Mechanical Engineering (ME)

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5105. Basic Concepts of Continuum Mechanics

Three credits.

An introductory course in the theory of continuum mechanics. Development of physical principles using Cartesian tensors. Concepts of stress, strain and motion. Basic field equation for the Newtonian fluid and the elastic solid.

5110. Advanced Thermodynamics

Three credits.

Microscopic view of thermodynamics: probability and statistics of independent events, thermodynamic probabilities and most probable thermodynamic distributions, molecular structure and partition function, Ensemble of microstates describing macroscopic behavior, with ideal gas as an example, Macroscopic descriptions of thermodynamic equilibrium and equilibrium states, Reversible processes, Heat and Work interactions, Mixtures of pure substances and chemical equilibrium, Stability and phase transitions, Irreversible thermodynamics, Onsager reciprocity relations and thermo-electric effects, Kinetic theory of gases.

5120. Advanced Thermo-Fluids I

Three credits.

Fluid as a continuum, Kinematics and decomposition of fluid motion, Conservation of mass and momentum, Navier-Stokes equations, Conservation of energy, Exact solutions to governing equations, Potential flows, Vorticity dynamics and low Reynolds number flows, Laminar boundary layers including heat transfer, Laminar free shear flows including heat transfer, Flow instabilities and transition.

5130. Advanced Heat and Mass Transfer

Three credits.

Review of thermophysical properties of matter including nanoscale effects. Exact and computational solutions of heat conduction equation. Dimensionless conduction rate approach for steady-state and transient conduction. Species diffusion equations with emphasis on stationary media and partitioning effects. Navier-Stokes equations and exact solutions for special cases. Correlation approach for treatment of single phase laminar, turbulent and two-phase flow. Radiative properties and treatment of surface radiation with spectral and directional effects. Emphasis on multimode heat transfer with applications in manufacturing, nanotechnology, information technology and biotechnology.

5140. Heat and Mass Transfer in Multiphase Systems

Three credits.

Presentation of basic principles for analysis of transport phenomena in multi-phase systems and how they can be applied to a wide variety of applications. The scope is limited to thermodynamics and heat and mass transfer fundamentals in solid <-> liquid, liquid <-> vapor and solid <-> vapor with emphasis in condensation, evaporation, sublimation, vapor deposition, boiling, two phase flow, melting and solidification.

5150. Analytical and Applied Kinematics

Three credits.

Analytical methods of coordinate transformation and two and three dimensional motion, analysis of relative motion and relative freedom through kinematics connections, study of finite and instantaneous properties of motion, study of the geometry of single and multi-parameter engineering curves, surfaces and motions. Application in the analysis and design of linkages and mechanisms.

5155. Geometric Modeling

Three credits.

Mathematical modeling, computer representations and algorithms for manipulating geometry on a computer. Basic concepts of solid and geometric modeling from geometry and topology. Uses these concepts to develop computational techniques for creating, editing, rendering, analyzing and computing with models of physical objects, mechanical parts, assembly and processes.

5160. Theory and Design of Automatic Control Systems

Three credits.

Design features of a closed loop control system. Laplace domain analysis of electromechanical, pneumatic, hydraulic, thermal, and mechanical systems. Computer simulation of dynamic responses using software tools. Stability issues, Routh analysis, root locus, Bode and Nyquist analyses are addressed. An open-ended, hands-on design project from a current research topic is assigned.

5180. Dynamics

Three credits.

Three-dimensional particle and rigid-body mechanics. Particle kinematics. Newton's laws, energy and momentum principles. Systems of particles. Rigid body kinematics, coordinate transformations. Rigid body dynamics, Euler's equations. Gyroscopic motion. Lagrange's equations.

5190. Advanced Solid Mechanics

Three credits.

Fundamental idealizations used in linear solid mechanics and the fundamental principles of the subject. Idealizations covered include beams, circular torsion, struts and thick cylinders. Basic principles include principle of minimum potential energy, principle of minimum complementary energy, virtual work, equations of static equilibrium and direct and potential methods of solving equilibrium equations. Example applications vary but may include, bounding of elastic properties of composites, derivation of finite elements, solution of plate problems by Green's functions and others.

5210. Intelligent Material Systems and Structures

Three credits.

Overview of piezoelectric materials and electrostrictive materials, shape memory alloys, magnetostrictive materials, and ER/MR fluids. Development of adaptive structure integrated with piezoelectric material, actuation and sensing, simultaneous optimal design/control of electromechanical integrated system, nonlinear and robust control. Design of shape memory alloy system for position control. Development of semi-active control using ER/MR fluids. Structural health monitoring and system identification research.

5220. Principles of Machining and Machine Tools

Three credits.

Theories and applications of machining. Fundamentals of machine tools and machining automation. Physics and mechanics in machining, machining forces and stresses, shear angle theories. Basic phenomena pertinent to process characteristics, such as tribology and tool life, machinability, surface integrity, and economics. Mechanisms of machining and machine tool errors. Machining error compensation with feedback sensors. Machining chatter and vibration analyses. Case studies.

5301. Macroscopic Equilibrium Thermodynamics I

Three credits.

Review of zeroth, first and second laws of thermodynamics, development of equilibrium thermodynamics from a postulatory viewpoint, examination of thermodynamic potentials and equilibrium states, stability of thermodynamic systems including implications on phase and chemical equilibrium. Thermodynamic availability analysis.

5311. Computational Methods of Viscous Fluid Dynamics

Three credits. Prerequisite: Instructor consent.

An advanced course on integral and finite-difference methods of solution of the parabolic and elliptic equations of viscous fluid flow. Method of weighted residuals; Crank-Nicolson; Dufort-Frankel; Peaceman-Rachford alternating direction method; truncation error analysis; stability. Applications to boundary layer and heat transfer problems. A background of FORTRAN programming and numerical analysis is necessary.

5320. Flow of Compressible Fluids I

Three credits.

Equations of motion of a compressible fluid. Quasi-one-dimensional flow including effects of friction, heat addition, and normal shocks. Two and three-dimensional flows. Velocity potential and stream function. Small perturbation theory. Subsonic pressure correction formulas. Kelvin and Crocco Theorems. Method of characteristics for steady and unsteady, rotational and irrotational flows. Curved and oblique shock waves. Shock tube theory.

5340. Conduction Heat Transfer

Three credits.

Mathematical development of the fundamental equations of heat conduction in the steady and unsteady state, with or without internal heat generation or absorption. Study of exact and approximate methods used in the solution of heat conduction boundary value problems. Analytical, graphical, numerical and experimental evaluation of the temperature field in conducting media.

5341. Radiation Heat Transfer

Three credits. Prerequisite: ME 5507.

Fundamentals of radiative emission (black body behavior and Planck's law), surface properties (emissivity, absorptivity, reflectivity, and transmissivity), electromagnetic theory for prediction of radiative properties, development of the methods of solution for radiant energy interchange between surfaces and in enclosures with and without absorbing, emitting, and scattering medi present.

5410. Theory of Elasticity

Three credits. Prerequisite: ME 5105.

The mathematical theory of linear elasticity. The theory of torsion of prismatic members. Two-dimensional elasticity problems. Thermal stress. Variational methods.

5415. Advanced Dynamics

Three credits. Prerequisite: ME 5180.

Variational principles of mechanics: Legranges equations, Hamilton's principle. Hamilton-Jacobi theory, canonical transformations, integrability. Introduction to special relativity, applications to orbital problems. Current topics in analytical dynamics.

5420. Mechanical Vibrations I

Three credits.

Variational principles, Lagrange's equation. Equations of motion for multi-degree of freedom systems. Free vibration eigenvalue problem: modal analysis. Forced solutions: general solutions, resonance, effect of damping, and superposition. Vibrations of continuous systems: vibration frequencies and mode shapes for strings, bars, membranes, beams, and plates. Experimental methods and techniques.

5425. Principles of Machine Tool Design

Three credits.

The basic principles and philosophies in the design of precision machine tools. Mathematical theory and precision machine tools. Mathematical theory and physics of errors. The building up of error budget and the mapping of geometric and thermal errors. Design case study of a precision machine tool. Discussion of various types of sensors and actuators, bearings, and transmissions. System design considerations.

5430. Mechanics of Composite Materials

Three credits. Prerequisite: ME 5410 or CE 5124.

Provides students with the fundamental knowledge to perform stress analysis of fiber-reinforced composite materials. Focus on the use of mechanics to study the stresses due to applied deformations, loads, and temperature changes. Begins with an introduction to composite materials, including their constituent properties, applications, advantages and limitations, and manufacturing techniques. Elasticity theory of anisotropic solids is also reviewed. Next, the determination of composite macroscopic constitutive relations through micromechanics is discussed, followed by the development of Classical Lamination Theory (CLT) for composite structural members, and applications to buckling and free vibration analyses. Concludes with a discussion on the use of CLT for failure analysis of composite structures subjected to mechanical and thermal loads.

5431. Fatigue in Mechanical Design

Three credits. Not open for credit to students who have passed ME 3228.

Design calculation methods for the fatigue life of engineering components, fundamentals of fracture mechanics. Crack initiation and crack propagation fatigue lives. Neuber analysis, multiaxial stress, cyclic stress-strain behavior, mean and residual stress effects. Selected current research topics, advanced research and design projects.

5433. Theory of Plasticity

Three credits. Prerequisite: ME 5410.

Introduces the physical basis for inelastic behavior and various mathematical descriptions for non-linear deformation. Provides and overview of plastic deformation in metals, including the role of dislocation behavior in strain hardening and strengthening. Detailed topics include yield surfaces, flow rules, hardening rules and introduction to viscoplastic modeling; emphasis is on finite element computer-based implementation of the concepts and their use in predicting the behavior of structures.

5442. Composites Design

Three credits.

Fundamental principles and best practices for designing structural parts made from composite materials. Students will apply the knowledge and skills obtained throughout the course towards solving a practical design problem. Students will learn and use engineering software for predicting laminated composite properties, designing composite parts, and predicting the part performance under specified loads. At the end of the course, students will have created a complete definition of their design that may be manufactured and tested in subsequent courses.

5443. Composites Manufacturing

Three credits.

This course will provide an overview of multiple manufacturing methods for a select group of material types. Manufacturing methods will focus on production and process qualification for Aerospace Components. Students will have the opportunity to survey multiple materials, methods, and processes for part fabrication. Part evaluation methods will also be covered (destructive and non-destructive). There will be entry level exposure to manufacturing risk analysis through the use of industry standard tools (Manufacturing Flow, PFMEA, Control Plan, and PPAP).

5507. Engineering Analysis I

Three credits.

Matrix algebra, indicial notation and coordinate transformations. Cartesian and general vectors and tensors, vector and tensor calculus. Partial differential equations: Fourier series, solution procedures to boundary value problems in various domains. Application to the mechanics of continuous media.

5511. Principles of Optimum Design

Three credits.

Engineering modeling and optimization for graduate students in all areas of engineering. Problem formulation, mathematical modeling, constrained and unconstrained optimization, interior and boundary optima constraint interaction, feasibility and boundedness, model reduction, sensitivity analysis, linear programming, geometric programming, nonlinear programming, and numerical methods in optimization.

5513. Modern Computational Mechanics

Three credits.

An advanced course in Computational Mechanics with emphasis on modeling problems using Finite Differences and Finite Element techniques. Projects include initial value problems, ordinary differential equations and partial differential equations. Course evaluation is made by the successful completion of several assigned projects.

5520. Finite Element Methods in Applied Mechanics I

(Also offered as CE 5164.) Three credits. Not open for credit to students who have passed CE 5162.

Formulation of finite elements methods for linear static analysis. Development of two and three dimensional continuum elements, axisymmetric elements, plate and shell elements, and heat transfer elements. Evaluation of basic modeling principles including convergence and element distortion. Applications using commercial finite element programs.

5521. Finite Element Methods in Applied Mechanics II

(Also offered as CE 5166.) Three credits.

Formulation of finite elements methods for modal and transient analysis. Development of implicit and explicit transient algorithms. Stability and accuracy analysis. Formulation of finite element methods for material and geometric nonlinearities. Development of nonlinear solution algorithms. Applications using commercial finite element code.

5522. Advanced Analysis of Composite Materials and Structures

Three credits.

Fundamental theories and computational skills to perform advanced analysis of composite materials and structures. The focus is on the damage and failure modeling of composites across multiple length scales. Various composite failure criteria and modeling techniques are reviewed, including the virtual crack closure technique, cohesive zone model and crack band model. Virtual simulations of composite manufacturing processes are introduced, with emphasis on the prediction of manufacturing-induced defects. Methods to evaluate the deformation response of 2D and 3D textile composites are also covered.

5702. Data Science for Materials and Manufacturing

(Also offered as SE 5702.) Three credits. Prerequisite: Undergraduate degree in engineering or computer science, departmental or unit consent required. Recommended preparation: knowledge or coursework in probability and statistics.

This course will provide students with data analytics skills for knowledge discovery and product design optimization. The students will also learn how to apply data mining and machine learning techniques to tackle the challenges in manufacturing and computational materials engineering. Topics include uncertainty quantification, design of experiment and data collection, data visualization, gradient/non-gradient-based optimization, supervised/unsupervised learning methods, and applications of data analytics in manufacturing and computational materials engineering problems.

5895. Special Topics in Mechanical Engineering

Variable (1-3) credits. Prerequisite: Instructor consent. May be repeated for a total of 12 credits.

Classroom and/or laboratory courses in special topics as announced in advance for each semester. The field of study or investigation is to be approved by the Head of the Department before announcement of the course.

6110. Statistical Thermodynamics

Three credits.

A microscopic development of thermodynamics including statistical ensembles, quantum statistical mechanics, and a comparison of various molecular models.

6130. Advanced Thermo-Fluids II

Three credits.

Review of governing flow equations, instability and transition, Reynolds averaging and closure approximations, Algebraic turbulence models, Two-equation turbulence models, Large eddy simulations, Turbulence statistics: probability density function and power spectral densities, Energy cascade and intermittency, Turbulent boundary layers including heat transfer, Turbulent free shear flows, Turbulent internal flows (pipes and channels) including heat transfer, Natural convection.

6140. Convection Heat Transfer

Three credits.

A study of heat transfer to laminar and turbulent boundary layers for both compressible and incompressible fluids. Free convection heat transfer is also investigated.

6160. Turbines and Centrifugal Machinery

Three credits. Prerequisite: ME 5320.

Theory, design and performance of centrifugal and exial flow machinery including turbines, blowers, fans, compressors, superchargers, pumps, fluid couplings and torque converters. A detailed study of the mechanics of the transfer of energy between a fluid and a rotor.

6170. Combustion and Air Pollution Engineering

Three credits.

Review of thermodynamics and chemical equilibrium. Introduction to chemical kinetics. Studies of combustion processes, including diffusion and premixed flames. Combustion of gases, liquid, and solid phases, with emphasis on pollution minimization from stationary and mobile systems. Air pollution measurement and instrumentation.

6173. Advanced Combustion

Three credits. Prerequisite: ME 6170, or ME 2234 and 3250.

Review of thermodynamic properties, transport properties, conservation equations of multicomponent reacting gas. Introduction to chemical kinetics. Classification of combustion waves. Deflagrations, detonations and diffusion flames. Ignition phenomena, droplet and spray combustion and some aspects of turbulent combustion.

6176. Hypersonic Aerodynamics

Three credits. Prerequisite: ME 5320.

Hypersonic small disturbance theory; similarity laws. Newtonian, shock-expansion and blast-wave theories of hypersonic flow. Aerodynamic shapes for minimum hypersonic drag. Physical properties of real gases; shock waves in real gas flow.

6177. Aerothermal Analysis

Three credits. Prerequisite: ME 5320; instructor consent required.

High-speed, viscous compressible flow. Equations of motion. Thermodynamic and transport properties of high temperature gases. Blunt body heating. Boundary layer equations and transformations. Hypersonic boundary layers with heat and mass transfer. Reference enthalpy methods.

6222. Non-Linear Vibrations

Three credits.

Vibrations of non-linear single-degree-of-freedom systems. Singular points. Liapunoff function. Approximation techniques. Stability. Self-excited vibrations. Vibrations of non-linear multi-degree-of-freedom systems.

6260. Advances in Control Systems Design

Three credits. Prerequisite: ME 5160 or 5507.

Review of the state space design concepts for control systems. Mathematical modeling of dynamic systems. Lagrange's and Newton’s representations. Decentralized or linearized control. Variable structure systems. Sliding mode control of nonlinear systems and discussions of constraint control cases. Time-delayed systems. Stability-based analysis and synthesis. Engineering applications. Open-ended control system design projects.

6300. Independent Study in Mechanical Engineering

Three credits. Prerequisite: Instructor consent. May be repeated for a total of 12 credits.

Individual exploration of special topics as arranged by student and instructor.

6301. Macroscopic Equilibrium Thermodynamics II

Three credits. Prerequisite: ME 5301.

Review of zeroth, first and second laws of thermodynamics, development of equilibrium thermodynamics from a postulatory viewpoint, examination of thermodynamic potentials and equilibrium states, stability of thermodynamic systems including implications on phase and chemical equilibrium. Thermodynamic availability analysis.

6330. Advanced Measurement Techniques

Variable (1-3) credits. Prerequisite: Instructor consent.

A critical examination of measurement techniques. Principles of operation of various instruments. Estimates of accuracy, precision, and resolution of measurements. Intended primarily for students contemplating experimental theses. When possible, specific topics covered will be structured to the needs of the class.

6340. Graduate Seminar

Zero credits. Students taking this course will be assigned a final grade of S (satisfactory) or U (unsatisfactory).

Presentations by invited guest speakers on topics of current interest in various Mechanical Engineering and allied fields.

6511. Advanced Optimum Design

Three credits. Prerequisite: MATH 3410 or ME 5511.

Advanced techniques in engineering design and process modeling optimization for graduate students in all areas of engineering. Review of theories of multi-variable constrained and unconstrained optimization, and computational techniques in nonlinear programming, structured programming, including integer programming, quadratic programming, genetic algorithms, theories of multivariable optimization from calculus of variations, computational techniques in functional optimization.