

# Civil Engineering (CE)

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## **CE 111. Introduction to Civil Engineering. 1 Credit.**

This course is designed to introduce students to the field of civil engineering and to review the disciplines and types of jobs within the field. It also introduces the student to the roles and duties of a professional engineer. Students also work in groups on design projects to illustrate the steps involved in the design-build process.

## **CE 112. Computer Applications in Civil Engineering. 1 Credit.**

This course is designed to introduce students to the use of spreadsheet software, engineering applications, data analysis and basic programming methods to solve civil engineering problems.

## **CE 194. Individual Study. 1-3 Credits.**

## **CE 196. Field Experience. 1-15 Credits.**

## **CE 199. Special Topics. 1-5 Credits.**

## **CE 204. Surveying. 3 Credits.**

Measurements and errors; topographical and construction surveys; vertical and horizontal control methods; field exercises and computation techniques for surveying data; computation of earthwork volumes. 2 one-hour lectures, 1 three-hour laboratory. Prereq: MATH 105.

## **CE 212. Civil Engineering Graphic Communications. 3 Credits.**

Integrating manual drafting and computer-aided drafting/design in one course with emphases on civil engineering practices.

## **CE 291. Seminar. 1-3 Credits.**

## **CE 292. Global Practicum: Study Abroad. 1-15 Credits.**

Pre-Arranged study at accredited foreign institutions (study abroad), domestic institutions (National Student Exchange) or on approved study abroad programs. Pre-requisite: Sophomore standing and prior approval by International Student and Study Abroad Services and major department. Graded 'P' or 'F' (Undergraduate), or 'S' or 'U' (Graduate).

## **CE 294. Individual Study. 1-5 Credits.**

## **CE 299. Special Topics. 1-5 Credits.**

## **CE 303L. Civil Engineering Materials Laboratory. 1 Credit.**

Tests for evaluating raw materials and mix designs of different types of bituminous materials and Portland cement concrete. 1 three-hour laboratory. Prereq: ME 223. Co-req: CE 303, F S.

## **CE 303. Civil Engineering Materials. 2 Credits.**

Physical, mechanical and chemical properties of different types of bituminous materials and Portland cement concrete; industry standards for evaluating raw materials and mix designs. 2 one-hour lectures. Prereq: ME 223. F, S.

## **CE 309. Fluid Mechanics. 3 Credits.**

Statics, kinematics, and dynamics of fluid flow; momentum and energy concepts; flow through pipes; uniform flow in open channels; pumps and measurement of flow. 3 one-hour lectures. Prereq: ME 222. F, S.

## **CE 310. Fluid Mechanics Laboratory. 1 Credit.**

Visualization and verification of the concepts of fluid flow, pumps, turbines, and flow meters. 1 two-hour laboratory. Prereq: CE 309. F, S.

## **CE 316. Soil Mechanics. 3 Credits.**

Principles of soil mechanics including three-phase composition, classification, effective stress, consolidation, shear strength, compaction, and site investigation. 2 lectures, 1 two-hour laboratory. Prereq: ME 222, ME 223. Co-req or Prereq: MATH 266.

## **CE 343. Structural Engineering and Analysis. 4 Credits.**

Structural loading and analysis of statically determinate and indeterminate structures. Covers the elastic analysis and deformations of trusses, beams, and frames using force methods, displacement methods, matrix methods, and moment distribution. Prereq: ME 223.

## **CE 370. Introduction to Environmental Engineering. 3 Credits.**

Introduction to various municipal and industrial pollutants being introduced into water, air, and land systems and their effects on the environment. Application of chemical, physical, and biological principles to the management of these pollutants. 3 one-hour lectures. Prereq: CE 309, CHEM 122.

## **CE 371. Environmental Engineering Laboratory. 1 Credit.**

Water, wastewater, and solid waste analyses regarding their theory, objectives, and practices. Exposure to practical applications of the scientific and design theories presented in CE 370. 1 three-hour laboratory. Co-req: CE 370.

## **CE 379. Global Seminar. 1-6 Credits.**

NDSU instructed experience or field study in a foreign country. Conducted in English for residence credit. Pre-requisite: Prior approval by International Student and Study Abroad Services and major department. May be repeated. Standard Grading.

**CE 391. Seminar. 1-3 Credits.**

**CE 392. Global Practicum: Study Abroad. 1-15 Credits.**

Pre-Arranged study at accredited foreign institutions (study abroad), domestic institutions (National Student Exchange) or on approved study abroad programs. Pre-requisite: Sophomore standing and prior approval by International Student and Study Abroad Services and major department. Graded 'P' or 'F' (Undergraduate), or 'S' or 'U' (Graduate).

**CE 394. Individual Study. 1-5 Credits.**

**CE 397. Fe/Coop Ed/Internship. 1-4 Credits.**

**CE 399. Special Topics. 1-5 Credits.**

**CE 403. Civil Engineering Materials II: Steel, Wood and Polymers. 2 Credits.**

Composition, properties, structure, and behavior of steel, wood, and polymeric materials; elastic, plastic, and viscous behavior under various environmental and loading conditions. Prereq: CE 303. {Also offered for graduate credit - see CE 603.}

**CE 404. Reinforced Concrete. 3 Credits.**

Principles of design and analysis of reinforced concrete members, flexural and shear design of rectangular and tee beams, serviceability criteria, short and slender columns. 2 one-hour lectures, 1 two-hour session. Prereq: CE 343. F, S.

**CE 405. Advanced Reinforced Concrete. 2 Credits.**

Development and anchorage of reinforcement, details of reinforcement in flexural members, continuous beams and one-way slabs, slender columns, two-way slabs. 1 one-hour lecture, 1 two-hour session. Prereq: CE 404. F, S {Also offered for graduate credit - see CE 605.}

**CE 408. Water Resources and Supply. 3 Credits.**

Hydrologic concepts, development of water supply sources, principles involved in the collection and transportation of water/wastewater/storm runoff, and distribution of water for municipal use. Prereq: CE 309. F, S.

**CE 410. Water and Wastewater Engineering. 3 Credits.**

Principles involved in treatment, disposal, reuse, and recycling of municipal water supplies and wastewaters. Laboratory introduces tests to evaluate treatment requirements and effectiveness. 3 one-hour lectures, 1 three-hour laboratory. Prereq: CE 370. {Also offered for graduate credit - see CE 610.}

**CE 411. Design of Pre-stressed Concrete. 2 Credits.**

Theory and design of pre-stressed concrete structures, pre- and post-tensioning, loss of pre-stress, proportioning of flexural members, deflections. 2 one-hour lectures. Prereq: CE 404. S {Also offered for graduate credit - see CE 611.}

**CE 417. Slope Stability and Retaining Walls. 3 Credits.**

Performance and design of retaining walls, sheet pile walls, braced walls, and reinforced earth. Also evaluation and mitigation of unstable earth slopes. Prereq: CE 316. S {Also offered for graduate credit - see CE 617.}

**CE 418. Transportation Engineering. 4 Credits.**

Location, analysis, modeling, and design of multi-modal facilities including highways, railways, airports, terminals, harbors, ports, canals, waterways, pipelines, and conveyor systems. 3 one-hour lectures, 1 two-hour session. Prereq: CE 204, ME 221, MATH 259.

**CE 419. Pavement Design. 3 Credits.**

Design of flexible and rigid pavements including sub-grade, base courses, surface courses; evaluation criteria including soil, climate, traffic, material, drainage; initial and maintenance cost considerations; construction practices. 3 one-hour lectures. Co-req: CE 303. {Also offered for graduate credit - see CE 619.}

**CE 421. Open Channel Flow. 3 Credits.**

Geometric and hydraulic properties of open channels, continuity, momentum and energy principles, design of channels, gradually varied flow, critical flow and culvert design. 3 one-hour lectures. Prereq: CE 309. S {Also offered for graduate credit - see CE 621.}

**CE 425. Bridge Evaluation and Rehabilitation. 3 Credits.**

Topics include bridge evaluation methodologies, review of bridge codes, behavior of constructed bridges, sources of bridge deterioration, rehabilitation design with advanced composite materials, structural health monitoring. Prereq: CE 343 and CE 404. {Also offered for graduate credit - see CE 625.}

**CE 430. Timber and Form Design. 3 Credits.**

Analysis and design of wood structures and concrete formwork. 2 seventy-five minute lectures. Prereq: ME 223.

**CE 441. Finite Element Analysis. 3 Credits.**

Weak and strong solutions to governing differential equations in bars, boundary conditions, Galerkin approximation, nodal basis functions, shape functions. Beam and two-dimensional problems with triangular and quadrilateral elements. Prereq: CE 343. {Also offered for graduate credit - see CE 641.}

**CE 442. Matrix Analysis of Structures. 2 Credits.**

Review of matrix algebra, flexibility and stiffness methods, direct stiffness method, introduction to finite element analysis. 2 lectures. Prereq: CE 343. F, S {Also offered for graduate credit - see CE 642.}

**CE 444. Structural Steel Design. 3 Credits.**

Design of metal structures including mechanical behavior of metals; behavior and proportioning of tension and compression members; beams, beam columns, and connections; selection of metal structural systems. 2 one-hour lectures, 1 two-hour session. Prereq: CE 343. F.

**CE 445. Advanced Steel Design. 2 Credits.**

Analysis and design of metal structures including connections, selection of structural systems. 1 one-hour lecture, 1 two-hour session. Prereq: CE 444. S {Also offered for graduate credit - see CE 645.}.

**CE 446. Basic Dynamics of Structures. 3 Credits.**

Analysis of single degree of freedom structural systems to harmonic and general dynamic loading, free vibration of multiple degree of freedom systems, modal superposition, earthquake engineering. 3 one-hour lectures. Prereq: CE 343. F {Also offered for graduate credit - see CE 646.}.

**CE 447. Stability of Structures. 3 Credits.**

Concepts of stability of equilibrium; stability criteria, work, energy and variational methods; elastic buckling of columns, beams, frames, and plates; FE implementations of stability; design of locally unstable sections. Prereq: CE 343. {Also offered for graduate credit - see CE 647.}.

**CE 452. Fundamentals of Oil & Gas Pipeline: Design, Operation, Inspection & Maintenance. 3 Credits.**

This course introduces the fundamentals to design, operate, inspect, and maintain oil & gas pipelines, including basics for pipeline materials, design, network, construction, measuring and detection technology, maintenance, and repair. Prereq: CE 418. {Also offered for graduate credit - see CE 652.}.

**CE 454. Geometric Highway Design. 3 Credits.**

Location and design of highways and streets; design controls, elements of design; cross-section design; design of intersections, interchanges, safety appurtenances, and 3R projects. 2 one-hour lectures, 1 two-hour session. Prereq: CE 418. F {Also offered for graduate credit - see CE 654.}.

**CE 455. Airport Planning and Design. 2 Credits.**

System planning and demand forecasting; siting and configuration of airports; aircraft characteristics; air traffic controls; standards for geometric design, pavement design, drainage and safety. 2 one-hour lectures. Prereq: CE 418. F {Also offered for graduate credit - see CE 655.}.

**CE 456. Railroad Planning and Design. 3 Credits.**

Rail planning and location analysis, track/rail structure, track layout and control system, locomotives and train resistance, track safety standards and geometrics, terminal design. 3 one-hour lectures. Prereq: CE 418. F {Also offered for graduate credit - see CE 656.}.

**CE 457. Pavement Management Systems. 2 Credits.**

Pavement design, maintenance, and rehabilitation strategies; planning, budgeting, and programming for pavement management at network and project levels; development, design, and maintenance of pavement management systems. 2 one-hour lectures. Prereq: CE 303.

**CE 458. Bituminous Materials and Mix. 3 Credits.**

This course presents fundamental knowledge of asphalt material properties, performance requirements, specifications and related test characteristics. Prereq: CE 303 {Also offered for graduate credit - see CE 658.}.

**CE 461. Foundation Engineering. 3 Credits.**

Performance and selection of the following foundations: shallow, mat, combined pile, and drilled piers. 3 one-hour lectures. Prereq: CE 316. F {Also offered for graduate credit - see CE 661.}.

**CE 462. Designing with Geosynthetics. 2 Credits.**

Theories, principles, and engineering design using geosynthetic materials for a variety of civil engineering applications. Applications to geotechnical, environmental, transportation, and water resources fields are emphasized. Includes construction issues. Prereq: CE 316. S {Also offered for graduate credit - see CE 662.}.

**CE 463. Geotechnical Earthquake Engineering. 3 Credits.**

Wave propagation in soils, dynamic properties of soils, cyclic stress-strain behavior of soils, ground response analysis, liquefaction, soil-structure interaction, seismic design of foundations, retaining walls, and seismic slope stability analysis. Prereq: CE 316. {Also offered for graduate credit - see CE 663.}.

**CE 464. Advanced Soil Mechanics. 2 Credits.**

This course introduces the students to advanced topics in soil mechanics, 1) unsaturated soil mechanics and 2) molecular modeling of clay-fluid interactions, for the design of foundations, retaining walls and slopes for realistic soil moisture conditions. Prereq: CE 316. {Also offered for graduate credit - see CE 664.}.

**CE 471. Environmental Nanotechnology. 3 Credits.**

This course introduces nanotechnology with special emphasis on environmental science and engineering. Applications and environmental implications of nanotechnology will be discussed from a national and global perspective. Prereq: CE 370 for CE majors and ENVE 360 for ENVE majors. {Also offered for graduate credit - see CE 671.}.

**CE 472. Solid Waste Management. 3 Credits.**

Basic study of solid waste materials, current collection methods, available disposal techniques, recycling and resource conservation, and economics of solid waste collection and disposal. 3 one-hour lectures. Prereq: CE 370. {Also offered for graduate credit - see CE 672.}.

**CE 474. Groundwater Sustainability Design. 3 Credits.**

To study groundwater flow using mathematical, field, and computational methods; to become prepared to design solutions to North Dakota and international groundwater sustainability challenges. Prereq: CE 309. {Also offered for graduate credit - See CE 674.}.

**CE 476. Watershed Modeling. 3 Credits.**

Concepts of watershed, watershed hydrology, application of GIS tools, DEM-based watershed delineation, watershed hydrologic modeling, state-of-the-art watershed modeling software, and hands-on applications. Prereq: CE 408. {Also offered for graduate credit - see CE 676.}.

**CE 477. Applied Hydrology. 3 Credits.**

Scope of hydrology, hydrologic cycle and components, runoff volume and peak flow estimation, hydrograph analysis, probabilistic concepts in water resources, flood- frequency analysis, application of risk concepts to hydrological design, flow estimation for ungaged watersheds. Two 75-minute lectures. Prereq: CE 408. F {Also offered for graduate credit - see CE 677.}.

**CE 478. Water Quality Management. 3 Credits.**

Physical, chemical, biological, hydrological characteristics, and hydrodynamic elements of receiving waters. Characterizations, measurement, and modeling methods of river/streams, lakes/reservoirs, and groundwater systems. 2 one-hour lectures. Prereq: CE 370 for CE students and ENVE 360 for ENVE students. {Also offered for graduate credit - see CE 678.}.

**CE 479. Advanced Water and Wastewater Treatment. 3 Credits.**

Selected problems in the investigation and design of sewerage systems, water distribution systems, wastewater treatment plants, and water purification plants. 2 one-hour lectures. Prereq: CE 370 and CE 410 for CE majors or ENVE 412 for ENVE majors. {Also offered for graduate credit - see CE 679.}.

**CE 483. Contracts and Specifications. 3 Credits.**

Formation, interpretation, and termination of engineering contracts. Engineering specifications and drawings. Other legal matters of concern to engineers. 2 one-hour lectures. Prereq: Junior or Senior standing.

**CE 486. Nanotechnology and Nanomaterials. 3 Credits.**

This course covers principles of nanotechnology, nanomaterials and develops a framework for their understanding. The basic tools of nanotechnology: nanoscale characterization, physics and materials design will be discussed in the context of current technological advances. Prereq: Senior standing in Engineering or Sciences. Cross-listed with ME 486. {Also offered for graduate credit - see CE 686.}.

**CE 489. Senior Design. 3 Credits.**

An open-ended capstone design project encompassing a number of civil engineering disciplines. Management, business, public policy, and leadership concepts. Importance of professional licensure. 3 one-hour lectures. Prereq: Senior standing. F, S.

**CE 491. Seminar. 1-5 Credits.****CE 492. Global Practicum: Study Abroad. 1-15 Credits.**

Pre-Arranged study at accredited foreign institutions (study abroad), domestic institutions (National Student Exchange) or on approved study abroad programs. Pre-requisite: Sophomore standing and prior approval by International Student and Study Abroad Services and major department. Graded 'P' or 'F' (Undergraduate), or 'S' or 'U' (Graduate).

**CE 493. Undergraduate Research. 1-5 Credits.****CE 494. Individual Study. 1-5 Credits.****CE 496. Field Experience. 1-15 Credits.****CE 499. Special Topics. 1-5 Credits.****CE 603. Civil Engineering Materials II: Steel, Wood and Polymers. 2 Credits.**

Composition, properties, structure, and behavior of steel, wood, and polymeric materials; elastic, plastic, and viscous behavior under various environmental and loading conditions. {Also offered for undergraduate credit - see CE 403.}.

**CE 605. Advanced Reinforced Concrete. 2 Credits.**

Development and anchorage of reinforcement, details of reinforcement in flexural members, continuous beams and one-way slabs, slender columns, two-way slabs. 1 one-hour lecture, 1 two-hour session. F, S {Also offered for undergraduate credit - see CE 405.}.

**CE 610. Water & Wastewater Engineering. 3 Credits.**

Principles involved in treatment, disposal, reuse, and recycling of municipal water supplies and wastewaters. Laboratory introduces tests to evaluate treatment requirements and effectiveness. 3 one-hour lectures, 1 three-hour laboratory. F {Also offered for undergraduate credit - see CE 410.}.

**CE 611. Design of Pre-stressed Concrete. 2 Credits.**

Theory and design of pre-stressed concrete structures, pre- and post-tensioning, loss of pre-stress, proportioning of flexural members, deflections. 2 one-hour lectures. S {Also offered for undergraduate credit - see CE 411.}.

**CE 617. Slope Stability and Retaining Walls. 3 Credits.**

Performance and design of retaining walls, sheet pile walls, braced walls, and reinforced earth. Also evaluation and mitigation of unstable earth slopes. S {Also offered for undergraduate credit - see CE 417.}.

**CE 619. Pavement Design. 3 Credits.**

Design of flexible and rigid pavements including sub-grade, base courses, surface courses; evaluation criteria including soil, climate, traffic, material, drainage; initial and maintenance cost considerations; construction practices. 3 one-hour lectures. {Also offered for undergraduate credit - see CE 419.}.

**CE 621. Open Channel Flow. 3 Credits.**

Geometric and hydraulic properties of open channels, continuity, momentum and energy principles, design of channels, gradually varied flow, critical flow and culvert design. 3 one-hour lectures. S {Also offered for undergraduate credit - see CE 421.}.

**CE 625. Bridge Evaluation and Rehabilitation. 3 Credits.**

Topics include bridge evaluation methodologies, review of bridge codes, behavior of constructed bridges, sources of bridge deterioration, rehabilitation design with advanced composite materials, structural health monitoring. {Also offered for undergraduate credit - see CE 425.}.

**CE 630. Timber and Form Design. 3 Credits.**

Analysis and design of wood structures and concrete formwork. 2 seventy-five minute lectures. {Also offered for undergraduate credit - see CE 430.}.

**CE 641. Finite Element Analysis. 3 Credits.**

Weak and strong solutions to governing differential equations in bars, boundary conditions, Galerkin approximation, nodal basis functions, shape functions. Beam and two-dimensional problems with triangular and quadrilateral elements. F, S {Also offered for undergraduate credit - see CE 441.}.

**CE 642. Matrix Analysis of Structures. 2 Credits.**

Review of matrix algebra, flexibility and stiffness methods, direct stiffness method, introduction to finite element analysis. 2 lectures. F, S {Also offered for undergraduate credit - see CE 442.}.

**CE 645. Advanced Steel Design. 2 Credits.**

Analysis and design of metal structures including connections, selection of structural systems. 1 one-hour lecture, 1 two-hour session. S {Also offered for undergraduate credit - see CE 445.}.

**CE 646. Basic Dynamics of Structures. 3 Credits.**

Analysis of single degree of freedom structural systems to harmonic and general dynamic loading, free vibration of multiple degree of freedom systems, modal superposition, earthquake engineering. 3 one-hour lectures. F {Also offered for undergraduate credit - see CE 446.}.

**CE 647. Stability of Structures. 3 Credits.**

Concepts of stability of equilibrium; stability criteria, work, energy and variational methods; elastic buckling of columns, beams, frames, and plates; FE implementations of stability; design of locally unstable sections. {Also offered for undergraduate credit - see CE 447.}.

**CE 652. Fundamentals of Oil & Gas Pipeline: Design, Operation, Inspection & Maintenance. 3 Credits.**

This course introduces the fundamentals to design, operate, inspect, and maintain oil & gas pipelines, including basics for pipeline materials, design, network, construction, measuring and detection technology, maintenance, and repair. {Also offered for undergraduate credit - see CE 452.}.

**CE 654. Geometric Highway Design. 3 Credits.**

Location and design of highways and streets; design controls, elements of design; cross-section design; design of intersections, interchanges, safety appurtenances, and 3R projects. 2 one-hour lectures, 1 two-hour session. F {Also offered for undergraduate credit - see CE 454.}.

**CE 655. Airport Planning and Design. 2 Credits.**

System planning and demand forecasting; siting and configuration of airports; aircraft characteristics; air traffic controls; standards for geometric design, pavement design, drainage and safety. 2 one-hour lectures. F {Also offered for undergraduate credit - see CE 455.}.

**CE 656. Railroad Planning and Design. 3 Credits.**

Rail planning and location analysis, track/rail structure, track layout and control system, locomotives and train resistance, track safety standards and geometrics, terminal design. 3 one-hour lectures. F {Also offered for undergraduate credit - see CE 456.}.

**CE 658. Bituminous Materials and Mix. 3 Credits.**

This course presents fundamental knowledge of asphalt material properties, performance requirements, specifications and related test characteristics. {Also offered for undergraduate credit - see CE 458.}.

**CE 661. Foundation Engineering. 3 Credits.**

Performance and selection of the following foundations: shallow, mat, combined pile, and drilled piers. 3 one-hour lectures. F {Also offered for undergraduate credit - see CE 461.}.

**CE 662. Designing with Geosynthetics. 2 Credits.**

Theories, principles, and engineering design using geosynthetic materials for a variety of civil engineering applications. Applications to geotechnical, environmental, transportation, and water resources fields are emphasized. Includes construction issues. S {Also offered for undergraduate credit - see CE 462.}.

**CE 663. Geotechnical Earthquake Engineering. 3 Credits.**

Wave propagation in soils, dynamic properties of soils, cyclic stress-strain behavior of soils, ground response analysis, liquefaction, soil-structure interaction, seismic design of foundations, retaining walls, and seismic slope stability analysis. {Also offered for undergraduate credit - see CE 463.}.

**CE 664. Advanced Soil Mechanics. 2 Credits.**

This course introduces the students to advanced topics in soil mechanics, 1) unsaturated soil mechanics and 2) molecular modeling of clay-fluid interactions, for the design of foundations, retaining walls and slopes for realistic soil moisture conditions. {Also offered for undergraduate credit - see CE 464.}.

**CE 671. Environmental Nanotechnology. 3 Credits.**

This course introduces nanotechnology with special emphasis on environmental science and engineering. Applications and environmental implications of nanotechnology will be discussed from a national and global perspective. {Also offered for undergraduate credit - see CE 471.}.

**CE 672. Solid Waste Management. 3 Credits.**

Basic study of solid waste materials, current collection methods, available disposal techniques, recycling and resource conservation, and economics of solid waste collection and disposal. 3 one-hour lectures. {Also offered for undergraduate credit - see CE 472.}.

**CE 674. Groundwater Sustainability Design. 3 Credits.**

To study groundwater flow using mathematical, field, and computational methods; to become prepared to design solutions to North Dakota and international groundwater sustainability challenges. {Also offered for undergraduate credit - See CE 474.}.

**CE 676. Watershed Modeling. 3 Credits.**

Concepts of watershed, watershed hydrology, application of GIS tools, DEM-based watershed delineation, watershed hydrologic modeling, state-of-the-art watershed modeling software, and hands-on applications. {Also offered for undergraduate credit - see CE 476.}.

**CE 677. Applied Hydrology. 3 Credits.**

Scope of hydrology, hydrologic cycle and components, runoff volume and peak flow estimation, hydrograph analysis, probabilistic concepts in water resources, flood- frequency analysis, application of risk concepts to hydrological design, flow estimation for ungaged watersheds. Two 75-minute lectures. F {Also offered for undergraduate credit - see CE 477.}.

**CE 678. Water Quality Management. 3 Credits.**

Physical, chemical, biological, hydrological characteristics, and hydrodynamic elements of receiving waters. Characterizations, measurement, and modeling methods of river/streams, lakes/reservoirs, and groundwater systems. 2 one-hour lectures. {Also offered for undergraduate credit - see CE 478 .}.

**CE 679. Advanced Water and Wastewater Treatment. 3 Credits.**

Selected problems in the investigation and design of sewerage systems, water distribution systems, wastewater treatment plants, and water purification plants. 2 one-hour lectures. {Also offered for undergraduate credit - see CE 479.}.

**CE 686. Nanotechnology and Nanomaterials. 3 Credits.**

This course covers principles of nanotechnology, nanomaterials and develops a framework for their understanding. The basic tools of nanotechnology: nanoscale characterization, physics and materials design will be discussed in the context of current technological advances. Cross-listed with ME 686. {Also offered for undergraduate credit - see CE 486.}.

**CE 690. Graduate Seminar. 1-3 Credits.****CE 695. Field Experience. 1-15 Credits.****CE 696. Special Topics. 1-5 Credits.****CE 701. Theory of Elasticity. 2 Credits.**

Theoretical and applied study of the classical theories of plates and shells as they pertain to engineering problems including small displacement of rectangular and circular plates and thin shells. 2 one-hour lectures.

**CE 702. Plates and Shells. 2 Credits.**

A theoretical study of linear elasticity, Saint Venant's problems, plain stress, plain strain, strain energy, and torsion. 2 one-hour lectures.

**CE 706. Plastic Design in Structural Steel. 2 Credits.**

Inelastic bending of beams and frames, application of upper and lower bound theorems, calculation of deflection, effect of axial and shearing forces on flexural strength, connections, structural safety, and rules of plastic design. 2 one-hour lectures.

**CE 709. Dynamics of Structures and Foundations. 2 Credits.**

Advanced topics in structural dynamics, frequency domain response, generalized coordinates, nonlinear structural response, dynamic analysis of framed structures, structures with distributed properties, seismic design considerations. 2 one-hour lectures.

**CE 714. Theory of Elastic Stability. 2 Credits.**

Bending of beams under simultaneous action of axial and lateral loads, buckling of compressed bars in both the elastic and plastic ranges, design formulas, lateral buckling of beams. 2 one-hour lectures.

**CE 720. Continuum Mechanics. 3 Credits.**

Tensor analysis in affined and metric spaces, kinematics of motion, general principles of continuum mechanics, thermodynamics of deformation, and postulates on constitutive laws. 3 one-hour lectures. Cross-listed with ME 720. F.

**CE 725. Biomaterials-Materials in Biomedical Engineering. 3 Credits.**

This course covers the fundamentals of synthesis, properties, and biocompatibility of metallic, ceramic, polymeric and composite materials that are designed for replacement of biological materials such as hard and soft tissues.

**CE 738. Deep Learning for Engineers. 3 Credits.**

This is an introductory course for Deep learning. The students will become familiar with the mathematical background, applications, and limitations of popularly used deep neural network architectures for supervised deep learning tasks. Students will be expected to write codes in standard programming languages. Students without programming experience will be given directed readings and tutorials to cope up with the coding part of this course. Prereq: ENGR 729 Machine Learning for Engineers is the prerequisite for this course. Alternatively, graduate students in any department with good mathematical/ coding/ AI background can request the instructor to waive the prerequisite.

**CE 739. Computational Methods for Engineering. 3 Credits.**

This course introduces computational methods for graduate students with special emphasis on computational mechanics. Computational methods using High-Performance Computing techniques will be discussed for a wide range of applications. Success in this course requires preexisting familiarity with elementary techniques for solving elementary differential equations. Permission of instructor is required for enrollment.

**CE 757. Pavement Evaluation and Rehabilitation. 3 Credits.**

Advanced knowledge of pavement performance; pavement evaluation; implementation of pavement management at network and project level; maintenance and rehabilitation strategies; life-cycle-cost analysis.

**CE 762. Advanced Foundation Engineering. 2 Credits.**

Advanced topics in performance and design of foundations. Current topics include a two-dimensional finite element analysis of the foundation and its supporting soil. 2 one-hour lectures. Prereq: CE 661.

**CE 770. Hazardous Waste Site Remediation. 3 Credits.**

Overview of hazardous waste issues, classification, legislation, process fundamentals, fate and transport of contaminants, management, and treatment/remediation methods. 3 one-hour lectures. S.

**CE 771. Economics of Transportation Systems. 3 Credits.**

The course will provide an understanding of transportation economics and policy issues facing society. Topics include transportation demand, model costs, transportation competition and market power, transportation regulation, transportation investment, and the economics of transportation safety. Cross-listed with AGECE 771.

**CE 772. Rural Logistics and Distribution Management. 3 Credits.**

Logistical systems and concepts, distribution management, management of railroads and motor carriers, and location of facilities. Includes agribusiness and natural resource case studies. Cross-listed with AGECE 772.

**CE 776. Ground Water and Seepage. 3 Credits.**

Groundwater as a resource, relation to hydrologic cycle, well hydraulics, seepage, ground water quality and contamination, ground water flow models. 3 one-hour lectures. S.

**CE 778. Transportation Administration. 3 Credits.**

Public organization behavior and administration, fund accounting, public budgeting, financial management, and strategic management of transportation agencies. Includes transportation case studies.

**CE 779. Watershed Water Quality Modeling. 3 Credits.**

Watershed characteristics, non-point source pollution and modeling, latest watershed-scale water quality modeling tools and software, hands-on applications.

**CE 780. Transportation Planning. 3 Credits.**

Types of transportation planning; history of urban and statewide transportation planning; development and trends in travel demand forecasting; trip generation, trip distribution, mode choice, traffic assignment; transportation plans for modal, and multi-modal alternatives; policy formulation and analysis. 1 three-hour lecture. S.

**CE 781. Traffic Engineering. 3 Credits.**

Traffic characteristics, studies, and control devices; operations analysis and design; aspects of signing, signalization, markings, and lighting; accident analysis; traffic laws and ordinances; work zone safety practices; arterial and freeway management. 1 three-hour lecture plus two-hour laboratory work. S.

**CE 782. Introduction to Intelligent Infrastructure. 3 Credits.**

Intelligent infrastructure and associated technologies for sensing, detection, and measurements used in civil infrastructure applications (can be applied to structure, transportation, and geotechnical engineering field).

**CE 790. Graduate Seminar. 1-3 Credits.****CE 791. Temporary/Trial Topics. 1-5 Credits.****CE 793. Individual Study/Tutorial. 1-5 Credits.****CE 795. Field Experience. 1-15 Credits.****CE 796. Special Topics. 1-5 Credits.****CE 797. Master's Paper. 1-3 Credits.****CE 798. Master's Thesis. 1-10 Credits.****CE 892. Graduate Teaching Experience. 1-6 Credits.****CE 899. Doctoral Dissertation. 1-15 Credits.**