4600:500 Thermal System Components (3 Credits)
Performance analysis and design of basic components of thermal energy exchange and conversion systems. Components studied include heat exchangers, pumps, compressors, turbines and expansion engines.

4600:510 Heating & Air Conditioning (3 Credits)
Prerequisite: permission. Thermodynamics of gas mixtures. Design and selection of air conditioning equipment. Control of gas mixtures, heating, cooling, and humidity.

4600:511 Compressible Fluid Mechanics (3 Credits)

4600:512 Fundamentals of Flight (3 Credits)
Introduction to basic aerodynamics, airplane performance, stability and control, aeronautics and propulsion. Design considerations are emphasized.

4600:513 Introduction to Aerodynamics (3 Credits)
Introduction of aerodynamic concepts; conformal transformations, theory of thin airfoils, 2-dimensional airfoil theory, wings of finite span, lifting line theories, lumped-vortex, vortex-lattice, and panel methods.

4600:514 Introduction to Aerospace Propulsion (3 Credits)
Introduction to propulsion systems currently used in aerospace fields; propulsion principles for turbojets, chemical rockets, and electrical rocket propulsion.

4600:515 Energy Conversion (3 Credits)
Prerequisite: permission. Topics from fields of internal combustion engines, cycle analysis, modern conversion devices.

4600:516 Heat Transfer Processes (3 Credits)
Prerequisite: permission. Analysis, design of extended surfaces. Natural convection and mixed convection, combined modes of heat transfer with phase changes.

4600:522 Experimental Stress Analysis I (3 Credits)
Prerequisite: permission. Experimental methods of determining stress or strain: brittle lacquer, strain gages, photoelasticity, full field thermal techniques.

4600:530 Machine Dynamics (3 Credits)
Prerequisite: permission. Static and dynamic forces in machines, products of inertia, dynamic equivalence, flywheels. Balancing of rating, reciprocating, cyclic plane motion. Computer simulation of transient mechanism dynamics, other topics in advance dynamics.

4600:531 Fundamentals of Mechanical Vibrations (3 Credits)
Prerequisite: permission. Undamped and forced vibrations of systems having one or two degrees of freedom.

4600:532 Vehicle Dynamics (3 Credits)

4600:540 System Dynamics & Control (4 Credits)

4600:541 Control Systems Design (3 Credits)
Prerequisite: permission. Methods of feedback control design such as minimized error, root-locus, frequency domain. Compensation techniques. Multivariable and nonlinear design methods and computer-aided control design.

4600:542 Industrial Automatic Control (3 Credits)
Prerequisite: permission. Operation of basic control mechanisms. Study of mechanical, hydraulic, pneumatic, fluidic control systems, including application areas. Tuning of control devices for optimum performance of system. Case studies on control applications from industry, e.g. boilers, furnaces, process heaters.

4600:543 Optimization Methods in Mechanical Engineering (3 Credits)
Prerequisite: permission. Development and method of solution of optimization problems in mechanical engineering. The use of dynamic programming and operational research methods for optimization including computer utilization and applications.

4600:544 Robot Design, Control & Application (3 Credits)
Prerequisite: permission. Robot design and control. Kinematic transformations, velocities and accelerations, path trajectories and dynamics, control and sensing in robotics. The automated factory with robot applications.

4600:550 Introduction to Computational Fluid Flow & Convection (3 Credits)
Prerequisite: permission. Numerical modeling of fluid/thermal systems, numerical solution of the momentum and thermal boundary layer equations; flow simulation using advanced heat transfer/fluid/graphics packages.

4600:562 Pressure Vessel Design (3 Credits)
Prerequisite: permission. Introduction to modern pressure vessel technology. Topics include basic structural considerations, materials and their environment and design-construction features.

4600:563 Computer Aided Design & Manufacturing (3 Credits)
Prerequisite: permission. The use of computer systems to assist in the creation, modification, analysis, or optimization of engineering designs, and to plan, manage, and control manufacturing plants.

4600:585 3D Printing and Additive Manufacturing (3 Credits)
Understanding principles and theories in additive manufacturing processes; Understanding process models, materials, design for additive manufacturing (DFAM), and applications; Hands-on practice and research project; State of the art of additive manufacturing.

4600:600 Gas Dynamics (3 Credits)

4600:608 Thermodynamics (3 Credits)
Extension and generalization of basic laws of thermodynamics with application to a variety of physical and biological systems. Introduction to irreversible thermodynamics, the third law and statistical thermodynamics.
4600:609 Finite Element Analysis I (3 Credits)
Prerequisite: 4600:622. Introductory development of finite element method as applied to various topics from continuum mechanics. Areas covered include plane; axisymmetric and 3-D stress analysis; conduction; fluid mechanics; transient problems and geometric and material nonlinearity.

4600:610 Dynamics of Viscous Flow I (3 Credits)
Derivation and solution of equations governing laminar viscous flow. Applications include unsteady flows, slow viscous flows, parallel flows, lubrication theory and laminar boundary layers.

4600:611 Computational Fluid Dynamics I (3 Credits)
Prerequisite: 4600:610 or permission of instructor. Study of numerical methods in fluids; numerical errors and stability, finite differencing, nonlinear convection terms, Poisson equations, boundary conditions, turbulence, spectral and finite element techniques.

4600:615 Conduction Heat Transfer (3 Credits)
Study of one-, two- and three-dimensional heat conduction. Development of analytical techniques for analysis and design.

4600:616 Convection Heat Transfer (3 Credits)
Heat transfer from laminar, turbulent external, internal flows. Convective heat transfer at high velocities. Heat transfer to liquid metals; high Prandtl number fluids.

4600:617 Radiation Heat Transfer (3 Credits)
Study of governing radiation laws. Black and real systems, geometric factors, gray enclosures, non-gray systems, gaseous radiation, radiation equipment.

4600:618 Boiling Heat Transfer & Two-Phase Flow (3 Credits)
Current techniques to determine heat transfer and pressure drop in components such as boilers, heat exchangers, and steam generators, with boiling. Boiling mechanism, slip ratio, critical heat flux and instabilities in boiling flow systems.

4600:620 Experimental Stress Analysis II (2 Credits)
Prerequisite: 4600:522. Dynamic strain gage methods, transducer design, Moiré fringe techniques and topics in photoelasticity.

4600:621 Introduction to Tire Mechanics (3 Credits)
Prerequisite: permission. Topics include tire as vehicle component, tire traction and wear, laminated structures, tire stress and strains and advanced tire models.

4600:622 Continuum Mechanics (3 Credits)
Prerequisite: permission. Analysis of stress and deformation at a point. Derivation of fundamental field equations of fluid and solid mechanics by applying basic laws of dynamics, conservation of mass and energy. Development of constitutive laws.

4600:623 Applied Stress Analysis I (3 Credits)
Prerequisite: 4600:622. Continuation of 4600:622 with specific application to solid mechanics. Development of energy theorems due to Reissner, Washizu and generalized Hamilton’s principle. Solutions to static and dynamic problems.

4600:624 Fundamental of Fracture Mechanics (3 Credits)

4600:625 Analysis of Mechanical Components (3 Credits)
Theories of failure and plastic flow. Fatigue, creep analysis and introduction to fracture mechanics.

4600:626 Fatigue of Engineering Materials (3 Credits)
Prerequisite: 4600:624 or permission. Quasi-static and cyclic behavior; dislocation networks and their interactions; correlation of dislocation-microstructure interactions; crack initiation; crack propagation; short cracks; crack closure; environmental effects.

4600:627 Advanced Materials & Manufacturing Processes (3 Credits)
Manufacturing processes for advanced materials; classification; technological aspects of bulk deformation, casting, joining, forming, machining, molding, powder metallurgy, rapid solidification; economic aspects; technical activity.

4600:628 Mechanical Behavior of Materials (3 Credits)
Prerequisite: permission. Mechanical behavior of engineering materials; metallurgy of deformation; dislocation effects and deformation; strengthening mechanisms; thermomechanical processing; mechanical testing.

4600:629 Nonlinear Engineering Problems (3 Credits)

4600:630 Vibrations of Discrete Systems (3 Credits)

4600:631 Kinematic Design (3 Credits)
Prerequisite: permission of instructor. The geometry of constrained motion. Analysis of relative plane motion using vectors and the digital computer. Curvature theory. Synthesis of linkages and gearing. Introduction to computer-aided design.

4600:632 Reliability in Design (3 Credits)
Prerequisite: 3470:561. The reliability determination of mechanical components and systems and its use in design. Failure functions, elementary reliability determination, normal log-normal, Weibull theory, life spectrum analysis, renewal theory and confidence limits.

4600:633 Computerized Modal Analysis of Structures (3 Credits)
Prerequisite: 4600:630 or equivalent. Modal analysis theory and measurement techniques, digital signal processing concepts, structural dynamics theory, modal parameter estimation with "hands-on" experience in the application of modal measurement methods in vibration analysis.

4600:634 Advanced Dynamics of Rotating Machinery (3 Credits)
Prerequisite: 4600:530 or equivalent. Dynamic modeling and simulation of complex rotor-bearing systems. Steady state, transient and stability analysis with inertia, gyroscopic, imbalance, rotor-bow, disk-skip and impeller-rub interaction effects.

4600:635 Stress Waves in Solids & Fluids (3 Credits)

4600:642 System Analysis & Control Design (3 Credits)
Uniform methods of modeling and response analysis, controllability and observability, stability theory and analysis of linear and nonlinear engineering processes. Design of feedback controls for optimum performance for multivariable real-time control application.
4600:645 Process Identification & Computer Control (3 Credits)
Prerequisite: permission. Obtaining mathematical models of processing from noisy observations. Methods of digital control design. Case studies on computer control of selected processes.

4600:646 Expert Systems in Controls & Manufacturing (3 Credits)
Prerequisite: 4600:540 or equivalent or by permission. Expert system methodologies for process control, computer integrated flexible manufacturing and robotics.

4600:647 Neural & Fuzzy Control Systems (3 Credits)
Prerequisite: 4600:540 or permission of instructor. Analysis and design of intelligent control systems. Neural networks and fuzzy sets for process identification and controller design. Applications and case studies in industry.

4600:650 Tribology (3 Credits)
Fundamentals of friction lubrication and wear treated; includes basic theory, advanced topics, applications to bearings, seals, gears, cams. Specific topics include adhesive and abrasive friction/wear, boundary lubrication, fluid film lubrication and bearings, rolling element bearings, bearing dynamics.

4600:655 Micro- and Nano-Fluid Dynamics (3 Credits)
Prerequisite: 46900:611 or permission of instructor. The course includes fundamentals of the analytical and numerical solutions of the problems pertinent to fluid mechanics on nano- and micro- scales. Applications will include micro-engines, MEMS, micro-filters, and synthesis of nano-materials.

4600:658 Mechanical Behavior of Nanostructured Materials & Composites (3 Credits)
The course is open to students in mechanical engineering, polymer science and polymer engineering, biology and all other engineering disciplines. Some prior consultation with the instructor is encouraged. The course is considered as a graduate elective in ME. An Overview of Lattice Dislocation Theory, Nanostructured Materials: Processing and Properties, Grain Boundaries, Nanoindentation, Electron Microscopy, Atomic Force Microscopy, Carbon Nanotubes, Polymer and Bio-MEMS.

4600:660 Engineering Analysis (3 Credits)
Prerequisite: B.S. in engineering. Study of analysis techniques as applied to specific engineering problems. Applications include beam deflections, acoustics, heat conduction and hydrodynamic stability.

4600:661 Failure Analysis of Mechanical Systems (3 Credits)
Prerequisites: 4600:625 or permission by instructor. This course emphasizes engineering techniques for predicting yielding, buckling, fracture and fatigue of mechanical systems. Students will be taught how to link theory with practice by examining case studies of structural and mechanical failures and will obtain practical experience in modeling real complex systems in an end-of-term project.

4600:662 Microscale Heat and Mass Transfer (3 Credits)
Prerequisites: 4600:608 and 4600:615 or permission. Kinetics theory, classical and quantum statistics, structure of solids, phonons in solids, free electrons in metals, Boltzmann transport theory, hyperbolic heat conduction, thermal conductivity of thin films, laser materials processing.

4600:663 Web-Based Solid Modeling and e-Manufacturing (3 Credits)
Prerequisite: 4600:563 or equivalent, or permission. Team-based collaborative design with a web-based solid modeling library, feature-based manufacturing analysis, and process planning using cross-platform interoperable tools including JAVA, VRML for optimized product realization.

4600:664 Fundamentals of Crystallization and Solidification (3 Credits)
Prerequisite: 4600:608 or equivalent, or permission. Fundamental theories and modeling of crystalline nucleation and growth, interface stability and morphology, microstructure formation, and microsegregation. Applications in casting, welding, laser processing, and single crystal growth.

4600:666 Analysis of Manufacturing Systems (3 Credits)
This course will examine general problems in the design, planning, and control of manufacturing systems. No prerequisites or corequisites are required.

4600:670 Integrated Flexible Cellular Manufacturing System-Analysis & Design (3 Credits)
Prerequisite: 4600:563 or equivalent or by permission of instructor. The analysis of integrated computer-aided manufacturing systems, design of automated manufacturing components and simulations of flexible cellular manufacturing systems.

4600:671 Fundamentals and Applications of Micro Electro (3 Credits)
Prerequisite: consent of instructor. Fundamentals of MEMS based sensors and actuators, MEMS materials, bulk and surface micromachining and MEMS device testing. Applications in optics, automotive, and biomedical instrumentation.

4600:672 Design of Microsystems and Nano Devices (3 Credits)
Prerequisite: consent of instructor. Design principles of various micro and nano sensors and actuators, microfluidic devices, microstructure analysis and simulation, microfabrication process design rule. Applications in MOEMS, Lab-on-a-chip devices, BioMEMS and NEMS.

4600:682 Fundamentals of Composite Processing and Mechanics (3 Credits)
This course covers mainly composite processing, manufacturing and mechanics. The emphasis is on discontinuous fiber composites.

4600:693 Measurements Methods & Experimental Error in Thermofluid Sciences (3 Credits)
Prerequisites: viscous flow, conduction heat transfer convection heat transfer. The course will incorporate elements of experimental error analysis, optics, and optical ray tracing, principles of testing, methods and devices for fluid flow quantization and temperature measurements. Laboratory work with hands-on experience.

4600:694 Deformation and Failure of Polymers and Soft Materials (3 Credits)
This course introduces the concepts of deformation, fracture and failure analyses of engineering polymers, soft and biological materials.

4600:696 Special Topics in Mechanical Engineering (1-4 Credits)
Prerequisite: Permission. For qualified candidate for graduate degree. Supervised research in the student's major field of training or experience. Credit depends upon nature and extent of project as determined by advisor and department chair.

4600:697 Engineering Report (2 Credits)
Prerequisite: Permission of advisor. A relevant problem in mechanical engineering for students electing the non-thesis option. The final engineering report must be approved by the advisor and the advisory committee.

4600:698 Master's Research: Mechanical Engineering (1-6 Credits)
Prerequisite: Permission of advisor. (May be repeated.) Research on a suitable topic in mechanical engineering culminating in a master's thesis.

4600:699 Master's Thesis (1-6 Credits)
Prerequisite: permission of advisor. (May be repeated.) Supervised research in a specific area of mechanical engineering.
4600:704 Finite Element Analysis II (3 Credits)

4600:705 Finite Element Analysis III (3 Credits)

4600:710 Dynamics of Viscous Flow II (3 Credits)

4600:711 Computational Fluid Dynamics II (3 Credits)
Prerequisite: 4600:611 or permission of instructor. Development of advanced computational techniques for convection-dominated flows. Higher order explicit and implicit schemes including nonoscillatory front-capturing methods applied to benchmark problems.

4600:715 Hydrodynamic Stability (3 Credits)

4600:719 Advanced Heat Transfer (3 Credits)
Prerequisites: 4600:615, 4600:616. Topics include nonhomogeneous or nonlinear boundary value problems of heat conduction, heat transfer with melting, solidification and ablation, heat transfer in porous systems and hydrodynamically and thermally unsteady convection.

4600:723 Applied Stress Analysis II (3 Credits)
Prerequisite: 4600:623. Continuation of 4600:623. Development of approximate solution techniques including finite elements, method of weighted residuals (Rayleigh-Ritz, Galerkin, Trefftz, collocation, least squares, etc.) and finite differences.

4600:726 Non-Linear Continuum Mechanics (3 Credits)
Prerequisite: 4600:622. Finite deformation and strain, stress, constitutive equations, strain energy functions. Solution of finite deformation problems in hypoelasticity, coupled thermoviscoelasticity and plasticity, electroelasticity and micropolar theories.

4600:730 Vibrations of Continuous Systems (3 Credits)
Prerequisite: 4600:630. Continuation of 4600:630. Analysis of continuous vibrating systems, using separation of variables, energy, variational, Rayleigh-Ritz and other approximate techniques. Concepts and solutions of integral equations as applied to continuous systems.

4600:732 Advanced Modal Analysis of Structures (3 Credits)

4600:741 Optimization Theory & Applications (3 Credits)
Prerequisite: permission. Theory of optimization in engineering systems, development and method of solution optimization problems for physical processes, large systems. Use of dynamic programming, operational research methods of system optimization, control.

4600:763 Advanced Methods in Engineering Analysis (3 Credits)
Applications of finite difference and finite element methods, variational methods, integral methods and similarity transforms to engineering problems in heat transfers, fluid mechanics and vibrations.

4600:790 Advanced Seminar in Mechanical Engineering (1-4 Credits)
(May be repeated for a total of nine credits) Prerequisite: permission of department chair. Advanced projects and studies in various areas of mechanical engineering. Intended for student seeking Ph.D in engineering degree.

4600:898 Preliminary Research (1-15 Credits)
Prerequisite: approval of dissertation director. Preliminary investigations prior to the submission of a dissertation proposal to the Interdisciplinary Doctoral Committee.

4600:899 Doctoral Dissertation (1-15 Credits)
(May be taken more than once.) Prerequisite: acceptance of research proposal by the Interdisciplinary Doctoral Committee and approval by the dissertation director. Original research by the doctoral student.