CIVIL & SYSTEMS ENGINEERING

https://engineering.jhu.edu/case/

Offering academic and research programs at the undergraduate, graduate, and postdoctoral levels, the Department of Civil and Systems Engineering aims to build knowledge and provide tools that will enable students to move the field away from empirical ad hoc approaches into strategies based on scientifically-grounded analysis.

With a foundation rooted in fundamental structural engineering and mechanics, systems thinking, advanced computational methods, and uncertainty quantification, our programs successfully navigate the conflicting objectives inherent in addressing grand societal challenges, such as resilient cities, human safety and security, space exploration, and habitation, decision making and health, and future energy infrastructure.

The department’s small size fosters a collegial, close-knit relationship between students, staff, and faculty, giving students a high-quality, comprehensive education where leading civil and systems engineering research in the areas of mechanics of materials, structures, and systems is cross-fertilized with research from other fields. Partnerships and collaborations with the departments of Computer Science, Environmental Health and Engineering, Mechanical Engineering, Biomedical Engineering, Materials Science and Engineering, Applied Mathematics and Statistics, Public Health, and other Johns Hopkins groups provide a wide range of opportunities that rival those of much larger programs.

The department sponsors an undergraduate and graduate seminar series, as well as the Richard J. Carroll endowed lectureship; all of which are designed to bring prominent civil and systems engineers to campus to speak with students and faculty.

Undergraduate Programs

The Civil and Systems Engineering undergraduate programs build the foundation for a lifetime of learning by giving students an education that is unique in its depth, while providing access to faculty and an extraordinary range of educational opportunities beginning in freshman year. Building on the foundation of creative problem-solving skills, teamwork, and independent inquiry, our students pursue a wide array of research and professional experiences that provide exposure to more highly specialized subject matter. Our alumni have successful careers in a variety of fields, including academia, civil and systems engineering practice, law, medicine, technology and finance. With opportunities ranging from using a variety of skills to address a real-life issue during the senior design course to connecting with employers via our annual CaSE Career Fair, CaSE undergraduates are prepared for the workforce, wherever that may be.

Graduate Programs

Powerful computational methods, advanced mathematics, and high-strength materials offer new opportunities and new challenges. The Department of Civil and Systems Engineering offers graduate programs that are based primarily on the mechanics of materials, structures, and systems engineering. Fundamental to these areas is research in solid, structural, stochastic mechanics, operations research, and network modeling. The graduate programs are designed to instill in the student fundamental theoretical concepts, numerical algorithms, and practical knowledge of modern materials, structural, and systems engineering. To be admitted to the program, students are expected to have graduated with an outstanding record in an appropriate undergraduate program.

Facilities

The Department’s teaching and research labs are located in Latrobe Hall. Teaching laboratories include a modern multi-use facility for exploring experiments in statics, mechanics of materials, dynamics, and other courses, and a dedicated soil mechanics laboratory. Research laboratories include the Thin-walled Structures Laboratory, Structural Testing Laboratory, Structural Materials at High Temperature Laboratory, and Digital Fabrication and Programmable Matter Laboratory. The Department also possesses an array of modern fabrication equipment, including 3-D printers, modern CNC, and other fabrication facilities for the purposes of building prototypes, specimens and maintaining equipment and experiments. The Civil Engineering High Performance Cluster (CE-HPC) is a medium-scale high-performance computing cluster used primarily for research. We are also pleased to provide an undergraduate Design Studio and computer lab, as well as office space for doctoral students and a graduate student lounge.

Programs

- Civil Engineering, Bachelor of Science (https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/civil-engineering/civil-engineering-bachelor-science/)
- Systems Engineering, Bachelor of Science (https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/systems-engineering/systems-engineering-bachelor-science/)
- Civil Engineering, Master of Science in Engineering (MSE) (https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/civil-engineering/civil-engineering-mse/)
- Civil Engineering, Minor (https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/civil-engineering/civil-engineering-minor/)
- Civil and Systems Engineering, PhD (https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/civil-engineering/civil-engineering-phd/)
- Systems Engineering, Master of Science in Engineering (MSE) (https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/degree-programs/civil-engineering/systems-engineering-mse/)

For current course information and registration go to https://sis.jhu.edu/classes/

Courses

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.560.112. Electromagnetism & Sensors Lab. 1 Credit.
Electricity and magnetism underpins much of modern engineering, as an alternative or addendum to classical Physics this, largely, hands-on laboratory course exposes engineers to the principles of electromagnetism and how they are leveraged in the modern world with a focus on their application in infrastructure and sensor networks.
Area: Engineering, Natural Sciences

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.560.192. CaSE Design. 0.5 Credits.
Through this course, students will be introduced to various design principles and further explore the role of civil and systems engineering design in communities and society. Students will work collaboratively with a civil and systems engineering senior design team or research group to explore the impact of their intended design on communities.
Area: Engineering

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. For most majors, students are required to register for both 560.201 Statics and Mechanics of Materials and 560.211 Statics and Mechanics of Materials Laboratory.
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.560.211. 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. For most majors, students are required to register for both 560.201 Statics and Mechanics of Materials and 560.211 Statics and Mechanics of Materials Laboratory.
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.560.240. 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.560.250. Intro to Mathematical Decision Making. 3 Credits.
This first course in mathematical decision-making and optimization uses quantitative approaches to problem solving. The students are introduced to mathematical modeling and its formulations, solutions methods, output analysis, and hands-on solution techniques. An array of practical problems from Energy, Health, Space, Management, Engineering, and other fields are reviewed, and a number of solution methods including but not limited to, linear optimization, integer optimization, convex optimization, decision analysis, and heuristic algorithms are introduced.
Area: Engineering, Quantitative and Mathematical Sciences

EN.560.255. Dynamical Systems. 3 Credits.
This course will introduce students to the modeling and analysis of dynamical systems using analytical, numerical and qualitative (geometric) techniques. The course will focus on dynamical systems arising in mechanics and vibrations, global climate and infectious disease modeling. The following topics will be covered: linear first and second order ODEs, analytical methods, Laplace and Fourier transforms, control systems, numerical integration, finite differences, nonlinear systems, phase plane analysis, stability, bifurcations, chaos.
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.500.113
Area: Engineering

EN.560.292. CaSE Research. 0.5 Credits.
An introduction to the research process, students in this project-based course will develop an appreciation for the role of research in our society and will learn the tools indispensable to researchers, including how to conduct literature reviews, how to read and write technical literature, as well as how to formulate and test a research hypothesis. Students will explore the research process through a variety of methods including as an exercise in uncertainty quantification.
Area: Engineering

EN.560.301. Structural Systems I. 3 Credits.
This course will introduce students to the structural design workflow from concept and ideation to structural modeling and analysis to member and connection design using the reliability-based limit states approach. This first course in a two-course sequence will focus on the analysis and design of structural systems composed primarily of axial force members (e.g. trusses, cables, and arches). Connections to mechanics-based principles will be emphasized and practical applications using common structural materials such as timber, steel, and reinforced concrete will be covered.
Area: Engineering

EN.560.340. 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.560.350. Structure and Materials. 3 Credits.
This course will introduce students to the structural design workflow from concept and ideation to structural modeling and analysis to member and connection design using the reliability-based limit states approach. This first course in a two-course sequence will focus on the analysis and design of structural systems composed primarily of axial force members (e.g. trusses, cables, and arches). Connections to mechanics-based principles will be emphasized and practical applications using common structural materials such as timber, steel, and reinforced concrete will be covered.
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.
Prerequisite(s): EN.560.301 Structural Systems I OR EN.560.325 Structural Design II
Area: Engineering

EN.560.305. Soil Mechanics. 4 Credits.
Prerequisite(s): EN.560.201 AND EN.560.211; 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.560.330. 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

This course will address linear mechanics of solid and fluid media. Concepts will be reinforced through hands-on fabrication, machining and testing of materials, and by the use of finite element models.
Area: Engineering

EN.560.391. CaSE Careers I. 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.560.392. CaSE Careers II. 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 and Practice. 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.560.421. 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

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.560.445. Advanced Structural Analysis. 3 Credits.
Matrix methods for the analysis of statically 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. Co-listed with EN.560.619.
Prerequisite(s): EN.560.301
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 procedures 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.560.453. 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. Co-listed with EN.560.653.
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 Mechanics in Materials. 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.560.501. Undergraduate Research. 1 - 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. 1 - 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.560.601. 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.560.618. 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.560.635. **Applied Numerical Modeling for Thermal Structural Analysis. 3 Credits.**
This course discusses advanced topics in numerical modeling by the nonlinear finite element method with application to structural systems subjected to thermal loads. Covered topics include heat transfer and structural analyses, computational constitutive modeling, best practices for constructing and interpreting numerical models, and use of numerical modeling to support performance-based structural design. The course includes hands-on projects with a nonlinear finite element software. At least one graduate-level course in finite element method and one in structural analysis are prerequisites.
Area: Engineering
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.

Area: Engineering

EN.560.643. Optimization Modeling Foundations. 3 Credits.

The goal of this course is to introduce a series of optimization modeling techniques, including linear, integer, and robust optimization. The course covers theoretical aspects of modeling and solution methods, as well as foundations and tips for practical examples. Enrollees are expected to know basic linear algebra. Familiarity with linear programming, real analysis, and coding is recommended but not required.

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.

EN.560.646. Smart Cities. 3 Credits.

In recent years, sustainability progress has resulted mainly from developing and implementing smart, sustainable technology solutions. This course examines opportunities to drive sustainability through technology applications, deemed the “smart city”. Smart city technology ranges from intelligent infrastructure in modern cities to mobile applications that enable the “sharing economy” and facilitate energy access in remote regions of East Africa. This course will not only concern “first-world” problems; we will explore the transformative solutions currently driving growth in emerging markets and the developing world. Students will develop the skills to piece together a sustainable, smart city.

Area: Engineering

EN.560.650. Operations Research. 3 Credits.

An introduction to operations research and its applications. The course will review the basics of mathematical modeling, 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.560.655. Space Systems Cybersecurity. 3 Credits.

Our space systems are under attack. Cyberattacks are among the most prevalent threats to space assets. They are often stealthy, inexpensive and highly effective at achieving an adversary’s goal – be it data corruption, IP theft or physical destruction of the satellite. Given space systems are complex, composing ground stations, communications and satellites the surface area of attack is vast and considering the constrained computing capacity of space systems, many traditional security mechanisms are not applicable. This course introduces how an adversary would approach attacking a satellite, opportunities for systems engineers to develop cyber-resilient assets and relevant policies and best practices to support space system cybersecurity. Recommended classes - EP 675.600 and 675.601.

Area: Engineering

EN.560.657. System Dynamics. 3 Credits.

System dynamics is a powerful analytical framework to model and tackle complex problems that involve interactions among several variables and constraints. Fields of applications include engineering, climate change, resilience, logistics, public policy analysis, business, and decision-making. This course introduces the basics of systems thinking and system dynamics modeling and analysis. Students learn to identify and formulate systems, their parts, and interrelations. They are also trained in simulating systems’ behavior using specialized software, with attention to the underlying differential equations. The student also learns to examine the suitability of a model, understand the behavior of the simulated system, and devise potential interventions.

Area: Engineering
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.560.661. Additive Manufacturing and Design. 3 Credits.
Additive Manufacturing (AM) removes many geometric constraints imposed by traditional manufacturing processes. Resultingly, systems can be designed to support and improve multiple design objectives, which has the potential to alter the way products are designed. While this allows for the fabrication of more complex and often unprecedented geometries, it also increases the complexity designers face. In addition, engineers must not only understand AM technologies and materials, they must also be able to synthesize its economic and environmental impacts on a manufacturing value chain. Additive Manufacturing and Design will provide an in-depth overview of the most common — and promising — AM technologies, materials, and design methods by including examples from state-of-the-art research. A particular emphasis is placed on Design for Additive Manufacturing (DfAM), where the different topics will converge to fully utilize the newly created design space.
Area: Engineering
Writing Intensive

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.560.730. 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.

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

EN.560.741. Modern Machine Learning: Applicability, Interpretability, and Uncertainty Quantification. 3 Credits.
This course provides a broad overview of the different machine learning methods and their theoretical foundations. We focus on the applicability of each method for appropriate statistical design, the interpretability of simple or well-constrained methods, the explainability of complex models or black boxes, and the quantitative characterization of uncertainties. Theoretical and technical aspects related to model evaluation and actionable predictions will be covered, including feature selection, variable importance, model intercomparisons, and cross validation. Applications to real problems in natural sciences and engineering will be covered.
Area: Engineering

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.

Cross Listed Courses
For current faculty and contact information go to https://engineering.jhu.edu/case/faculty/