

501 Physics and Chemistry of Minerals and Materials
543 Rock Fracture
552 Global Seismology
553 Lithospheric Seismology
557 Theoretical Geophysics

Mechanical and Aerospace Engineering

501 Mathematical Methods of Engineering Analysis I
502 Mathematical Methods of Engineering Analysis II
542 Advanced Dynamics
551 Fluid Mechanics
553 Turbulent Flow
557 Simulation and Modeling of Fluid Flows
558 Simulation and Modeling of Turbulent Fluid Flows
562 Fracture Mechanics
564 Structural Materials

Operations Research and Financial Engineering

405 Regression and Applied-Time Series
515 Asset Pricing II: Stochastic Calculus and Advanced Derivatives
534 Financial Engineering

School of Architecture

514, 515 The Environmental Engineering of Buildings, Parts I and II
516 Architectural Acoustics and Lighting
562 The Professional Practice of Architecture
570 The Sociology of Contemporary Design
574 Computing and Imaging in Architecture

Woodrow Wilson School

535 Planning Methods

Princeton Institute for the Science and Technology of Materials (PRISM)

501 Introduction to Materials
502 Thermodynamics and Kinetics of Materials
503 Structure of Materials

504 Modeling and Simulation in Materials Science

505 Characterization of Materials

Environmental Engineering and Water Resources. The EEW program provides students with the training necessary to analyze quantitatively a broad spectrum of environmental and water resource problems, which by nature are multidisciplinary. Students and faculty in the Department of Civil and Environmental Engineering interact strongly with faculty from other departments and programs, such as atmospheric and oceanic sciences, chemical engineering, chemistry, ecology and evolutionary biology, geosciences, and the Princeton Environmental Institute as well as affiliated faculty at the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL). The interdepartmental element of the program provides students with opportunities to formally combine studies in civil engineering, atmospheric and oceanic sciences, ecology, and geological and geophysical sciences. To provide the sound background necessary for conducting significant research and carrying out applications in the area of environmental engineering and water resources, advanced analytical, numerical, and statistical methods are combined with elements of environmental fluid mechanics, geochemistry, hydroclimatology, hydrogeology, hydrology, and water quality.

Courses

CEE 505 Introduction to Probability Modeling in Civil Engineering and Environmental Sciences
Ignacio Rodriguez-Iturbe

An introduction to the treatment of uncertainty by the engineer and the scientist in a variety of situations. Special emphasis is on the direct application of all concepts and techniques to a broad range of problems in civil and environmental engineering, ecology, and hydrology. Stochastic modeling is stressed.

CEE 571 Environmental Chemistry
Catherine A. Peters

A focus on organic pollutants in the environment through the study of the theoretical basis for chemical, physicochemical, and microbiological processes. This foundation is used to explain chemical property estimation methods for phenomena such as phase partitioning, diffusion, and biodegradation. These processes are examined with respect to their implications for remediation technologies.

CEE 572 Geomicrobiology (see GEO 523)

CEE 573 Environmental Issues Seminar (see ENV 524)

CEE 576 Water Quality Modeling and Analysis
Peter R. Jaffé

The construction and solution of water-quality models for transport and transformation of pollutants in surface runoff, streams, lakes, estuaries, and groundwaters; and the basic principles of water-quality modeling are studied. The course reviews existing models and the utility and appropriateness of various modeling techniques for analysis and prediction.

CEE 577 Data Analysis and Modeling for the Environmental Sciences
Staff

A multidisciplinary course offering a practical introduction into a variety of methods for analysis and modeling of large data sets. Topics covered include sampling, image processing, spectral analysis, numerical simulations, and extreme-value statistics. Illustrative applications include seismic tomography, image deblurring, atmospheric fluctuations, and the analysis of flood peaks.

CEE 581 Theory of Groundwater Flow

Michael A. Celia

Fundamental physics of fluid flow and contaminant transport in porous media; derivation of governing equations; analytical solution of simplified equations, with application to well hydraulics; and parameter estimation and analysis of field problems are studied. The course examines the application of numerical models, and gives an introduction to multiphase flow systems and advanced methods for equation development.

CEE 582 Advanced Groundwater Modeling

Michael A. Celia

Advanced treatment of fluid flow and contaminant transport in natural porous media is studied. The course gives a comparison of the methodologies for deriving porous media equations, including volume averaging and stochastic methods; and explores the development of numerical methods for various flow and transport systems, the influence of heterogeneity and scale issues, and the use of numerical models to study scale effects in unsaturated flow, multiphase flow, and reactive transport. Some familiarity with numerical methods is assumed. Prerequisite: CEE 581.

CEE 586 Physical Hydrology

Eric F. Wood

Problems in surface hydrology, based on the underlying physics are explored. Precipitation and evapotranspiration; mechanisms of surface-runoff generation; propagation of flood waves overland and in channels; and water-balance modeling are studied.

CEE 587 Ecohydrology (also ENV 587)

Ignacio Rodriguez-Iturbe

A description of the hydrologic mechanisms that underlie ecological observations is studied. The space-time dynamics of soil-plant-atmosphere are studied at different temporal and spatial scales. A review is done of the role of environmental fluctuations in the distribution of vegetation. Emphasis is made in the dynamics of soil moisture. The signatures revealing fractal structures in landscapes and vegetation are reviewed as a result of self-organizing dynamics. Unifying concepts in the processes responsible for these signatures are studied, with examples from hydrology and ecology.

CEE 591 Radar Hydrometeorology

James A. Smith

Remote sensing of precipitation and the hydrometeorology of precipitation are the paired topics of this course. The fundamentals of radar remote sensing are introduced. Propagation and the scattering and absorption of electromagnetic waves are covered. Principles of Doppler radar are introduced, followed by techniques for measurement of precipitation and winds. The structure and evolution of precipitating cloud systems are covered as well.

CEE 599, 600 Special Topics in Environmental Engineering and Water Resources
Staff

Advanced studies in selected areas of water resources. Special topics vary according to the instructor's and the students' interests.

Pertinent Courses in Allied Departments

Atmospheric and Oceanic Sciences

527 Atmospheric Radiative Transfer

537 Atmospheric Chemistry

547 Atmospheric Thermodynamics and Convection

573 Physical Oceanography

577 Weather and Climate Dynamics

578 Chemical Oceanography

Chemical Engineering

505 Advanced Heat and Mass Transfer

522, 523 Colloidal Dispersions I and II

Ecology and Evolutionary Biology

519 Theoretical Ecology

Undergraduate Courses of Interest

Several upperclass courses listed in the *Undergraduate Announcement* are open for election by graduate students who have not had equivalent courses before coming to graduate school.