Mechanical Engineering (ME)

Courses

ME 010 Graphics for Engineering Design 0,3 Credits
Graphical description of mechanical engineering design for visualization and communication by freehand sketching, production drawings, and 3D solid geometric representations. Introduction to creation, storage, and manipulation of such graphical descriptions through an integrated design project using state-of-the art, commercially available computer-aided engineering software. Lectures and laboratory. (ES 1), (ED 2).

ME 017 Numerical Methods in Mechanical Engineering 2 Credits
Numerical methods applied to mechanical engineering problems. Techniques for interpolation, curve fitting, plotting of numerical data, etc. Numerical techniques for solving algebraic and differential equations. Computational platforms to be used include MATLAB.
Prerequisites: ENGR 010

ME 021 Mechanical Engineering Laboratory I 0,1 Credits
Experimental methods in mechanical engineering and mechanics. Analysis of experimental error and error propagation. Introduction to elementary instrumentation. Introduction to digital data acquisition.
Prerequisites: MECH 012
Can be taken Concurrently: MECH 012

ME 050 Supplemental Topics in Mechanical Engineering 1-2 Credits
Completion of material for Mechanical Engineering courses transferred from other institutions. Student wil be scheduled for that part of Mechanical Engineering that is required for completion of missing material. Subject matter and credit hours to be determined by department chair for each student.

ME 104 Thermodynamics I 0,3 Credits
Basic concepts and principles of thermodynamics with emphasis on simple compressible substances. First and second law development, energy equations, reversibility, entropy and efficiency. Properties of pure substances and thermodynamic cycles.
Prerequisites: (MATH 033 or MATH 023) and (PHY 011)
Can be taken Concurrently: MATH 033, MATH 023, PHY 011

ME 111 Professional Development 1 Credit
Examination of ethical and professional choices facing mechanical engineers. Written and oral communications. Must have senior standing in Mechanical Engineering and Mechanics.

ME 121 Mechanical Engineering Laboratory II 0,1 Credits
A continuation of ME 21 including use of transducers, advanced instrumentation, and data acquisition. Emphasis on experimental exercises that illustrate, and/or introduce material from thermodynamics, and fluid mechanics. Includes proposal writing and interpretation of results.
Prerequisites: ME 021 and ME 104 and ME 231
Can be taken Concurrently: ME 231

ME 141 General Aviation Technology and Operations 2 Credits
An FAA-certified, online video course for students interested in understanding the engineering and operational aspects of the general aviation industry, including aerodynamics, aircraft systems and performance, weather, navigation, flight procedures, regulations, maneuvers, and the physiology of flight. Upon successful completion of the course, the student will be provided with an endorsement to take the FAA Private Pilot Knowledge Test. A fee is required to purchase the online training course module.

ME 142 Instrument Ground Training 2 Credits
An FAA-certified, online video course for students interested in obtaining an instrument rating from the FAA. It covers the engineering and operational aspects of the general aviation industry, including aerodynamics, aircraft systems and performance, weather, navigation, flight procedures, regulations, maneuvers, and the physiology of flight. Upon successful completion of the course, the student will be provided with an endorsement to take the FAA Instrument Rating Knowledge Test. A fee is required to purchase the online training course module.
Prerequisites: ME 141

ME 205 Application of Differential Equations in Mechanical Engineering 3 Credits
Solution and application of differential equations in engineering, including linear methods underpinning solution methodologies. Applications of differential equations include: Newton's law of cooling; linear and nonlinear dynamical systems; mechanical vibrations; beam theory; column buckling; heat/diffusion, wave, and Laplace's equations. This course counts as a fifth mathematics course or an Engineering C elective for MEM students.
Prerequisites: MATH 022

ME 207 Mechanical Engineering Laboratory III 2 Credits
Formulation of laboratory experiments through open-ended planning, including decision criteria for laboratory techniques and approaches. Execution of experiments based on individual plans, followed by assessment of experimental results.
Prerequisites: ME 121

ME 211 (BIOC 211, BIOE 211, ENGR 211, MAT 211) Capstone Design Project I 3 Credits
Students work on teams, integrating knowledge and skills acquired in their prior course work, to design practical solutions to real-world problems, typically in collaboration with industry, entrepreneurs, faculty, or campus departments. Teams perform in-depth engineering design while considering engineering standards and the project business case. Constraints, including technical, financial, environmental, societal, supply chain, regulatory, and others are considered throughout. Teams produce written reports, oral presentations, and prototypes appropriate for the project.
Prerequisites: ME 104 and ME 231 and ME 240 and MECH 102
Can be taken Concurrently: ME 231, ME 240, MECH 102

ME 212 (BIOC 212, BIOE 212, ENGR 212, MAT 212) Capstone Design Project II 2 Credits
Students continue developing their solutions from ME 211 through prototype fabrication and testing, iteration, and failure mode analysis. New information about the project, as well as new knowledge, standards, and constraints, may be identified, considered and integrated into the solution. Teams are expected to produce a final project-specific prototype, an implementation plan appropriate to the project, as well as related business case financial models. Additional deliverables include written reports and presentations.
Prerequisites: ME 211

ME 215 Engineering Reliability 3 Credits
Applications of reliability methods to engineering problems. Modeling and analysis of engineered components and systems subjected to environmental and loading conditions. Modeling content encompasses mechanistically based probability and experientially based statistical approaches. Concepts needed for design with uncertainty are developed. Principles are illustrated through case studies and projects. Engineering applications software will be extensively utilized for the projects.
Prerequisites: (MATH 023 or MATH 033) and MECH 012
Can be taken Concurrently: MECH 012

ME 231 Fluid Mechanics 3 Credits
Kinematics of fluid flow and similarity concepts. Equations of incompressible fluid flow with inviscid and viscous applications. Turbulence. One-dimensional compressible flow, shock waves. Boundary layers, separation, wakes and drag.
Prerequisites: (MATH 205 or ME 205) and ME 104

ME 240 Manufacturing 0,3 Credits
Analytical and technological base for several manufacturing processes and common engineering materials. Processes include metal cutting, metal deformation, injection molding, thermoforming, and composites. Process planning, computer-aided manufacturing, manufacturing system engineering, and quality measurements. Design project. Weekly laboratory.
Prerequisites: ME 010 and MECH 012

ME 242 Mechanical Engineering Systems 3 Credits
The modeling and analysis of mechanical, fluid, electrical and hybrid systems, with emphasis on lumped models and dynamic behavior, including vibrations. Source-load synthesis. Analysis in temporal and frequency domains. Computer simulation of nonlinear models, and computer implementation of the superposition property of linear models.
Prerequisites: MECH 102 and MATH 205

ME 245 Engineering Vibrations 0,3 Credits
Physical modeling of vibrating systems. Free and forced single and multiple degree of freedom systems. Computer simulations. Engineering applications.
Prerequisites: MECH 102 and ME 017 and (MATH 205 or ME 205)

ME 252 Mechanical Elements 3 Credits
Methods for the analysis and design of machine elements such as springs, gears, clutches, brakes, and bearings. Motion analysis of cams and selected mechanisms. Projects requiring the design of simple mechanisms of mechanical sub-assemblies.
Prerequisites: MECH 012 and ME 010 and MECH 102

ME 255 Introduction to Aerospace Engineering 3 Credits
An introductory course in the core engineering principles used in the aerospace industry: aerodynamics, controls, propulsion, and structures. The course is designed for any engineering student who may intend to work in the aerospace industry and develops a basic understanding of the technologies used in the design and operation of today's aircraft, rockets, and spacecraft.
Prerequisites: ME 104

ME 299 Special Topics In Mechanical Engineering 1-4 Credits
Repeat Status: Course may be repeated.

ME 300 Apprentice Teaching 1-3 Credits
Repeat Status: Course may be repeated.

ME 304 Thermodynamics II 3 Credits
Availability and Second Law Analysis. Design of gas and vapor power cycles, and refrigeration systems. Generalized property relations for gases and gas-vapor. Combustion and chemical equilibrium. Design of engineering systems and processes incorporating thermodynamic concepts and analysis.
Prerequisites: ME 104

ME 309 (MAT 309) Composite Materials 3 Credits
Principles and technology of composite materials. Processing, properties, and structural applications of composites, with emphasis on fiber-reinforced polymers.
Prerequisites: MECH 003 and MAT 033

ME 310 (TE 310) Directed Study 1-3 Credits
Project work on any aspect of engineering, performed either individually or as a member of a team made up of students, possibly from other disciplines. Project progress is reported in the form of several planning and project reports. Direction of the projects may be provided by faculty from several departments and could include interaction with outside consultants and local communities and industries. Consent of department required.
Repeat Status: Course may be repeated.

ME 312 Analysis and Synthesis Of Mechanisms 3 Credits
Types of motion. Degrees of freedom of motion. Position, velocity and acceleration analysis of linkage mechanisms. Systematic approach to the design of linkage mechanisms. Motion generation, path synthesis and function synthesis. Structural synthesis of planar and spatial mechanisms. Static force analysis of mechanisms using virtual work.
Prerequisites: MATH 205 and MECH 102

ME 314 (MAT 314) Metal Forming Processes 3 Credits
Mechanical metallurgy and mechanics of metal forming processes. Yield criteria. Workability. Friction and lubrication. Engineering analysis of forging, extrusion, wire and tube drawing, rolling, sheet forming and other processes. Recent developments in metal forming.

ME 315 (BIOE 315) Bioengineering Statistics 3 Credits
Probability and statistics applied to bioengineering problems focusing on modeling and data analysis. Types of data, types of distributions, parametric and nonparametric analyses, goodness-of-fit, regression, power analysis, and multivariate analysis, life models, simulation, cluster analysis, and Bayesian statistics. Projects and case studies.
Prerequisites: MATH 231

ME 316 (BIOE 316) Introduction to Force Spectroscopy 3 Credits
Fundamentals of major force spectroscopy methods, including atomic force microscopy, optical tweezers, and magnetic tweezers. Principles of force measurement, force calibration, and signal and noise. Applications to the mechanical properties of biomaterials, such as polymer elasticity, protein folding, nanoindentation, and structural transitions in macromolecules. Closed to students who have taken BIOE 416.
Prerequisites: MECH 003

ME 321 Introduction to Heat Transfer 3 Credits
Analytical and numerical solutions to steady and transient one-and two-dimensional conduction problems. Forced and natural convection in internal and external flows. Thermal radiation. Thermal design of engineering processes and systems.
Prerequisites: ME 104 and ME 231

ME 322 Gas Dynamics 3 Credits
Flow equations for compressible fluids; thermodynamic properties of gases. Normal shock waves. Steady one-dimensional flows with heat addition and friction. Oblique shock waves. Expansion waves. Nozzle flows. Shock tubes; performance calculations and design. Supersonic wind tunnels; diffuser design. Real gas effects.
Prerequisites: ME 231 and ME 104

ME 323 Reciprocating and Centrifugal Engines 0,3 Credits
Thermal analysis and design of internal combustion engines (conventional and unconventional), gas turbine engines, air breathing jet engines, and rockets. Components such as jet nozzles, compressors, turbines, and combustion chambers are chosen to exemplify the theory and development of different types of components. Both ideal fluid and real fluid approaches are considered.
Prerequisites: ME 104

ME 325 Ethical Issues for Mechanical Engineers 3 Credits
Introduction to Engineering Ethics familiarizes students with the methods used for developing ethical approaches in engineering practice. Through reading, writing and discussion this course takes a 'case-study' approach. Cases are historical and contemporary and may include: Challenger, Chernobyl, Bhopal, Ford Pinto, Essure as well as more general areas as: Genetic Technology, Energy, AI, Medical Technology and the newly emerging study of Design Ethics. Each student will research and prepare a major presentation. Senior standing and/or instructor permission required.
Prerequisites: ME 111

ME 331 Advanced Fluid Mechanics 3 Credits
Kinematics of fluid flow. Conservation equations for inviscid and viscous flows; integral forms of equations. Two-dimensional potential flow theory of incompressible fluids with applications. Boundary layers. Introduction to free shear layer and boundary layer stability and structure of turbulence. Transition from laminar to turbulent boundary layers. Separation of flow. Steady and unsteady stall. Secondary flows. Hydrodynamic lubrication. Measurement techniques.
Prerequisites: ME 231

ME 333 Propulsion Systems 3 Credits
Comprehensive review of jet engine and rocket engine technology in use today. Review of the thermodynamic and aerodynamic principles that are needed to analyze the design and performance of today's jet engines and rocket engines. Focuses on understanding the design and performance of these technologies, including turbojet, turbofan, and turboprop jet engines. Rocket engines include liquid, cryogenic, solid, and electric propulsion.
Prerequisites: MECH 326
Can be taken Concurrently: MECH 326

ME 340 Advanced Mechanical Design 3 Credits
Probabilistic design of mechanical components and systems. Reliability functions, hazard models and product life prediction. Theoretical stress-strength-time models. Static and dynamic reliability models. Optimum design of mechanical systems for reliability objectives or constraints.

ME 341 Mechanical Systems 3 Credits
Advanced topics in mechanical systems design. Kinematics and dynamics of planar machinery. Shock and vibration control in machine elements. Balancing of rotating and reciprocating machines. Design projects using commercial computer-aided-engineering software for the design and evaluation of typical machine systems.
Prerequisites: ME 252

ME 342 Dynamics of Engineering Systems 3 Credits
Dynamic analysis of mechanical, electromechanical, fluid and hybrid engineering systems with emphasis on the modeling process. Lumped and distributed-parameter models. Use of computer tools for modeling, design and simulation. Design projects.
Prerequisites: ME 242

ME 343 Control Systems 3 Credits
A comprehensive course in classical and modern linear control systems. Includes root locus, frequency response, state space, and digital control techniques with extensive use of MATLAB. A design project provides experience with practical design issues and tradeoffs.
Prerequisites: ME 242 or ME 245 or ECE 125
Can be taken Concurrently: ME 245

ME 348 Computer-Aided Design 3 Credits
Impact of computer-aided engineering tools on mechanical design and analysis. Part geometry modeling and assembly modeling using solid representations. Analysis for mass properties, interference, kinematics, displacements, stresses and system dynamics by using state-of-the-art commercially available computer-aided-engineering software. Integrated design projects.
Prerequisites: ME 010 and MECH 012 and MECH 102 and MATH 205

ME 350 Special Topics 1-5 Credits
A study of some field of mechanical engineering not covered elsewhere. Consent of department chair required.
Repeat Status: Course may be repeated.

ME 354 Flight Dynamics 3 Credits
The forces and moments acting on an aircraft are developed from basic aerodynamics and used to determine the equations of motion and the resulting dynamic models. Analysis from these dynamic models supports the design of flight control, guidance, and autopilot systems. Modern control methods for missiles and spacecraft are also included.
Prerequisites: MECH 326 and ME 343

ME 355 Spacecraft Systems Engineering 3 Credits
Systems engineering approach to the design, integration, testing, and operations of spacecraft for a variety of missions. Reviews current technologies used in modern spacecraft bus and payload systems, astrodynamics, launch systems, life-cycle costs, and operational issues. Students develop the requirements for a specific mission and design a spacecraft that will meet those requirements.
Prerequisites: ME 255

ME 356 Astrodynamics 3 Credits
Kepler's Laws are reviewed and proven from basic mechanics, then used to determine the equations of motion for a satellite. Subsequent topics include the various kinds of orbits in use today, orbit determination, orbital maneuvers, rendezvous, lunar and interplanetary trajectories, and orbital perturbations. Satellite attitude and rocket vehicle dynamics are also reviewed.
Prerequisites: MECH 102

ME 360 Nuclear Reactor Engineering 3 Credits
A consideration of the engineering problems related to nuclear reactor design and operation. Topics include fundamental properties of atomic and nuclear radiation, reactor fuels and materials, reactor design and operation, thermal aspects, safety and shielding, instrumentation and control. Course includes several design projects stressing the major topics in the course. Must have senior standing in engineering or physical science.
Prerequisites: ME 104

ME 362 Nuclear Fusion and Radiation Protection 3 Credits
Structure of the nucleus. Quantum theory. Nuclear energy release: Fission vs. Fusion. Plasma for fusion. Power balances in fusion plasmas. Magnetic and inertial confinement fusion concepts. Magnetic equilibrium configurations and limitations. The Tokamak. Emerging and alternative concepts. Fusion reactor economics. Radiation sources and Radioactive decay. Interactions of radiation with matter, detectors and protection from radiation. Energy deposition and dose calculations. Applications in dosimetry, imaging and spectroscopy. Must have senior standing in engineering or physical science.
Prerequisites: ME 104

ME 364 Renewable Energy 3 Credits
Fundamentals and design aspects of Renewable Energy (RE) technologies; biofuels, hydropower, solar photovoltaic, solar thermal, wind, geothermal energies. Details and difficulties in implementing RE. Senior standing in Engineering. Credit not given for both ME 364 and ME 464.
Prerequisites: ME 104 and ME 231

ME 366 Power Generation Technologies 3 Credits
The energy matrix is changing due to economic, environmental, and political pressure, requiring a transition to become more efficient, carbon-neutral, resilient, and competitive. This course looks at the design and performance of conventional (coal and natural gas) power generation systems, including thermal cycles, power plant efficiency, technologies for environmental compliance, carbon capture and sequestration, plant flexibilization and energy storage, and advanced plant data analytics. Must have junior standing in engineering or physical science.
Prerequisites: ME 104

ME 368 Fundamentals of Energy Efficiency Practicum 3 Credits
Studies of the plant operation and energy usage. Students work with the Lehigh Industrial Assessment Center to do technical and economic feasibility studies of optimizing energy consumption. Industrial experience. Fundamentals of best practices to save energy, reduce waste, and increase productivity. Consent of instructor required.
Prerequisites: ME 104 and ME 231

ME 373 Mechatronics 3 Credits
Synergistic integration of mechanical engineering with electronics and intelligent computer control in designing and manufacturing machines, products and processes; semiconductor electronics, analog signal processing, with op amps, digital circuits, Boolean algebra, logic network designs, Karnaugh map, flip-flops and applications, data acquisition, A/D and D/A, interfacing to personal computers, sensors and actuators, microcontroller programming and interfacing.

ME 374 Mechatronics Laboratory 3 Credits
Experiments and applications utilizing combinations of mechanical, electrical, and microprocessor components. Theory and application of electronic and electromechanical equipment, operation and control of mechatronic systems. Projects integrating mechanical, electronic and microcontrollers.

ME 376 (CHE 376) Energy: Issues & Technology 3 Credits
Energy usage and supply, fossil fuel technologies, renewable energy alternatives and environmental impacts. The scope will be broad to give some perspective of the problems, but in-depth technical analysis of many aspects will also be developed.
Prerequisites: CHE 210 or ME 104 or CHM 342 or MAT 205

ME 385 Polymer Product Manufacturing 3 Credits
Polymer processes such as injection molding through a combination of theory development, practical analysis, and utilization of commercial software. Polymer chemistry and structure, material rheological behavior, processing kinetics, molecular orientation development, process simulation software development, manufacturing defects, manufacturing window establishment, manufacturing process design, manufacturing process optimization. Must have senior level standing in engineering or science. Credit not given for both ME 385 and ME 485.

ME 387 (CHE 387, ECE 387) Digital Control 3 Credits
Sampled-data systems; z-transforms; pulse transfer functions; stability in the z-plane; root locus and frequency response design methods; minimal prototype design; digital control hardware; discrete state variables; state transition matrix; Liapunov stability state feedback control (two lectures and one laboratory per week).
Prerequisites: CHE 386 or ECE 212 or ME 343

ME 388 Honors Project for Eckardt Scholar 1-4 Credits
Opportunity for Eckardt Scholars to pursue an extended project for senior honors.Transcript will identify department in which project was completed.
Repeat Status: Course may be repeated.

ME 389 (CHE 389, ECE 389) Control Systems Laboratory 2 Credits
Experiments on a variety of mechanical, electrical and chemical dynamic control systems. Exposure to state-of-the-art control instrumentation: sensors, transmitters, control valves, analog and digital controllers. Emphasis on design of feedback controllers and comparison of theoretical computer simulation predictions with actual experimental data. Lab teams will be interdisciplinary.
Prerequisites: CHE 386 or ECE 212 or ME 343

ME 401 (MSE 401) Integrated Product Development 3 Credits
An integrated and interdisciplinary approach to engineering design, concurrent engineering, design for manufacturing, industrial design and the business of new product development. Topics include design methods, philosophy and practice, the role of modeling and simulation, decision making, risk, cost, material and manufacturing process selection, platform and modular design, mass customization, quality, planning and scheduling, business issues, teamwork, group dynamics, creativity and innovation. The course uses case studies and team projects.

ME 402 (MAT 402) Advanced Manufacturing Science 3 Credits
The course focuses on the fundamental science-base underlying manufacturing processes, and applying that science base to develop knowledge and tools suitable for industrial utilization. Selected manufacturing processes representing the general classes of material removal, material deformation, material phase change, material flow, and material joining are addressed. Students create computer-based process simulation tools independently as well as utilize leading commercial process simulation packages. Laboratory experiences are included throughout the course.

ME 413 Numerical Methods in Mechanical Engineering 3 Credits
Zeros of functions, difference tables, interpolation, integration, differentiation. Divided differences, numerical solution of ordinary differential equations of the boundary and initial value type. Eigen problems. Curve fitting, matrix manipulation and solution of linear algebraic equations. Partial differential equations of the hyperbolic, elliptic and parabolic type. Application to problems in mechanical engineering.

ME 420 Advanced Thermodynamics 3 Credits
Critical review of thermodynamics systems. Criteria for equilibrium. Applications to electromagnetic systems. Statistical thermodynamics. Irreversible thermodynamics. Thermoelectric phenomena.

ME 421 Topics in Thermodynamics 3 Credits
Emphasis on theoretical and experimental treatment of combustion processes including dissociation, flame temperature calculations, diffusion flames, stability and propagation; related problems in compressible flow involving one-dimensional, oblique shock waves and detonation waves. Methods of measurement and instrumentation.

ME 423 Heat and Mass Transfer 3 Credits
This course is a first graduate course in the basic concepts of heat and mass transfer, providing a broad coverage of key areas in diffusion, conduction, convection, heat and mass transfer, and radiation. Topics covered include: the conservation equations, steady and transient diffusion and conduction, periodic diffusion, melting and solidification problems, numerical methods, turbulent convection, transpiration and film cooling, free convection, heat transfer with phase change, heat exchanges, radiation, mixed mode heat and mass transfer.

ME 424 Unsteady and Turbulent Flow 3 Credits
Stability of laminar flow; transition to turbulence. Navier-Stokes equations with turbulence. Bounded turbulent shear flows; free shear flows; statistical description of turbulence.

ME 430 Advanced Fluid Mechanics 3 Credits
This course is a first graduate course in incompressible fluid mechanics, providing a broad coverage of key areas of viscous and inviscid fluid mechanics. Topics covered include: Flow kinematics, differential equations of motion, viscous and inviscid solutions, vorticity dynamics and circulation, vorticity equation, circulation theorems, potential flow behavior, irrotational and rotational flows, simple boundary layer flows and solutions, and real fluid flows and consequences.

ME 431 Advanced Gas Dynamics 3 Credits
Method of characteristics. Unsteady continuous flow. Unsteady flows with discontinuities. Shock tubes. Detonation waves. Two-dimensional and axisymmetric supersonic flows. Momentum and energy equation of compressible viscous fluids.

ME 433 (CHE 433, ECE 433) Linear Systems and Control 3 Credits
This course covers the following topics in linear systems and control theory: review of fundamental concepts in linear algebra, state-space representation of linear systems, linearization, time-variance and linearity properties of systems, impulse response, transfer functions and their state-space representations, solution to LTI and LTV state equations, Jordan form, Lyapunov stability, input-output stability, controllability, stabilizability, observability, detectability, Canonical forms, minimal realizations, introduction to optimal control theory, Linear Quadratic Regulator (LQR), Algebraic Riccati Equation (ARE), frequency domain properties of LQR controllers.

ME 434 (CHE 434, ECE 434) Multivariable Process Control 3 Credits
A state-of-the-art review of multivariable methods of interest to process control applications. Design techniques examined include loop interaction analysis, frequency domain methods (Inverse Nyquist Array, Characteristic Loci and Singular Value Decomposition) feed forward control, internal model control and dynamic matrix control. Special attention is placed on the interaction of process design and process control. Most of the above methods are used to compare the relative performance of intensive and extensive variable control structures.
Prerequisites: CHE 433 or ME 433 or ECE 433

ME 435 Robot Motion Planning and Control 3 Credits
This course covers motion planning algorithms - including potential & navigation function-based motion planning and graph search based motion planning - for different robotic systems, including holonomic and non-holonomic mobile robots, spatial robots, and robotic manipulators. Sensor-based motion planning and motion planning under uncertainties, estimation & filtering, and probabilistic robot action models will be introduced. Application to multi-robot coordination, coverage, pursuit-evasion, task allocation and exploration problems will be discussed. Students will be introduced to topological motion planning.

ME 436 (CHE 436, ECE 436) Systems Identification 3 Credits
The determination of model parameters from time-history and frequency response data by graphical, deterministic and stochastic methods. Examples and exercises taken from process industries, communications and aerospace testing. Regression, quasilinearization and invariant-imbedding techniques for nonlinear system parameter identification included.

ME 439 Formal Methods in Robotics 3 Credits
The course is an introduction to formal methods with emphasis on robotics application. The aim is to develop computational frameworks that take rich temporal and logic specifications and automatically construct or certify robot behaviors (controllers). It covers formal specification languages, automatic controller synthesis, and formal verification. Methods are based on abstractions, automata, mathematical programming and algorithms from control theory, robot motion planning, and machine learning. The material is grounded in examples involving aerial and ground vehicles, manipulators, and self-driving cars.

ME 440 General Examination 3 Credits
A critical assessment and definition of major unresolved issues for an assigned research topic during the first half of the semester, followed by formulation of a research proposal in accord with the format of a federal funding agency during the second half of the semester. In addition to the written proposal, the student gives a presentation to the Doctoral Committee, followed by extensive discussion. Grade assigned by the committee; minimum grade of B+ required. Instructor (doctoral student adviser) approval required.

ME 450 Special Topics 3 Credits
An intensive study of some field of mechanical engineering not covered in more general courses.
Repeat Status: Course may be repeated.

ME 452 (BIOE 452, CHE 452, ENGR 452) Mathematical Methods In Engineering I 3 Credits
Analytical techniques relevant to the engineering sciences are described. Vector spaces; eigenvalues; eigenvectors. Linear ordinary differential equations; diagonalizable and non-diagonalizable systems. Inhomogeneous linear systems; variation of parameters. Non-linear systems; stability; phase plane. Series solutions of linear ordinary differential equations; special functions. Laplace and Fourier transforms; application to partial differential equations and integral equations. Sturm-Liouville theory. Finite Fourier transforms; planar, cylindrical, and spherical geometries.

ME 453 Mathematical Methods in Engineering II 3 Credits
Theory of complex functions; Cauchy-Riemann relations. Integration in the complex plane, Cauchy's integral formula. Laurent series; singular points; contour integrals; Fourier and Laplace transforms. Evaluation of real integrals; Cauchy principal values. Laplace's equation; conformal mappings; Poisson formulae. Singular integral equations. Classification of partial differential equations. Hyperbolic systems of partial differential equations; uniqueness, shock formation. Nonlinear parabolic equations; Burger's equation.

ME 454 Aeroelastic Flight Dynamics 3 Credits
The forces and moments acting on an aircraft are developed from basic aerodynamics and used to determine the equations of motion and the resulting aeroelastic dynamic models. Analysis from these models supports the design of flight control, guidance, and autopilot systems. Modern control methods for missiles and spacecraft are also included. ME 454 is the graduate-level version of ME 354; requires additional assignments and/or projects. Credit will not be given for both ME 354 and ME 454.

ME 455 Methods of Convex Optimization in Engineering 3 Credits
This course benefits students using scientific computing or optimization in engineering, especially from Mechanical (robotics, control, navigation, design), Electrical (power networks, signal/image processing, communications, control, EDA & CAD), Civil (structural analysis, optimization, design), Computer Science (machine learning, robotics, graphics, algorithms, computational geometry), and Industrial Engineering (operations research). Students gain tools to identify convex optimization problems, formulate them efficiently to reduce computational complexity, and solve them thoroughly, acquiring a strong background for research applications.

ME 456 Astrodynamics 3 Credits
Kepler's Laws are proven from basic mechanics, then used to determine the equations of motion for a satellite. Subsequent topics include various kinds of orbits in use today, orbit determination, orbital maneuvers, and rendezvous. Interplanetary trajectories, satellite attitude dynamics, rocket vehicles, and orbital perturbations are also discussed. ME 456 is the graduate level version of ME 356; requires additional assignments and/or projects appropriate for graduate level study. Credit will not be given for both ME 356 and ME 456.

ME 460 Engineering Project 1-6 Credits
Project work on some aspect of mechanical engineering in an area of student and faculty interest. Selection and direction of the project could involve interaction with local communities or industries. Consent of department required.
Repeat Status: Course may be repeated.

ME 461 Integrated Product Development (IPD) Projects-1 2 Credits
Technical and economic feasibility study of new products. Selection and content of the project is determined by the faculty project advisor in consultation with the student, progress and final reports, oral and posters presentations. Consent of the program director and faculty project adviser required.
Prerequisites: TE 401 or ME 401

ME 462 IPD: Manufacturing 3 Credits
Industry sponsored Integrated Product Development Project (IPD) projects. The student works with an industry sponsor to create detailed design specifications, fabricate and test a prototype new product and plan for production. Selection and content of the project is determined by the faculty project advisor in consultation with the industry sponsor. Deliverables include progress and final reports, oral presentations, posters and a prototype. Consent of the department chair and faculty project advisor required.

ME 464 Renewable Energy 3 Credits
Fundamentals and design aspects of Renewable Energy (RE) technologies; bio-fuels, hydropower, solar photovoltaic, solar thermal, wind, geothermal energies. Details and difficulties in implementing RE. ME 464 is graduate level version of ME 364 and will require additional assignments and/or projects appropriate for graduate level study. Closed to students who have taken ME 364.

ME 468 Advanced Energy Efficiency Practicum 3 Credits
Critical assessments of energy management systems. Establishment of framework for industrial facilities to manage energy systems. Fundamentals of best practices for energy efficiencies associated with industrial energy savings. Progress and final reports required. Engineering graduate students only. Consent of instructor required.

ME 475 Directed Studies 1-3 Credits
Special problems related to a topic in mechanical engineering and mechanics.

ME 485 Polymer Product Manufacturing 3 Credits
An exploration of the science underlying polymer processes such as injection molding through a combination of theory development, practical analysis, and utilization of commercial software. Polymer chemistry and structure, material rheological behavior, processing kinetics, molecular orientation development, process simulation software development, manufacturing defects, manufacturing window establishment, manufacturing process design, manufacturing process optimization. This course is a version of ME 385 for graduate students, with research projects and advanced assignments. Closed to students who have taken ME 385. Must have graduate level standing in engineering or science.

ME 490 Thesis 1-6 Credits
Repeat Status: Course may be repeated.

ME 499 Dissertation 1-15 Credits
Repeat Status: Course may be repeated.