

EN.560 (CIVIL ENGINEERING)

EN.560.100. Civilization Engineered. 3 Credits.

Civilizations have always faced challenges – whether naturally occurring or manmade – and have had to design solutions in order to survive. Our modern civilization is no different; we face major societal challenges related to resilient cities, human safety and security, decision-making and healthcare, energy infrastructure, and space exploration and habitation, among others, and solving these challenges will require an interdisciplinary approach. This course will look to the past – studying the engineering solutions developed by ancient civilizations – and at the current state of affairs – in preparation for designing solutions to the grand challenges of the future.

Area: Engineering

EN.560.101. Freshman Experiences in Civil Engineering. 1 Credit.

An introduction to civil engineering for first-year students. This course welcomes freshmen to the major by exploring civil engineering design and the range of design projects in which professional civil engineers engage. Students will have the opportunity to practice the design process using hands-on team-based projects, with emphasis on creative design, graphical communication, and teamwork.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

Area: Engineering

EN.560.141. Perspectives on the Evolution of Structures. 3 Credits.

Why do buildings and bridges look the way they do today? Students will be provided the tools to answer this question for themselves through a study of the history of the design of buildings and bridges throughout the world from both engineering and architectural/aesthetic perspectives. Only simple mathematics is required (no calculus). Students will participate in individual and group critique of structures from engineering, architectural, and social points of view.

Area: Engineering, Quantitative and Mathematical Sciences
Writing Intensive

EN.560.191. CaSE Collaborative. 0.5 Credits.

From sketching to 3D printing, students in this course will work directly with the tools that civil and systems engineers use to plan and communicate their ideas. Hands-on learning activities will help students develop these skills, with an emphasis on communication and collaboration using graphical tools such as CAD and GIS software and physical specimens fabricated with manual construction and 3D printing.

Area: Engineering, Natural Sciences

EN.560.201. Statics & Mechanics of Materials. 3 Credits.

This course combines statics - the basic principles of classical mechanics applied to the equilibrium of particles and rigid bodies at rest, under the influence of various force systems - with mechanics of materials - the study of deformable bodies and the relationships between stresses and deformations within those bodies. Fundamental concepts in statics include the proper use of free body diagrams, the analysis of simple structures, centroids and centers of gravity, and moments of inertia. The study of mechanics of materials will focus on the elastic analysis of axial force, torsion, and bending members to determine corresponding stresses and strains. Stress transformations and principal stresses will be introduced.

Prerequisite(s): AS.171.101 OR AS.171.107 OR (EN.530.123 AND EN.530.124) or instructor permission.

Corequisite(s): EN.560.211

Area: Engineering

EN.560.202. Dynamics. 4 Credits.

Basic principles of classical mechanics applied to the motion of particles, system of particles and rigid bodies. Kinematics: analytical description of motion; rectilinear and curvilinear motions of particles; rigid body motion. Kinetics: force, mass, and acceleration; energy and momentum principles. Introduction to vibration. Includes laboratory experience.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.; (EN.560.201 OR EN.530.201) AND AS.110.109

Area: Engineering

EN.560.206. Solid Mechanics & Theory of Structures. 3 Credits.

Application of the principles of structural analysis for statically determinant and indeterminate structures (trusses, cables, beams, arches, and frames). Calculation of internal forces and stresses in members and structures. Determination of deflections by equilibrium and energy methods. Analysis of indeterminate structures by flexibility and stiffness methods.

Prerequisite(s): EN.560.201 OR EN.530.201

Area: Engineering

EN.560.207. Civil Engineering Undergraduate Research Laboratory. 1 Credit.

Laboratory course to be taken by Civil Engineering students concurrently with EN.560.206 (Solid Mechanics & Theory of Structures).

Prerequisite(s): To be taken concurrently with EN.560.206.; Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

Area: Engineering

EN.560.211. Statics and Mechanics of Materials Laboratory. 1 Credit.

The complementary laboratory course for and required corequisite to EN.560.201 Statics and Mechanics of Materials.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

Corequisite(s): EN.560.201

Area: Engineering

EN.560.220. Civil Engineering Programming. 3 Credits.

Civil engineering problems are formulated and then solved by numerical methods. Matrix inversion, data fitting and interpolation, root-finding, and solutions of ordinary and partial differential equations are presented. Matlab programming will be introduced to facilitate the solutions. Recommended Course Background: AS.110.106/AS.110.108, AS.110.107/AS.110.109

Area: Engineering

EN.560.240. Uncertainty, Reliability and Decision-making. 3 Credits.

Development and applications of the analysis of uncertainty, including basic probability, statistics and decision theory, with applications in various engineering disciplines, with some emphasis on problems in civil and systems engineering.

Area: Engineering, Quantitative and Mathematical Sciences

EN.560.291. CaSE Coding. 0.5 Credits.

Having taken a computing course in the freshman year, students will further develop their programming skills to solve, understand, or automate problems specific to civil and systems engineering.

Prerequisite(s): AS.110.109 AND EN.500.112

Area: Engineering

EN.560.302. Structural Systems II. 3 Credits.

This second course in the two-course structural systems sequence will reinforce the structural design workflow from concept and ideation to structural modeling and analysis to limit states design, but with a focus on the analysis and design of structural systems composed of bending members (e.g. frames). Connections to mechanics-based principles will again be emphasized and practical applications using common structural materials such as timber, steel, and reinforced concrete will be covered.

Area: Engineering

EN.560.305. Soil Mechanics. 4 Credits.

Basic principles of soil mechanics. Classification of soils. Compaction theory. Consolidation seepage and settlement analysis. Stress-strain and shear strength of soils. Introduction to earth pressure theories and slope stability analysis.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.560.206 OR EN.570.351

Area: Engineering

EN.560.320. Structural Design I. 3 Credits.

Introduction to structural design using common building materials (structural steel, reinforced concrete, and wood). Emphasis will be placed on the application of solid mechanics principles to the design of structural components (beams, columns, and tension members).

Prerequisite(s): EN.560.206

Area: Engineering

EN.560.325. Structural Design II. 3 Credits.

A continuation of Structural Design I, this course explores the behavior and conceptual design of structures. Emphasis is placed on identifying load paths through typical gravity and lateral load systems, modeling loads on real structures, and designing structural systems. Designing connections capable of transferring loads through a structural system will also be covered. Recommended Course Background: EN.560.320

Prerequisite(s): EN.560.320

Area: Engineering

EN.560.330. Foundation Design. 3 Credits.

Application of soil mechanics theory and soil test results to the analysis and design of foundations for structures; retaining walls; embankments; design of pile and shallow footing foundations; slope stability.

Prerequisite(s): EN.560.305

Area: Engineering

EN.560.348. Probability & Statistics in Civil Engineering. 3 Credits.

Development and applications of the analysis of uncertainty, including basic probability, statistics and decision theory, in civil engineering systems. Recommended Course Background: AS.110.109.

Area: Engineering, Quantitative and Mathematical Sciences

EN.560.391. Seminar/Prof Dev. 0.5 Credits.

Civil Engineering Seminar provides students with opportunities to explore the wide range of civil engineering career paths (e.g. consulting, academia, government, industry, and construction) through invited speakers, field trips to design offices / construction sites, and attendance at professional society meetings. Topics related to engineering ethics, professional licensure, and other professional issues are also discussed.

Area: Engineering

EN.560.401. Design Theory & Pract.. 3 Credits.

Survey of the major theories of engineering design and the contexts in which they have evolved, and are applied. Practice in three dominant schools of modern engineering design: (i) waterfall or sequential design as commonly employed in civil construction; (ii) iterative/spiral design as employed in rapid prototyping or agile development for devices and software; and (iii) human-centric design as employed by engineers challenged to confront individual or social scale needs.

Area: Engineering

EN.560.404. Engineering Mechanics. 3 Credits.

This course will build a strong foundation in engineering mechanics, from fundamental theory to computational modeling. Constitutive relations governing various physical systems will be discussed, with a particular focus on constitutive symmetries and characteristic failure mechanisms corresponding to specific materials. Examples include ductile yielding and fracture in metals, shear banding in granular materials, fracture in composites, nonlinear inelasticity in biomaterials, and micro-buckling in architected materials. Finite element software will be used to model examples of these mechanisms.

Prerequisite(s): EN.560.206 or permission of instructor

Area: Engineering

EN.560.421. Architectural Engineering - Form, Function and Technology. 3 Credits.

This course will cultivate broad knowledge of the use of engineering principles in the art of architecture. Fundamental definitions of architecture in the basic provision of shelter and social use are paired with aesthetics and cultural heritage. The course emphasizes structural frameworks and systems within the Civil Engineering curriculum, while expanding upon their critical intersections with the highly varied specialized components and systems of modern architecture, and the corresponding community of specialists that represent them. Topics include a historical view of the evolution of specialization in architecture, a quantitative review of loads and resistance systems, architectural and structural determinants of form, the function and aesthetics of building surface, and an introduction to environmental systems and their role in design sustainability. The class will include a trip to Fallingwater, the house designed by Frank Lloyd Wright, in western Pennsylvania, which stands as an iconic example of American architecture and a complex example of architectural engineering. This course is co-listed with EN.560.621 and EN.565.621.

Area: Engineering

EN.560.423. Bridge Engineering. 3 Credits.

This course will explore bridge design and analysis by studying local bridges of various forms, materials, and load demands. Topics include an overview of the history of bridge engineering, an introduction to the AASHTO Standard Specifications for Highway Bridges, analysis techniques and load ratings, bridge details, and substructure design.

Prerequisite(s): EN.560.320 AND EN.560.325

Area: Engineering

EN.560.429. Preservation Engineering: Theory and Practice. 3 Credits.

The renovation of existing buildings often holds many advantages over new construction, including greater economy, improved sustainability, and the maintenance of engineering heritage and architectural character in our built environment. Yet, the renovation of existing structures presents many challenges to structural engineers. These challenges include structural materials that are no longer in widespread use (e.g., unreinforced masonry arches and vaults, cast iron, and wrought iron) as well as structural materials for which analysis and design practices have changed significantly over the last half-century (e.g., wood, steel, and reinforced concrete). This course will examine structures made of a wide variety of materials and instruct the student how to evaluate their condition, determine their existing capacity, and design repairs and/or reinforcement. The investigation and analysis procedures learned from this course may then be applied to create economical and durable structural alterations that allow for the reuse of older buildings. Site visits near Homewood campus will supplement lectures.

Prerequisite(s): EN.560.320 AND EN.560.325 or equivalent for graduate students.

Area: Engineering

EN.560.431. Preservation Engineering II: Theory and Practice. 3 Credits.

Building on the content in Preservation Engineering I: Theory and Practice, this course will begin with materials introduced at the start of the Industrial Revolution—namely with the beginning of the use of iron materials as major structural elements within buildings. The course will continue with the introduction of cast iron, wrought iron, and finally, structural steel members. After introducing iron materials the course will continue with the early use of reinforced concrete as a major structural material. The course will discuss the historic structural analysis methods associated with such materials and contrast such methods with more modern analytical approaches. It will also discuss concrete deterioration and repair methods. Concepts related to masonry facade investigation and repair will be presented along with the analytical methods associated with thin-shell masonry construction from the 19th and 20th centuries. The course will conclude with a review of the assessment and retrofit of historic foundations. Course is co-listed with EN.560.631 and EN.565.631.

Prerequisite(s): EN.560.429 OR Permission from the instructor.

Area: Engineering

EN.560.434. Structural Fire Engineering. 3 Credits.

This course will discuss the analysis and design of structures exposed to fire. It will cover the fundamentals of fire behavior, heat transfer, the effects of fire loading on materials and structural systems, and the principles and design methods for fire resistance design. Particular emphasis will be placed on the advanced modeling and computational tools for performance-based design. Applications of innovative methods for fire resistance design in large structural engineering projects, such as stadiums and tall buildings, will also be presented. Course is co-listed with graduate-level EN.560.634.

Area: Engineering

EN.560.442. Equilibrium Models in Systems Engineering. 3 Credits.

Provide an introduction to equilibrium problems involving systems. The course will start with an introduction to optimization theory followed by various equilibrium problems including market, spatial, and network models. Solution techniques to these types of problems will be discussed, along with applications to systems engineering. Recommended Course Background: AS.110.201 and AS.110.109 or equivalent.

Area: Engineering

EN.560.445. Advanced Structural Analysis. 3 Credits.

Matrix methods for the analysis of statistically indeterminate structures such as beams, plane and space trusses, and plane and space frames. Stiffness and flexibility methods. Linear elastic analysis and introduction to nonlinear analysis.

Prerequisite(s): EN.560.206

Area: Engineering

EN.560.450. Operations Research. 3 Credits.

An introduction to operations research and its applications. The course will review the basics of mathematical modelling, linear programming, primal and dual Simplex methods, post-optimization analysis, decomposition methods, and heuristic methods along with sample applications. Recommended course background AS.110.201 and AS.110.109 or equivalent. This course is co-listed with EN.560.650.

Area: Engineering

EN.560.451. Civil Engineering Design I. 2 Credits.

A study of the engineering design process from problem definition to the schematic or conceptual design. There are both individual and team projects which include written and oral presentations. The students' understanding of and communication about the built environment is exercised with three languages – Speech (written and verbal), Graphics (drawings and diagrams) and Mathematics (engineering calculations). First principles of mechanics and design procedures are connected with real world constructions and design concepts.

Area: Engineering

EN.560.452. Civil Engineering Design II. 3 Credits.

A study of the engineering design process from conceptual to the final design. There are team projects which include written and oral presentations. A common project is defined for the class, however each group is allowed freedom to develop their designs independently, which typically demonstrates the great range of design solutions to a given problem. Work during the semester takes on a design studio approach, with team engineering and regular reviews and input from the instructor. In addition to engineering calculations, students produce a 3D digital model, engineering drawings, and presentation posters with written summary. The culmination of the semester is the final presentation of their design projects in an open forum of peers, professors, and representatives from the profession.

Area: Engineering

EN.560.453. An Introduction to Network Modeling. 3 Credits.

Many real-world problems can be modeled using network structures, and solved using tools from network theory. For this reason, network modeling plays a critical role in various disciplines ranging from physics and mathematics, to biology and computer science, and almost all areas of social science. This course will provide an introduction to network theory, network flow algorithms, modeling processes on networks and examples of empirical network applications spanning transport, health and energy systems.

Prerequisite(s): EN.553.291

Area: Engineering, Quantitative and Mathematical Sciences

EN.560.458. Natural Disaster Risk Modeling. 3 Credits.

This course will introduce the student to disaster risk modeling process, including: structure of catastrophe models and uses in loss estimation and mitigation, study and modeling of hazards (esp. hurricanes and earthquakes; also flood, landslide, and volcanic), vulnerability assessment including simulation of building damage, and estimation of post-disaster injuries and casualties. Additionally topics will include, exposure modeling (building typology distribution), introduction to disaster economic loss modeling, interpretation of risk metrics (return periods, PML, AAL, VaR, TVaR), their uncertainty, and applicability to management and financial decision making process and elements of present and future risk, such as, climate and exposure changes. Students will gain introductory experience in the use of GIS and simulation with Matlab. This course is co-listed with EN.560.658.

Area: Engineering

EN.560.462. Failure Mechanisms in Str Matls. 3 Credits.

This course provides an overview of the various modes of failure found in structural materials. The concepts will be demonstrated through both experimental demonstrations and finite element models.

Area: Engineering

EN.560.491. Civil Engineering Seminar I. 0.5 Credits.

Seminar series of speakers on various aspects of civil engineering. Juniors and Seniors in Civil Engineering are expected to enroll in this sequence; juniors and seniors receive one-half credit. Different speakers are invited each semester. Satisfactory/ Unsatisfactory only.

Area: Engineering

EN.560.492. Civil Engineering Seminar II. 0.5 Credits.

Seminar series of speakers on various aspects of civil engineering. Juniors and Seniors in Civil Engineering are expected to enroll in this sequence; juniors and seniors receive one-half credit. Different speakers are invited each semester. Satisfactory/ Unsatisfactory only

Prerequisite(s): EN.560.491

Area: Engineering

EN.560.493. Civil Engineering Seminar III. 0.5 Credits.

Seminar series of speakers on various aspects of civil engineering. Juniors and Seniors in Civil Engineering are expected to enroll in this sequence; juniors and seniors receive one-half credit. Different speakers are invited each semester. Satisfactory/ Unsatisfactory only

Prerequisite(s): EN.560.492

Area: Engineering

EN.560.494. Civil Engineering Seminar IV. 0.5 Credits.

Seminar series of speakers on various aspects of civil engineering. Juniors and Seniors in Civil Engineering are expected to enroll in this sequence; juniors and seniors receive one-half credit. Different speakers are invited each semester. Satisfactory/ Unsatisfactory only

Prerequisite(s): EN.560.493

Area: Engineering

EN.560.501. Undergraduate Research. 0 - 3 Credits.

Research in Civil Engineering

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration & Online Forms.

EN.560.511. Group Undergraduate Research. 0 - 3 Credits.

This section has a weekly research group meeting that students are expected to attend.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration & Online Forms.

EN.560.526. Independent Study - Civil Engineering. 1 - 3 Credits.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration & Online Forms.

EN.560.590. Civil Engineering Internship. 1 Credit.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration & Online Forms.

EN.560.597. Summer Research - Civil Engineering. 3 Credits.

Independent academic work conducted for credit for undergraduates working with an Civil Engineering instructor.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration & Online Forms.

EN.560.601. Applied Math for Engineers. 3 Credits.

This course presents a broad survey of the basic mathematical methods used in the solution of ordinary and partial differential equations: linear algebra, power series, Fourier series, separation of variables, integral transforms.

Area: Engineering, Quantitative and Mathematical Sciences

EN.560.604. Introduction to Solid Mechanics. 3 Credits.

Basic solid mechanics for structural engineers. Stress, strain and constitutive laws. Linear elasticity and viscoelasticity. Introduction to nonlinear mechanics. Static, dynamic and thermal stresses. Specialization of theory to one- and two-dimensional cases: plane stress and plane strain, rods, and beams. Work and energy principles; variational formulations.

EN.560.608. Multilevel and Multiobjective Optimization in Systems. 3 Credits.

This course will introduce nonlinear optimization and convexity in higher dimensions to model large-scale systems. Graduate students only. Recommended Course Background: AS.110.201 or EN.553.291, AS.110.202.

Prerequisite(s): EN.560.442 OR EN.560.641

Area: Engineering

EN.560.618. Probabilistic Methods in Civil Engineering and Mechanics. 3 Credits.

Covers probabilistic computational modeling in civil engineering and mechanics: Monte Carlo simulation, sampling methods and variance reduction techniques, simulation of stochastic processes and fields, and expansion methods. Applications to stochastic finite element, uncertainty quantification, reliability analysis, and model verification and validation.

EN.560.619. Advanced Structural Analysis. 3 Credits.

Matrix methods for the analysis of statistically indeterminate structures such as beams, plane and space trusses, and plane and space frames. Stiffness and flexibility methods. Linear elastic analysis and introduction to nonlinear analysis.

Area: Engineering

EN.560.621. Architectural Engineering - Form, Function and Technology. 3 Credits.

This course will cultivate broad knowledge of the use of engineering principles in the art of architecture. Fundamental definitions of architecture in the basic provision of shelter and social use are paired with aesthetics and cultural heritage. The course emphasizes structural frameworks and systems within the Civil Engineering curriculum, while expanding upon their critical intersections with the highly varied specialized components and systems of modern architecture, and the corresponding community of specialists that represent them. Topics include a historical view of the evolution of specialization in architecture, a quantitative review of loads and resistance systems, architectural and structural determinants of form, the function and aesthetics of building surface, and an introduction to environmental systems and their role in design sustainability. The class will include a trip to Fallingwater, the house designed by Frank Lloyd Wright, in western Pennsylvania, which stands as an iconic example of American architecture and a complex example of architectural engineering. This course is co-listed with EN.560.421 and EN.565.621.

Area: Engineering

EN.560.623. Bridge Engineering. 3 Credits.

This course will explore bridge design and analysis by studying local bridges of various forms, materials, and load demands. Topics include an overview of the history of bridge engineering, an introduction to the AASHTO Standard Specifications for Highway Bridges, analysis techniques and load ratings, bridge details, and substructure design.

Area: Engineering

EN.560.629. Preservation Engineering I: Theory and Practice. 3 Credits.

The renovation of existing buildings often holds many advantages over new construction, including greater economy, improved sustainability, and the maintenance of engineering heritage and architectural character in our built environment. Yet, the renovation of existing structures presents many challenges to structural engineers. These challenges include structural materials that are no longer in widespread use (e.g., unreinforced masonry arches and vaults, cast iron, and wrought iron) as well as structural materials for which analysis and design practices have changed significantly over the last half-century (e.g., wood, steel, and reinforced concrete). This course will examine structures made of a wide variety of materials and instruct the student how to evaluate their condition, determine their existing capacity, and design repairs and/or reinforcement. The investigation and analysis procedures learned from this course may then be applied to create economical and durable structural alterations that allow for the reuse of older buildings. Site visits near Homewood campus will supplement lectures. This course is co-listed with EN.565.628.

Area: Engineering

EN.560.630. Structural Dynamics. 3 Credits.

Functional and computational examination of elastic and inelastic single degree of freedom systems with classical and non-classical damping subject to various input excitations including earthquakes with emphasis on the study of system response. Extension to multi-degree of freedom systems with emphasis on modal analysis and numerical methods. Use of the principles of structural dynamics in earthquake response.

EN.560.631. Preservation Engineering II: Theory and Practice. 3 Credits.

Building on the content in Preservation Engineering I: Theory and Practice, this course will begin with materials introduced at the start of the Industrial Revolution—namely with the beginning of the use of iron materials as major structural elements within buildings. The course will continue with the introduction of cast iron, wrought iron, and finally, structural steel members. After introducing iron materials the course will continue with the early use of reinforced concrete as a major structural material. The course will discuss the historic structural analysis methods associated with such materials and contrast such methods with more modern analytical approaches. It will also discuss concrete deterioration and repair methods. Concepts related to masonry facade investigation and repair will be presented along with the analytical methods associated with thin-shell masonry construction from the 19th and 20th centuries. The course will conclude with a review of the assessment and retrofit of historic foundations. This course is co-listed with EN.560.431 and EN.565.631.

Area: Engineering

EN.560.633. Investigations, Diagnosis, and Rehabilitation. 3 Credits.

Why do buildings deteriorate, and how do we address this problem? This course examines the deterioration (by human and nature) of building materials and systems. Through lectures and a field trip, students will learn how to set up and execute an investigation, study the symptoms, diagnose the problems, determine what kinds of tests are needed, design the necessary repairs, and maintain existing systems. This course is co-listed with Engineering for Professionals EN.565.633.

Area: Engineering

EN.560.634. Structural Fire Engineering. 3 Credits.

This course will discuss the analysis and design of structures exposed to fire. It will cover the fundamentals of fire behavior, heat transfer, the effects of fire loading on materials and structural systems, and the principles and design methods for fire resistance design. Particular emphasis will be placed on the advanced modeling and computational tools for performance-based design. Applications of innovative methods for fire resistance design in large structural engineering projects, such as stadiums and tall buildings, will also be presented.

Area: Engineering

Writing Intensive

EN.560.636. Lateral Forces: Analysis and Design of Building Structures. 3 Credits.

From earthquakes to wind events, lateral forces constitute some of the most extreme loading conditions for which new and existing building structures must be analyzed and designed to resist. This course provides a fundamental yet practical introduction to the development and application of earthquake and wind loadings on building structures, the dynamic response and behavior of structures to lateral forces, and the bases and requirements for ductile design and detailing of steel, concrete, wood, and masonry lateral force resisting elements. The course will build on these analysis and design fundamentals to examine the technical considerations and methodologies for evaluating the lateral force resisting systems of existing, oftentimes monumental, building structures, and for designing and implementing repairs and retrofits to these lateral systems, including the application of Performance Based Design. This course is co-listed with EN.565.636.

Area: Engineering

EN.560.637. Preservation Engineering in the Urban Context. 3 Credits.

Technical expertise is fundamental to design and construction within and around historic buildings in the urban context. This course will cover topics related to both design and construction. For below-grade engineering, the course will cover underpinning, bracket piles, secant piles, slurry walls, tie-backs and general shoring approaches to building below or adjacent to existing constructions. For upward additions to existing construction, the course covers strengthening techniques (including temporary shoring and bracing, temporary access options, and temporary protection) and the requirements of the International Existing Building Code (IEBC). Each class will provide both technical guides and case studies, offering perspectives from guest speakers practicing the diverse range of professions tasked to meet this challenge. In lieu of a final exam, students will be required to submit a final paper/project. The final class meeting will be held in New York City and will include site visits to ongoing construction that exemplify the course material. Class meets on 3/2, 3/9, 4/6, and 4/13.

Area: Engineering

EN.560.641. Equilibrium Models in Systems Engineering. 3 Credits.

Provide an introduction to equilibrium problems involving systems. The course will start with an introduction to optimization theory followed by various equilibrium problems including market, spatial, and network models. Solution techniques to these types of problems will be discussed, along with applications to systems engineering.

Area: Engineering

EN.560.645. Topics in Optimization: Integer and Robust Optimization. 3 Credits.

The goal of this course is to introduce various advanced topics in optimization, including integer optimization, robust optimization, and inverse optimization. The course covers theoretical aspects of modeling and solution methods, as well as foundations and tips for practical examples. Enrollees are expected to have completed EN.553.761 or a comparable course on Linear Programming.

Prerequisite(s): EN.553.761 Or Instructor Permission.

EN.560.650. Operations Research. 3 Credits.

An introduction to operations research and its applications. The course will review the basics of mathematical modelling, linear programming, primal and dual Simplex methods, post-optimization analysis, decomposition methods, and heuristic methods along with sample applications. Course meets with EN.560.450

Area: Engineering

EN.560.653. An Introduction to Network Modeling. 3 Credits.

Many real-world problems can be modeled using network structures, and solved using tools from network theory. For this reason, network modeling plays a critical role in various disciplines ranging from physics and mathematics, to biology and computer science, and almost all areas of social science. This course will provide an introduction to network theory, network flow algorithms, modeling processes on networks and examples of empirical network applications spanning transport, health and energy systems.

Area: Engineering, Quantitative and Mathematical Sciences

EN.560.658. Natural Disaster Risk Modeling. 3 Credits.

This course will: • Introduce the student to disaster risk modeling process, including: - Structure of catastrophe models. Uses in loss estimation and mitigation. - Study and modeling of hazards (esp. hurricanes and earthquakes; also flood, landslide, and volcanic) - Vulnerability assessment: simulation of building damage, and estimation of post-disaster injuries and casualties. - Exposure modeling (building typology distribution). • Introduction to disaster economic loss modeling: - Interpretation of risk metrics (return periods, PML, AAL, VaR, TVaR), their uncertainty, and applicability to management and financial decision making process. - Elements of present and future risk: climate and exposure changes. - Student will gain introductory experience in the use of GIS and simulation with Matlab. This course is co-listed with EN.560.458.

Area: Engineering

EN.560.667. Topology Optimization and Design for Additive Manufacturing. 3 Credits.

This course will discuss the computational design tool of topology optimization and its application to the design of "structures", including structural systems, complaint mechanisms, multifunctional devices, and material architectures. Particular emphasis will be placed on the emerging trend known as Design for Additive Manufacturing (AM), and the role of topology optimization in guiding the design of parts to be fabricated by AM processes (3D printing, Selective Laser Sintering, etc). The course will largely focus on design problems concerned with mechanical properties, with extensions to fluidic, thermal, optical, etc. properties also discussed. The course assumes some familiarity with finite element methods and assumes no prior coursework in optimization.

Area: Engineering

EN.560.691. Graduate Seminar. 1 Credit.

Graduate students are expected to register for this course each semester. Both internal and outside speakers are included.

EN.560.692. Civil Engineering Graduate Seminar. 1 Credit.

Seminar series of speakers on various aspects of civil engineering. Different speakers are invited each semester. Full time civil engineering graduate students must enroll in the seminar course every semester unless excused by the Department.

EN.560.724. Cold-Formed Steel Structures. 3 Credits.

Practical introduction to the analysis, design, and experimentation of cold-formed steel members and structures. Followed by an in-depth treatment of the theories which underpin modern analytical and computational tools used in exploring cold-formed steel behavior, and an introduction to topics under current research.

EN.560.730. Finite Element Methods. 3 Credits.

Variational methods and mathematical foundations, Direct and Iterative solvers, 1-D Problems formulation and boundary conditions, Trusses, 2-D/ 3D Problems, Triangular elements, QUAD4 elements, Higher Order Elements, Element Pathology, Improving Element Convergence, Dynamic Problems.

EN.560.731. Structural Stability. 3 Credits.

Concepts of stability of equilibrium, stability criteria, work energy and variational methods. Elastic buckling of columns, beams, frames, and plates. Introduction to inelastic and dynamic buckling.

EN.560.740. Optimization and Learning. 3 Credits.

This course offers an optimization perspective of machine learning. We use fundamental, bottom-up optimization methods to introduce formal concepts in machine learning. The course then builds on these fundamentals to show how optimization formulations can be used to improve the performance and interpretation of machine learning models. Applications to energy and healthcare systems will be provided. A background in optimization is preferred, but no background in machine learning is required. Programming experience is a pre-requisite.

Area: Engineering
Writing Intensive

EN.560.762. Mechanics of Architected Materials. 3 Credits.

This upper level graduate course will focus on the linear and nonlinear mechanics of a wide range of architected materials; we aim to cover: linear elastic properties of 2D and 3D cellular solids, micromechanics and homogenization, localization, microscopic and macroscopic instabilities, natural architected materials (bone, wood, nacre), wave propagation in lattices and phononics, mechanical metamaterials, and nanostructured materials (carbon nanotubes pillars, DNA origami).

Area: Engineering

EN.560.770. Advanced Finite Element Methods and Multi-Scale Methods. 3 Credits.

Addresses advanced topics in various areas of the finite element methodology. Covers a range of topics, viz. element stability and hourglass control, adaptive methods for linear and nonlinear problems, mixed and hybrid element technology, eigen-value problems, multi-scale modeling for composites and polycrystalline materials. Recommended Course Background: EN.530.730 or EN.560.730

EN.560.772. Non-Linear Finite Elements. 3 Credits.

This course will discuss state of the art theoretical developments and modeling techniques in nonlinear computational mechanics, for problems with geometric and material nonlinearities. Large deformation of elastic-plastic and visco-plastic materials, contact-friction and other heterogeneous materials like composites and porous materials will be considered. A wide variety of applications in different disciplines, e.g. metal forming, composite materials, polycrystalline materials will be considered.

EN.560.775. Bilevel Optimization in Energy Systems. 3 Credits.

This course provides an overview of bilevel optimization in large-scale, regional-level energy systems. Topics covered include Mathematical Programs and Equilibrium Problems with Equilibrium Constraints, Binary Equilibrium, Energy Infrastructure, and Pricing in Electricity Markets. At least one graduate-level course in continuous optimization as well as programming experience are prerequisites.

EN.560.826. Graduate Independent Study. 1 - 3 Credits.

Independent Study.

Area: Engineering

EN.560.835. Graduate Research. 3 - 20 Credits.**EN.560.836. Graduate Research. 3 - 20 Credits.****EN.560.890. Independent Study. 1 - 3 Credits.****EN.565.604. Structural Mechanics. 3 Credits.**

This course presents basic solid mechanics for structural engineers, including stress, strain, and constitutive laws; linear elasticity and visco-elasticity; introduction to nonlinear mechanics; static, dynamic, and thermal stresses; specialization of theory to one- and two-dimensional cases; plane stress and plane strain, rods, and beams; work and energy principles; and variational formulations. Course Note(s): This course is a requirement for the general Civil Engineering program and the Structural Engineering focus area.

EN.565.606. Geotechnical Engineering Principles. 3 Credits.

This course aims to review and reinforce knowledge of soil mechanics and geotechnical engineering principles for application in a variety of structural and civil engineering projects. The course presents examples of geotechnical engineering design problems. The course then discusses the origin of soil and types of soil, and various relations between weight and volume; methods used to characterize the index properties of soil, and classification of soil; theory of compaction; Darcy's law and the role of permeability, and the theory of two-dimensional seepage; stresses induced in soil by footing and other loading; compressibility of soil, and consolidation and consolidation settlements; shear strength of soil and the laboratory methods of determining shear strength parameters; theories of lateral earth pressure and their application to the analysis of retaining walls; fundamentals of slope stability analysis; fundamentals of the bearing capacity analysis of shallow foundations; and methods of subsoil exploration. Prerequisite(s): 560.305 Soil Mechanics or equivalent. 560.305 is offered on-site through the full-time Civil Engineering Department. Course Note(s): This course is a requirement for the general Civil Engineering program.

EN.565.608. BIM Applications in Civil Engineering. 3 Credits.

This course will introduce students to basic building information modeling (BIM) theory with an emphasis on how BIM is used in the design and construction of buildings. Students will learn how to model basic architectural, structural, and MEP systems in buildings using Autodesk Revit and how to schedule various model elements and create 2D drawings from the 3D model. They will be introduced to algorithmically generated content using Autodesk Dynamo.

EN.565.616. Applied Finite Element Methods. 3 Credits.

This course will introduce finite element methods for the analysis of solids and structures. The following topics will be considered: procedure for defining a mechanics problem (governing equations, constitutive equations, boundary and initial value problems); theory and implementation of the finite element method for static analysis using linear elasticity; and the verification/validation of results using finite element analysis software.

EN.565.619. Advanced Structural Analysis. 3 Credits.

The course will focus on matrix implementations of the stiffness method for the analysis of statically indeterminate structures such as plane/space trusses and plane/space frames. Computational aspects of the stiffness method will be discussed with connections made to commercial software. Linear elastic analysis will be the primary focus, but topics in nonlinear analysis will also be introduced. This course may be used to satisfy the structural analysis requirement for the Structural Engineering focus area.

EN.565.620. Advanced Steel Design. 3 Credits.

This course examines advanced designs of structural steel buildings including consideration of torsion, lateral-torsional buckling, local buckling, plate girder design, connection design, framing systems for seismic design, nonlinear frame behavior, and principles of stability per the Direct Analysis Method. Prerequisite(s): 560.320/325 Structural Design I/II or equivalent. 560.320/325 are offered on-site through the fulltime Civil Engineering Department.

EN.565.622. Advanced Reinforced Concrete Design. 3 Credits.

This intensive course covers reinforced concrete materials and specifications and includes the following topics: conception, analysis, and design of beams and columns, slabs, foundations and walls with emphasis on the ultimate strength method. Advanced seismic design topics are then covered building from the basic knowledge of reinforced concrete design. Prerequisite(s): 560.320/325 Structural Design I/II or equivalent. 560.320/325 are offered on-site through the fulltime Civil Engineering Department.

EN.565.623. Bridge Design and Evaluation. 3 Credits.

Through lectures, design problems and existing bridge examples, this course illustrates basic bridge knowledge from preliminary design to final design of major structural components. The course covers conventional bridges and other bridge types, including concrete segmental box girders, arch bridges, and cable-stayed bridges. The course is not intended to provide students with intensive training in any particular area of bridge design. The course requires problem solving, a term project, and a final exam. A background in reinforced concrete design and steel design will be helpful in this course. Course Note(s): Recommended Course Background: 560.320/325 Structural Design I/II or equivalent. 560.320/325 are offered on-site through the full-time Civil Engineering Department.

EN.565.626. Design of Wood Structures. 3 Credits.

This course introduces students to the design of wood structures. Wood structures may be constructed of sawn lumber, glulam, or engineered wood products. The primary focus in this class is on light-framed low-rise wood buildings constructed of sawn lumber or glulam, but concepts related to heavy timber-framed structures and tall wood buildings using cross-laminated timber (CLT) are introduced. Structural behavior under gravity and lateral loads is emphasized, as are analysis and design of the components within the gravity and lateral load resisting systems. The current version of the National Design Specification (NDS) for Wood Construction is used.

EN.565.628. Preservation Engineering I: Theory and Practice. 3 Credits.

The renovation of existing buildings often holds many advantages over new construction, including greater economy, improved sustainability, and the maintenance of engineering heritage and architectural character in our built environment. Yet, the renovation of existing structures presents many challenges to structural engineers. These challenges include structural materials that are no longer in widespread use (e.g., unreinforced masonry arches and vaults, cast iron, and wrought iron) as well as structural materials for which analysis and design practices have changed significantly over the last half-century (e.g., wood, steel, and reinforced concrete). This first course in the theory and practice of preservation engineering will include a review of the building code requirements related to work on existing buildings and a discussion of the load paths (both vertical and horizontal) through such structures. Further, this course will begin its review of structural materials with those that were available prior to the Industrial Revolution—namely masonry and timber. The course will conclude with an overview of the response of wood structures to wind and seismic loads. Wood deterioration mechanisms and structural repair strategies for wood will also be presented.

EN.565.630. Prestressed Concrete Design. 3 Credits.

Topics include prestressed concrete concepts for both pretensioning and post-tensioning: materials, types of prestress, and prestress losses; design of sections for flexure, shear, torsion, and compression; load balancing technique; consideration of partial prestress, composite sections, and slab systems. Prerequisite(s): 560.320/325 Structural Design I/II or equivalent. 560.320/325 are offered through the full-time Civil Engineering Department.

EN.565.631. Preservation Engineering II: Theory & Practice. 3 Credits.

Building on the content in Preservation Engineering I: Theory and Practice, this course will begin with materials introduced at the start of the Industrial Revolution—namely with the beginning of the use of iron materials as major structural elements within buildings. The course will continue with the introduction of cast iron, wrought iron, and finally, structural steel members. After introducing iron materials the course will continue with the early use of reinforced concrete as a major structural material. The course will discuss the historic structural analysis methods associated with such materials and contrast such methods with more modern analytical approaches. It will also discuss concrete deterioration and repair methods. Concepts related to masonry facade investigation and repair will be presented along with the analytical methods associated with thin-shell masonry construction from the 19th and 20th centuries. The course will conclude with a review of the assessment and retrofit of historic foundations.

Prerequisite(s): 565.628 Preservation Engineering I: Theory and Practice

EN.565.633. Investigation, Diagnosis, and Rehabilitation. 3 Credits.

Why do buildings deteriorate? And how do we investigate and diagnose the causes, as well as design and implement appropriate solutions? This course examines the deterioration of building materials and systems caused by both humans and nature. Through weekly lectures and one weekend workshop, students will learn how to plan and execute an investigation, identify the symptoms, determine what tests are needed, diagnose the causes, and design and administer necessary repairs to address deterioration and system deficiencies. Weekly lectures will use a combination of Virtual Live and online formats; a weekend workshop in Baltimore (date TBD) will include hands-on activities and a field trip to a local project site.

EN.565.636. Lateral Forces: Analysis and Design of Building Structures. 3 Credits.

From earthquakes to wind events, lateral forces constitute some of the most extreme loading conditions for which new and existing building structures must be analyzed and designed to resist. This course provides a fundamental yet practical introduction to the development and application of earthquake and wind loadings on building structures, the dynamic response and behavior of structures to lateral forces, and the bases and requirements for ductile design and detailing of steel, concrete, wood, and masonry lateral force resisting elements. The course will build on these analysis and design fundamentals to examine the technical considerations and methodologies for evaluating the lateral force resisting systems of existing, oftentimes monumental, building structures, and for designing and implementing repairs and retrofits to these lateral systems, including the application of Performance Based Design. This course is co-listed with 560.615.

EN.565.637. Preservation Engineering in the Urban Context. 3 Credits.

Technical expertise is fundamental to design and construction within and around historic buildings in the urban context. This course will cover topics related to both design and construction. For below-grade engineering, the course will cover underpinning, bracket piles, secant piles, slurry walls, tie-backs and general shoring approaches to building below or adjacent to existing constructions. For upward additions to existing construction, the course covers strengthening techniques (including temporary shoring and bracing, temporary access options, and temporary protection) and the requirements of the International Existing Building Code (IEBC). Each class will provide both technical guides and case studies, offering perspectives from guest speakers practicing the diverse range of professions tasked to meet this challenge.

EN.565.658. Natural Disaster Risk Modeling. 3 Credits.

Natural hazards such as floods, earthquakes, and hurricanes exert a heavy toll of victims and economic losses every year. Yet, concentrations of population in hazard-prone-areas, the growth of infrastructure and climate change are aggravating the risk of future losses. Consequently, adequate interventions must be implemented to mitigate the damaging effects of natural hazards. To do this, public agencies, non-profits, and companies formulate mitigation actions such as emergency preparedness plans and building retrofits. Catastrophe models are tools to inform all these efforts, which simulate the socioeconomic risk resulting from the interaction of geophysical events and the spatial distribution of infrastructure. Course note(s): This course is cross-listed with 575.658 Natural Disaster Risk Modeling.

EN.565.664. Advanced Foundation Design. 3 Credits.

This course will introduce the principles and specifics of the geotechnical design of shallow and deep foundations. Topics include design of shallow foundations, including spread footings, combined footings and mat foundations; design of deep foundations, including single piles, pile groups and drilled shafts; design of laterally-loaded piles; construction monitoring and testing methods for driven piles; design of foundations for vibration control; foundations on difficult soils; underpinning; and design of buried culverts.

Prerequisite(s): 560.305 Soil Mechanics (or equivalent) or 565.606 Geotechnical Engineering Principles.

EN.565.680. Marine Geotechnical Engineering. 3 Credits.

This course introduces students to soil mechanics in the marine environment. Topics covered include the nature of marine sediments, soil behavior due to cyclic loading, marine geotechnical investigations, shallow foundations and deadweight anchors, pile foundations and anchors, penetration and breakout of objects on the seafloor, marine slope stability, soft ground improvement, marine dredging, and project planning. Prerequisite(s): 560.305 Soil Mechanics or equivalent. 560.305 is offered through the full-time Civil Engineering Department.

EN.565.682. Design of Ocean Structures. 3 Credits.

This course presents a review of structural design theory and practice related to ocean structures. Basic elements of ocean structures are designed using current engineering design codes developed by the American Institute of Steel Construction (AISC) and American Petroleum Institute (API). Topics include ocean environmental forces, material selection, foundation design, and analysis/design of ocean structures.

EN.565.684. Port & Harbor Engineering. 3 Credits.

Planning and engineering of ports and harbors has received renewed worldwide interest as the newest super-large cargo ships push the envelope for channel depth and berth space. This course covers planning of marine terminals and small craft harbors, ship berthing and maneuvering considerations, port navigation, marine structures, inland navigation, marine construction planning, sediment management, and port economics.

EN.565.686. Sustainable Coastal Engineering. 3 Credits.

This course presents a review of sustainable engineering related to the ocean environment. Sustainable shore protection designs will be investigated such as living shorelines and sills, beach nourishment, and other sustainable methods in order to adapt to coastal hazards such as hurricanes, tsunamis, and sea level rise. Sustainable energy such as coastal wind energy, wave energy, tidal energy, and other sustainable energy sources will be also investigated as alternative energy designs. The importance of sustainable food production will be discussed and aquaculture system designs such as ocean aquaculture, shellfish aquaculture, and other sustainable food production will be studied.

EN.565.731. Structural Dynamics. 3 Credits.

This course provides an overview of rigid-body dynamics, free and deterministic forced vibration of undamped and damped single- and multi-degree-of-freedom systems, vibration of continuous systems, approximate methods of analysis, and introduction to random vibration of linear systems. Applications of the principles of structural dynamics to determine a structure's earthquake response are also covered. Instructor assumes that students who enroll in this course have a basic understanding of stiffness and stiffness matrices. Prerequisite(s): 535.641 Mathematical Methods for Engineers.

EN.565.732. Earthquake Engineering. 3 Credits.

Topics for this course include plate tectonics, seismicity of Earth, and engineering seismology-including quantification and classification of earthquake ground motions, dynamics of structures subjected to earthquake loads, design spectra, building code provisions, design concepts and detailing, soilstructure interaction, and response of special structures.

EN.565.734. Wind Engineering. 3 Credits.

This course covers atmospheric circulation, atmospheric boundary layer winds, bluff-body aerodynamics, modeling of wind-induced loads, introduction to random vibration theory, response of structures to fluctuating wind loads, aeroelastic phenomena, wind-tunnel and full-scale testing, computational wind engineering, non-synoptic winds (hurricanes, tornadoes, etc.), and wind-load standards and design applications.

EN.565.762. Ground Improvement Methods. 3 Credits.

This course addresses the selection, cost, design, construction, and monitoring of ground improvement methods for problematic soils and rock. Ground improvement methods covered include wick drains, micropiles, lightweight fill materials, soil nailing, mechanically stabilized slopes and walls, grouting, stone columns, dynamic compaction, and soil mixing. Prerequisite(s): 560.330 Foundation Design or equivalent and 565.606 Geotechnical Engineering Principles. 560.330 is offered on-site through the full-time Civil Engineering Department.

Prerequisite(s): 565.606 Geotechnical Engineering Principles.

EN.565.764. Retaining Structures and Slope Stability. 3 Credits.

Topics for this course include earth pressure theories; design and behavior of rigid, flexible, braced, tied-back, slurry, and reinforced soil structures; stability of excavation, cut, and natural slopes; methods of slope stability analysis; effects of water forces; shear strength selection for analysis; and stability and seepage in embankment dams. Prerequisite(s): 560.305 Soil Mechanics or equivalent. 560.305 is offered on-site through the full-time Civil Engineering Department.

EN.565.800. Independent Study in Civil Engineering. 3 Credits.

In this independent study course, qualified students are permitted to pursue short-term research or design projects under the guidance and direction of faculty members. Course prerequisite(s): The Independent Study/Project Form (ep.jhu.edu/student-forms) must be completed and approved prior to registration. Course note(s): This course is open only to candidates in the Master of Civil Engineering program.

EN.565.801. Independent Study in Civil Engineering. 3 Credits.

In this independent study course, qualified students are permitted to pursue short-term research or design projects under the guidance and direction of faculty members. Course prerequisite(s): The Independent Study/Project Form (ep.jhu.edu/student-forms) must be completed and approved prior to registration. Course note(s): This course is open only to candidates in the Master of Civil Engineering program.