

# ENGINEERING (ENGR)

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## **ENGR 3340 Product Development and Market Feasibility (4 Credits)**

In this course, students gain knowledge of designing products for market success by developing a product and optimizing its design for specific mass manufacturing technologies. Students gain experience through the design development process including market feasibility research, human-centered design, brainstorming and ideating new concepts, refinement through design iteration, and constructing alpha and beta prototypes that are designed with mass manufacturing considerations. Projects are based upon real world new product development principles. Students learn and practice the fundamentals of design thinking, design process, and entrepreneurship.

## **ENGR 3510 Renewable and Efficient Power and Energy Systems (4 Credits)**

This course introduces the current and future sustainable electrical power systems. Fundamentals of renewable energy sources and storage systems are discussed. Interfaces of the new sources to the utility grid are covered. Prerequisite: ENEE 2012.

## **ENGR 3520 Introduction to Power Electronics (4 Credits)**

This covers fundamentals of power electronics. We discuss various switching converters topologies. Basic knowledge of Efficiency and small-signal modeling for the DC-DC switching converters is covered. Furthermore, magnetic and filter design are introduced. Prerequisites: ENEE 2211 and ENGR 3722.

## **ENGR 3525 Power Electronics and Renewable Energy Laboratory (1 Credit)**

In this course the fundamentals of switching converters and power electronics in a real laboratory set-up are covered. The course incorporates hardware design, analysis, and simulation of various switching converters as a power processing element for different energy sources. The energy sources are power utility, batteries, and solar panels. Prerequisite: ENGR 3520.

## **ENGR 3540 Electric Power Systems (4 Credits)**

This course covers methods of calculation of a comprehensive idea on the various aspects of power system problems and algorithms for solving these problems. Prerequisite: ENGR 3530.

## **ENGR 3620 Advanced Engineering Mathematics (4 Credits)**

Applied mathematics for engineers. Systems and series solutions of ordinary differential equations, Fourier analysis, partial differential equations, linear algebra, vector calculus, special functions, unconstrained and combinatorial optimization, and applied probability and statistics. Cross listed with ENGR 3610. Prerequisites: MATH 2070 and MATH 2080.

## **ENGR 3621 Advanced Engineering Mathematics (4 Credits)**

Applied mathematics for engineers. Topics include vector spaces, normed vector spaces, inner product spaces, linear transformations, finite-dimensional linear transformations, linear operators, finite-dimensional linear operators, linear differential systems, linear difference systems, orthogonal transformations, amplitude estimation, fundamentals of real and functional analysis, and introduction to partial differential equations, and applications to engineering systems.

## **ENGR 3630 Finite Element Methods (4 Credits)**

Introduction to the use of finite element methods in one or two dimensions with applications to solid and fluid mechanics, heat transfer and electromagnetic fields; projects in one or more of the above areas. Prerequisites: ENME 2541 AND ENGR 1572.

## **ENGR 3650 Probability and Statistics for Engineers (4 Credits)**

This course covers quantitative analysis of uncertainty and decision analysis in engineering. It covers the fundamentals of sample space, probability, random variables (discrete and continuous), joint and marginal distributions, random sampling and point estimation of parameters. It also covers statistical intervals, hypotheses testing and simple linear regression. The course includes applications appropriate to the discipline. Prerequisite: MATH 1953.

## **ENGR 3721 Controls (3,4 Credits)**

Modeling, analysis and design of linear feedback control systems using Laplace transform methods. Techniques and methods used in linear mathematical models of mechanical, electrical, thermal and fluid systems are covered. Feedback control system models, design methods and performance criteria in both time and frequency domains. A linear feedback control system design project is required. Prerequisites: ENEE 2022, ENGR 3611 or permission of instructor.

## **ENGR 3722 Control Systems Laboratory (1 Credit)**

This laboratory course serves as supplement to ENGR 3721. It aims at providing "hands on" experience to students. It includes experiments on inverted pendulum, gyroscopes, motor control, feedback controller design, time-domain and frequency domain. Corequisite: ENGR 3721.

## **ENGR 3730 Robotics (3 Credits)**

Introduction to the analysis, design, modeling and application of robotic manipulators. Review of the mathematical preliminaries required to support robot theory. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning, and kinetics. Cross listed with ENGR 4730. Prerequisites: ENME 2520 and MATH 2060 or MATH 2200 or permission of instructor.

## **ENGR 3731 Robotics Lab (1 Credit)**

Laboratory that complements the analysis, design, modeling and application of robotic manipulators. Implementation of the mathematical structures required to support robot operation. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning and kinetics. Applications include programming and task planning of a manufacturing robot manipulator. Corequisite: ENGR 3730 or permission of instructor.

**ENGR 3800 Topics (ENGR) (1-4 Credits)**

Special topics in engineering as announced. May be taken more than once. Prerequisite: varies with offering.

**ENGR 3900 Engineering Internship (0-4 Credits)**

Students in engineering may receive elective credit for engineering work performed for engineering employers with the approval of the chair or associate chair of the department. At the end of the term, a student report on the work is required, and a recommendation will be required from the employer before a grade is assigned. Junior, senior, or graduate status in engineering is normally required. May not be used to satisfy technical requirements. May be taken more than one for a maximum of 6 quarter hours. Prerequisite: permission of instructor.

**ENGR 4100 Instrumentation and Data Acquisition (4 Credits)**

This course examines different instrumentation techniques and describes how different measurement instruments work. Measurement devices include length, speed, acceleration, force, torque, pressure, sound, flow, temperature, and advanced systems. This course also examines the acquisition, processing, transmission and manipulation of data. Final project or paper. Cross listed with ENGR 3100. Prerequisites: PHYS 1213 OR PHYS 1214.

**ENGR 4200 Introduction to Nanotechnology (4 Credits)**

The most important recent accomplishments so far in the application of nanotechnology in several disciplines are discussed. Then a brief overview of the most important instrumentation systems used by nanotechnologists is provided. The nature of nanoparticles, nanoparticle composites, carbon nanostructures, including carbon nanotubes and their composites is subsequently discussed. The course also deals with nanopolymers, nanobiological systems, and nanoelectronic materials and devices. The issues of modeling of nanomaterials and nanostructures is also covered. Multiscale modeling based on finite element simulations, Monte Carlo methods, molecular dynamics and quantum mechanics calculations are briefly addressed. Most importantly, students should obtain appreciation of developments in nanotechnology outside their present area of expertise. Cross listed with ENGR 3200.

**ENGR 4300 Advanced Numerical Methods (4 Credits)**

Fundamental and advanced numerical methods to approximate mathematical problems for engineering applications using modern software such as Matlab. Topics include numerical differentiation and integration, solution to linear and non-linear equations, ordinary and partial differential equations, and initial, boundary, and eigen value problems. Recommended prerequisite: MATH 2070.

**ENGR 4350 Reliability (4 Credits)**

An overview of reliability-based design. Topics include: fundamentals of statistics, probability distributions, determining distribution parameters, design for six sigma, Monte Carlo simulation, first and second order reliability methods (FORM, SORM). Most Probable Point (MPP) reliability methods, sensitivity factors, probabilistic design. Cross listed with ENGR 3350.

**ENGR 4501 Graduate Capstone Design I (3 Credits)**

This is a project-centered course. This is the first third of a practical class that plans the engineering design project prior to addressing the design in earnest. This requires teamwork to develop the plan that details the schedule, cost, and who is responsible for which portions of the design effort. In this segment, the engineering teams establish the starting point for the design. This class puts theory into practice with the "shredding" of the RFP, defining a strategy for the team, balancing what has to be done with existing constraints, understanding the "true" problem of the customer, capturing the associated risks, and capturing margins required for the start of any design activity.

**ENGR 4502 Graduate Capstone Design II (3 Credits)**

This is a project-centered course. This is the second third of a practical class that implements the engineering design process (left side of the vee). This requires teamwork to develop the detailed design, which is a continuation of the accepted proposal. In this segment, the engineering teams add the details to a conceptual design. This class puts theory into practice with requirements development, balancing requirements against the constraints, completing a functional decomposition, developing a CONOPs document, developing a physical architecture, developing a functional architecture, and defining the interfaces through an ICD.

**ENGR 4503 Graduate Capstone Design III (3 Credits)**

This is a project-centered course. This is the third of a practical class that implements the engineering design process (right side of the vee). This requires teamwork to build, checkout, and test the final product. In this segment, the engineering teams build or procure hardware as a step towards the integration of the system. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. Test data is collected through instrumentation of the final product with a buy-out and certification by the team. Testing may include performance testing and environmental testing as envisioned in the context diagram.

**ENGR 4504 Graduate Capstone Design IV (3 Credits)**

This is a project-centered course. This is the fourth of a practical class that implements the entire engineering "vee" design process. This requires teamwork to build, checkout, and test the final design product, e.g. hypothetical missile. In this segment, the engineering teams fine-tune the design process which may address advanced topics such as fault management and resilience. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. It may also include addressing the beginning of the program through early management and pre-phase A activities. Test data is collected through instrumentation of the final product with a buy-in and certification by the team. Testing may include performance testing, functional testing, and environmental testing as envisioned in the system process.

**ENGR 4530 Intro to Power and Energy (4 Credits)**

Basic concepts of AC systems, single-phase and three-phase networks, electromechanical energy conversion, electric power generation, transformers, transmission lines, AC machinery, DC motors, and contemporary topics in power and energy conversion. Cross listed with ENGR 3530.

**ENGR 4545 Electric Power Economy (4 Credits)**

This course covers economy aspects of electric power industry and the implications for power and energy engineering in the market environment. Cross listed with ENGR 3545.

**ENGR 4560 Power Generation Operation and Control (4 Credits)**

This course covers economic dispatch of thermal units and methods of solution; transmission system effects; generate with limited energy supply; production cost models; control of generation; interchange of power and energy; power system security; state estimation in power systems; optimal power flow. Prerequisite: ENGR 3530 or ENGR 4530 or permission of instructor.

**ENGR 4590 Power System Protection (4 Credits)**

This course covers methods of calculation of fault currents under different types of fault; circuit breakers, current transformers, potential transformers; basic principles of various types of relays; applications of relays in the protection of generator, transformer, line, and bus, etc. Prerequisite: ENGR 3530 or ENGR 4530.

**ENGR 4620 Optimization (4 Credits)**

The development and application of various optimization techniques will be explored with engineering examples. Topics include: analytical and numerical methods, linear and non-linear programming techniques for unconstrained and constrained problems, and advanced optimization techniques, e.g. global optimization. Optimization methods will be developed and evaluated in code and used in a real-world application project.

**ENGR 4622 Advanced Optimization (4 Credits)**

Optimization is an indispensable tool for many fields of science and engineering and is one of the pillars of data science and machine learning. This course introduces optimization methods that are suitable for large-scale problems arising in data science, machine learning, and other engineering applications. We will discuss the development, computation, and convergence aspects for algorithms including gradient methods, accelerated methods, quasi-Newton methods, stochastic optimization, variance reduction, online optimization, as well as distributed optimization. We will also exploit the efficacy of these methods in concrete data science problems, including learning low-dimensional models, deep learning, and (possible) reinforcement learning. This course together with ENGR 4620 Optimization will provide in-depth introductions to optimization.

**ENGR 4680 Fault Diagnosis & Prognostics for System Design (4 Credits)**

Reliability engineering is a sub-discipline of systems engineering that emphasizes dependability in the lifecycle management of a product. Reliability, describes the ability of a system or component to function under stated conditions for a specified period of time. Reliability is closely related to availability, which is typically described as the ability of a component or system to function at a specified moment or interval of time. Normally, quality focuses on the prevention of defects during the warranty phase whereas reliability looks at preventing failures during the useful lifetime of the product or system from commissioning to decommissioning. Diagnosis is used, with variations in the use of logic, analytics, and experience, to determine "cause and effect". In systems engineering, it is typically used to determine the causes of symptoms, mitigations, and solutions. Prognostics is an engineering discipline focused on predicting the time at which a system or a component will no longer perform its intended function. This lack of performance is most often a failure beyond which the system can no longer be used to meet desired performance. The predicted time then becomes the remaining useful life (RUL), which is an important concept in decision making for contingency mitigation. Success in this course requires knowledge of probability theory and statistics, and familiarity with MATLAB/Simulink.

**ENGR 4730 Introduction to Robotics (4 Credits)**

Introduction to the analysis, design, modeling and application of robotic manipulators. Review of the mathematical preliminaries required to support robot theory. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning, and kinetics. Applications include programming and task planning of a manufacturing robot manipulator. Cross listed with ENGR 3730. Prerequisites: ENME 2520 and MATH 2060 or MATH 2200 or instructor approval.

**ENGR 4735 Linear Systems (4 Credits)**

This course focuses on linear system theory in time domain. It emphasizes linear and matrix algebra, numerical matrix algebra and computational issues in solving systems of linear algebraic equations, singular value decomposition, eigenvalue-eigenvector and least-squares problems, linear spaces and linear operator theory. It studies modeling and linearization of multi-input/multi-output dynamic physical systems, state-variable and transfer function matrices, analytical and numerical solutions of systems of differential and difference equations, structural properties of linear dynamic physical systems, including controllability, observability and stability. It covers canonical realizations, linear state-variable feedback controller and asymptotic observer design, and the Kalman filter. Cross listed with ENGR 3735. Prerequisites: ENGR 3611, ENGR 3721, ENGR 3722, or permission of the instructor.

**ENGR 4740 Adaptive Control Systems (4 Credits)**

Theoretical and application aspects of robust adaptive control design for uncertain dynamical systems. Topics include: parameter estimation, stability, model reference adaptive systems, self-tuning regulators, gain scheduling, design for robustness against unmodeled dynamics and disturbance signals. Examples will be given from aerospace engineering (changes in the dynamics of aircraft), process control, and robotics. Modern alternatives to traditional adaptive control will be discussed (switching multi-model/multi-controller adaptive schemes). Prerequisites: ENEE 3111, ENGR 3611, and ENGR 3721, or permission of instructor. Familiarity with MATLAB/Simulink.

**ENGR 4745 Adv Non-Linear Control System (4 Credits)**

Nonlinear system analysis methods: Existence of solutions of ODEs, uniqueness, continuity, compactness, fixed point, linearization, metric spaces, Contraction Mapping Theorem, Gronwall-Bellman lemma. Phase plane analysis; Limit Cycles. Lyapunov stability of autonomous and non-autonomous systems. Circle criterion, absolute stability, Popov criterion. Passivity and Lyapunov stability. Input-to-State stability. Small Gain Theorem. Describing functions. Nonlinear control system synthesis methods: Passivity-based control. Stability via Feedback Linearization. Lie derivatives.

**ENGR 4750 Networked Control Systems (4 Credits)**

Fundamental tools and recent advances in networked control. Topics include the control of multi-agent networks found in multi-vehicle coordination, control of sensor networks, unmanned vehicles, and energy systems. Network models, distributed control and estimation, distributed control under limited communications and sensing, formation control, coverage control in mobile sensor networks. Prerequisites: linear algebra, linear control systems, differential equations, familiarity with MATLAB, or permission of instructor.

**ENGR 4755 Optimal Control (4 Credits)**

Introduction to optimal control theory (control laws that maximize a specified measure of a dynamical system's performance). Topics include: optimality conditions and constraints; calculus of variations; review of mathematical programming (Lagrange multipliers, convexity, Kuhn-Tucker theorem); Pontryagin's maximum principle (constraints, Hamiltonians, bang-bang control); dynamic programming and Linear Quadratic Regulation (Riccati, Hamilton-Jacobi equation). Prerequisites: ENGR 3721 (Controls) and ENGR 3735/4735 (Linear Systems) or equivalent courses.

**ENGR 4760 Multivariable Control (4 Credits)**

Multivariable aspects of control (systems with multiple actuators and sensors); performance analysis of feedback control systems; sensitivity; robustness and stability margins; disturbance attenuation; design tradeoffs; singular value; characteristic locus. Modern H-infinity control theory and 'mu' synthesis-based robust control design techniques. Enforced Prerequisites and Restrictions ENGR 3721 (Controls) and ENGR 4735 (Linear Systems at a graduate level) or equivalents.

**ENGR 4765 Robot Control (4 Credits)**

The course focuses on different techniques, methods, and theories for control of robots. The topics covered include: introduction to nonlinear control theory, review of independent joint control, nonlinear and multivariable robot control, feedback linearization control of robots, control of underactuated robots, control of nonholonomic and mobile robots. force and impedance control, and vision-based control. Pre-requisite or co-requisite: ENGR 3730 or ENGR 4730, or equivalent is recommended.

**ENGR 4790 Systems Engineering Requirements (4 Credits)**

The course covers fundamentals of design and requirements analysis of complex systems to meet overall mission requirements. It spans the whole requirements engineering phase that includes requirements analysis, decomposition, derivation, allocation, verification and validation planning. Students acquire expertise in creating UML and SYML case diagrams and in defining and implementing verification and validation plans. Requirement management methods and tools, associated vernacular, and requirements configuration control are also covered. Prerequisites: ENMT 4100, or permission by the Instructor.

**ENGR 4810 Advanced Topics (ENGR) (1-5 Credits)****ENGR 4865 Design, Innovation, and Entrepreneurship (4 Credits)**

The course focuses on design and innovation of engineering systems and products. It deals with entrepreneurship, critical and innovative thinking, creativity and lateral thinking, research and technology challenges that lead to innovation, entrepreneurship and new product development, problem solving and decision making. It discusses factors that affect innovation (e.g. tech insertion), as well as a wide range of case studies in diverse application domains. Course Requirements: Projects.

**ENGR 4910 Conceptual Design (4 Credits)**

Conceptual design is the part of the design process where—by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these into a working structure— the basic solution path is laid down through the elaboration of a solution principle. Conceptual design specifies the principle solution. Concept design rarely starts at the same point; you might have an existing design that needs iterating or the requirement to create a conceptualized form. Problem solving consists of using generic or ad hoc methods in an orderly manner to find solutions to problems. George Polya (mathematician) presented two important decision-making principles, understanding the problem and devising a plan. To understand what is new, students are asked to look at intellectual property, a category of property that includes intangible creations of the human intellect. There are many types of intellectual property such as patents, and some countries recognize more than others. Designers assess the many different directions a design could take at this stage will allow you to identify what you like and don't like from each one. The preferred concept will then be further developed using engineering drawings, schematics and possibly 3D models which will show how the design will look and operate.

**ENGR 4920 Aerospace Missions (4 Credits)**

The Design "Problem" in Advanced Aerospace Systems describes the problems in the conceptual design of various types of aircraft, spacecraft, and complex vehicles. It covers the following topics: design of orbital spacecraft, design for Moon missions (such as landers), design for Mars missions (including rovers), design of an unmanned drone for surveillance (high-altitudes), CubeSats (having large constellations), and rockets and missiles (including hypersonic). Problem statements are concise descriptions of design problems. Design teams use them to define the current and ideal states, to freely find user-centered solutions. This class stands as a reference of interest to engineers and scientists working in aerospace engineering and related topics.

**ENGR 4940 Mission Operation Controls (4 Credits)**

Space operations is based at a centralized control center, a facility used for command & control (C2), and related communication equipment (antennas, etc.). The human operators conduct the day-to-day operations for controlling the spacecraft. They control the spacecraft and its payloads, and carries out all activities related to mission planning and scheduling. For example, normal orbital operations are interrupted every six months to conduct orbital maneuvers. Launch operations begin with spacecraft integration and checked-out for launch. Once safely placed in orbit, command and control goes back and forth between the ground control station and the spacecraft or satellite. A key aspect of spacecraft operations is the transferring of data from the onboard instruments collected by its payload to the ground, eventually disseminating the data to concerned users and analysts through a ground data network. This requires an on-orbit communication architecture.

**ENGR 4991 Independent Study (1-5 Credits)****ENGR 4995 Independent Research (1-16 Credits)****ENGR 5991 Independent Study (0-10 Credits)****ENGR 5995 Independent Research (1-16 Credits)**