

# MECHANICAL ENGINEERING (MECH)

## **MECH-510 Analysis and Design of Machines and Mechanical Assemblies 4 Credits**

Corequisites: MECH-330

Prerequisites: MECH-300 and MECH-310 and MECH-312

The main aim of this course is to integrate the concepts of kinematic & dynamic analyses to the design of machines and mechanical assemblies used in automotive, medical equipment and other applications. These include (but are not limited to) the analysis and design of reciprocating engine sub-systems such as, piston cylinder mechanism, steering linkages, window and door-lock mechanisms, over-head valve linkage system, flywheel, gears & gearboxes, universal couplings and automotive differential. Synthesis of mechanism systems used in medical equipment area will also be covered. Kinematic and dynamic characteristics such as displacement, velocity, acceleration and forces are analyzed by graphical and analytical methods. CAE tools will be used to perform kinematic, dynamic and stress analyses and fatigue design of these systems using CAE tools. Temperature effects will also be included wherever appropriate in the design. Several practical design projects will be assigned during the term of this course.

Lecture: 4, Lab 0, Other 0

## **MECH-515 Failure and Material Considerations in Design 4 Credits**

Corequisites: MECH-412

Prerequisites: None

Designing components that are safe and reliable requires efficient use of materials and assurance that failure will not occur. Even still, components do fail. In this course, students will be introduced to the techniques of designing for life and material considerations involved in that process. In addition, students will also study how to analyze those components which do fail, and evaluate safe-life and remaining life in a design through the study of real-life component design and current failures.

Lecture: 4, Lab 0, Other 0

## **MECH-523 Applied Computational Fluid Dynamics 4 Credits**

Prerequisites: MECH-322 and (MATH-313 or MATH-418 or MATH-423)

This course includes solution methods to the Navier-Stokes equations in a discrete domain. Grid generation, coordinate transformation, discretization, explicit, implicit, semi-implicit, a variety of algorithms, post-processing, and interpretations of results are discussed. Solution techniques for compressible and incompressible flows, their applicability, robustness, and limitations are covered. External and internal flows with and without chemical reactions are also discussed. The learning process involves hands-on experience on grid generation, setting up a CFD code, post-processing, and a thorough discussion on the results. The students will work on a final project that is a practical problem of significant magnitude and importance to industry. This work must be publishable in the student's journal or presentable in a conference.

Lecture: 4, Lab 0, Other 0

## **MECH-525 Introduction to Multiphysics Modeling and Simulation in Fluid Mechanics and Heat Transfer 4 Credits**

Prerequisites: MECH-322 and MECH-420

This course solves a variety of engineering problems with the aid of computational software mainly in the field of fluid mechanics and heat transfer. Pipe flow, incompressible flow, laminar and turbulent flow, drag, and lift are subjects covered during the first part of the course. In the second part, topics in heat transfer are used such as conduction in solids, fin design, convection, heat exchangers, and radiation. In a third part, selected topics in electrical conductive media and reaction engineering are also covered. This course compliments MECH-322 and MECH-420 and could be considered an extension of the two courses where problems are solved in 2D and 3D using computational software. Different types of meshes will be discussed, post-processing of data will be analyzed through graphical techniques, and graphical results will be compared to well-known analytical solutions. Students will also complete a final project where both fluid mechanics and heat transfer physics will be used to solve practical engineering problems.

Lecture: 4, Lab 0, Other 0

## **MECH-562 Compressible Flow/Gas Dynamics 4 Credits**

Prerequisites: MECH-322

The derivation and physical interpretation of the Navier-Stokes equations for compressible flows. Analysis of one-dimensional flows with discussions on normal, oblique, and bow shocks. Sound waves and unsteady wave motion are also covered. The method of characteristic (MOC) is taught and standard JANNAF CFD codes is utilized to understand the compressible flows and shock formation and behavior. The study is then further carried out to nozzle flows and jet/shock layer interaction. The students are required to not only understand the conventional methods used to obtain solution for compressible flow problems, but also to be able to utilize CFD and experimental methods to obtain solution for complex problems.

Lecture: 3, Lab 2, Other 0

## **MECH-564 Aerodynamics and Wing Theory 4 Credits**

Prerequisites: MECH-322 and (MATH-305 or MECH-600)

Discussions on fundamentals of inviscid and viscous incompressible flows. Important topics in fluid mechanics such as potential flow, vortices, point sources, and coupling of inviscid and boundary layer flows are covered. Two and three dimensional wings (or airfoils) and some exact solutions to such flow problems are discussed. Semi-analytical methods for disturbance distribution on wings are introduced by perturbation method. The computational Panel method for two and three dimensional aerodynamics problems is discussed. Commercial computer programs are used to solve realistic problems in a three dimensional space.

Lecture: 4, Lab 0, Other 0

## **MECH-595 Automotive Seminar I 4 Credits**

Prerequisites: None

Kettering has a partnership with the Society of Automotive Engineers (SAE) to offer both a certificate in Automotive Systems, as well as, a graduate degree in either Automotive Systems or the Mechanical Cognate. This seminar course would be comprised of a total of four Continuing Education Units (CEU) from SAE seminars, which have been reviewed and approved by a faculty review committee, consistent with Graduate academic policy. The transfer of credit must be supported by documentation from SAE for each individual applicant seeking such transfer.

Lecture: 4, Lab 0, Other 0

**MECH-596 Automotive Seminar II 4 Credits**

Prerequisites: None

Kettering has a partnership with the Society of Automotive Engineers (SAE) to offer both a certificate in Automotive Systems, as well as, a graduate degree in either Automotive Systems or the Mechanical Cognate. This seminar course would be comprised of a total of four Continuing Education Units (CEU) from SAE seminars, which have been reviewed and approved by a faculty review committee, consistent with Graduate academic policy. The transfer of credit must be supported by documentation from SAE for each individual applicant seeking such transfer.

Lecture: 4, Lab 0, Other 0

**MECH-600 Engineering Mathematics with Applications 4 Credits**

Prerequisites: (MATH-305 or MATH-307) and MECH-420

The objectives of this course are to introduce students to various analytical and numerical methods used in the modeling, analysis, and design of engineering systems. The theory and application of these methods will be introduced. Applications to real-world mechanical and thermal-fluid systems will be performed.

Lecture: 3, Lab 0, Other 1

**MECH-601 ME Principles for Mobility Systems 4 Credits**

Prerequisites: None

This course introduces the basic principles of mechanical engineering that are required for application in mechanical automotive systems. Major topics include machine design, thermodynamics, fluid mechanics, heat transfer, and dynamic systems. Applications include chassis systems, suspension, steering, brakes, aerodynamics, powertrains, climate control, fuel cells, turbines, compressors, transmission systems, HVAC systems, shafts, and safety systems.

Lecture: 4, Lab 0, Other 0

**MECH-610 Mechanics of Materials I: Linear Elasticity 4 Credits**

Prerequisites: None

Introduction to the general model of deformation and displacements; and, their application to linear elastic solids are taught in this course. The formulation of deformation gradients, displacement gradient, strain, and stress tensors will be discussed. The derivation of the general equation of motion of a deforming solid will be conducted. The general constitutive relation of elastic materials will be introduced. The linearized general deformation measures and constitutive relation will be utilized with the general equation of motion and compatibility conditions to develop the general theory of linear elasticity. The developed theory will then be applied to solve for the deformation and stresses of elastic solids under plane strain, plane stress and beam theory conditions.

Lecture: 3, Lab 0, Other 1

**MECH-611 Mechanics of Material II: Nonlinear Elastic-Plastic Behavior 4 Credits**

Prerequisites: MECH-610

General nonlinear theory of deformation and its application to elastic-plastic behavior of materials is taught in this course. The linear elastic behavior will be reviewed along with its application to deformation of plates and shells. The geometric nonlinear deformation measures will be discussed. The application of the general equation of motion to nonlinear deformation of solids will be conducted. The nonlinear theories of elasticity and plasticity materials will be introduced. The nonlinear deformation measures and constitutive relation will be utilized with the general equation of motion to address the nonlinear deformation of elastic-plastic materials. The developed relations will then be applied to solve for the deformation and stresses of several nonlinear problems.

Lecture: 3, Lab 0, Other 1

**MECH-613 Nonlinear Finite Element Analysis 4 Credits**

Prerequisites: MECH-611

Introduction to the theory and application of nonlinear finite element analysis in engineering design is covered in this course. The classification and formulation of different nonlinear behaviors and computational techniques will be discussed. Material and geometric nonlinear behaviors will be studied. The computational techniques for solving the different classes of nonlinear problems will be formulated. These techniques include implicit and explicit methods. Commercial software will be used to apply the formulated algorithms to the analyses of nonlinear crash and metal forming engineering problems.

Lecture: 3, Lab 0, Other 1

**MECH-615 Engineering Optimization 4 Credits**

Prerequisites: MECH-600

Introduction to the general model of numerical optimization and its application to engineering design. The formulation and classification of the optimization problems will be discussed. The computational search techniques for solving the different classes of optimization problems will be studied. These techniques include single and multivariable, zero and first order constrained and unconstrained, linear and nonlinear search algorithms. The developed algorithms will be used to find the optimum solutions for a variety of engineering design problems.

Lecture: 3, Lab 0, Other 1

**MECH-621 Applied Transport Phenomena 4 Credits**

Prerequisites: MECH-420

Introduction to concepts normally not covered in undergraduate Heat Transfer and Fluid Flow courses. Concepts relating to advanced heat convection and mass diffusion, turbulent and laminar boundary layer flows with heat transfer and mass transfer will be introduced. Topics in advanced heat conduction and droplet evaporation will also be introduced. Heat transfer for internal and external flow problems will be considered. The relationship between fluid flow, heat, and mass transfer in engineering systems will be discussed. Analytical and approximate solutions to these problems will be presented.

Lecture: 3, Lab 0, Other 1

**MECH-622 Computational Heat and Mass Transfer 4 Credits**

Prerequisites: MECH-600

Introduction to the use of numerical methods that are commonly used to solve transient, non-linear, three-dimensional engineering problems with complicated geometries. Analytical methods that could be used to solve these types of problems will be presented. Some of these analytical methods can only be used to solve problems with simple geometries and simple boundary conditions. However, numerical methods can be used to solve problems with complicated geometries and boundary conditions. Engineering problems involving several different physical phenomena simultaneously, such as fluid flow with heat transfer and mass transfer, will be considered. In this case, the governing differential equations are coupled and should be solved simultaneously. Methods on how to treat non-linear terms will be discussed. Moreover, the method of staggered grids and upwind schemes that are used to solve fluid flow problems will be presented. For transient problems, implicit and explicit methods will also be presented. The student will be required to write his or her own computer code to implement these methods to solve engineering problems. For very complicated geometries, the student will be required to use a commercial or existing code. The student will be able to relate the computer output to the performance/behavior of the physical system. The limitations and convergence/stability issues associated with these numerical methods will be discussed.

Lecture: 3, Lab 0, Other 1

**MECH-626 Hydrogen Generation, Storage and Safety 4 Credits**

Prerequisites: None

This various methods of hydrogen production are covered: water electrolysis using photovoltaics, steam reformation and partial oxidation techniques of various types of conventional and alternative fuels. Various methods of hydrogen storage – compressed gas, liquefied gas, metal and chemical hydrides and nanotubes are included. Codes for underground and above ground pressurized hydrogen gas storage systems and safety aspects are covered. A comparison is made between hydrogen properties and known conventional fuels such as, methane (natural gas), gasoline, methanol and ethanol. Infrastructure design studies, dispensing transportation, codes and standards are covered. A hydrogen storage/production/safety laboratory for experimental studies is planned to be a major component of this course.

Lecture: 3, Lab 0, Other 1

**MECH-627 Green Energy Conversion 4 Credits**

Prerequisites: MECH-420

Radiant energy transfer from the sun and its application to solar exchangers are covered. Basic theory, energy balances for solar exchangers, economics, and practice of solar energy applications are included. The concepts are applied to renewable energy systems such as solar heating and cooling systems for homes, businesses, and industry. Windmill theory and applications as well as system design are also covered. Data obtained on large scale solar and windmill systems will be analyzed and discussed.

Lecture: 3, Lab 0, Other 1

**MECH-641 Advanced Auto Power Systems 4 Credits**

Prerequisites: MECH-420

Terms Offered: Winter, Spring

This course serves to expand student's knowledge of automotive power systems. Topics covered include, detailed thermodynamic cycle analysis of various power cycles, emerging alternative fuels and power systems for automotive use (current topics include high-blend alcohol/gasoline fuels, gasoline direct injections (GDI) engines, hybrid electronic Powertrains, and fuel-cells). Students are also expected to work on design projects which are determined by the instructor. Students are expected to work on projects leading to the development of presentations and/or technical papers for professional society meetings (i.e. SAE, Global Powertrain Congress, etc.). This course is an advanced version of MECH-441. Students in MECH-641 are required to complete additional project challenges and a final project in addition to the workload for MECH-441.

Lecture: 4, Lab 0, Other 0

**MECH-643 Noise, Vibration & Harshness 4 Credits**

Prerequisites: None

An integrated approach to the analysis of Noise, Vibration and Harshness of automotive engineering is presented. Techniques for evaluating the vibration and acoustic characteristics of vehicle systems are discussed. Then the principles of noise and vibrations control are presented through automotive applications.

Lecture: 4, Lab 0, Other 0

**MECH-644 Introduction to Automotive Powertrains 4 Credits**

Prerequisites: None

Terms Offered: Winter, Spring

An introduction to the performance of motor vehicle and the design of automotive power transmission systems. Topics covered include, loads on the vehicle, evaluation of various engine and vehicle drive ratios on acceleration performance and fuel economy, manual transmission design, and automatic transmission design. This course is an advanced version of MECH-444. Students in MECH-644 are required to complete additional project challenges and a final project in addition to the workload for MECH-444.

Lecture: 4, Lab 0, Other 0

**MECH-645 Hybrid Electric Vehicle Propulsion 4 Credits**

Prerequisites: None

An introduction to the principles of hybrid electrical vehicle propulsion systems for Mechanical and Electrical Engineering students. A major emphasis of the course will be to broaden the mechanical engineering student's knowledge of electrical engineering so that he/she can understand the fundamentals of electrical motors, electrical motor controls, and electrical energy storage systems. The course is also intended to strengthen the knowledge of electrical engineering students relative to automotive powertrain design. With this background, the integration of these hybrid electric components into the hybrid electric vehicle powertrain system will be studied, including electric energy storage (batteries, flywheels, ultra-capacitors) and electrical energy production-fuel cells. Relevant codes and standards will be emphasized. This course is an advanced version of MECH-445. Students in MECH-645 are required to complete additional project challenges and a final project in addition to the workload for MECH-445.

Lecture: 4, Lab 0, Other 0

**MECH-646 Advanced Vehicle Dynamics 4 Credits**

Prerequisites: None

Advanced vehicle dynamics is the study of the motion of rubber-tired ground vehicles. Dynamic vehicle responses result from the tire, gravitational, and aerodynamic forces that a vehicle is subjected to. Ride quality, handling characteristics, performance, and safety can be evaluated by examining a vehicle's dynamic responses. This course provides an advanced understanding of vehicle dynamics behavior and the means to model it from a mathematical point of view. Special emphasis is placed on dynamic systems modeling approaches, including the creation and numerical evaluation of state space mathematical models.

Lecture: 4, Lab 0, Other 0

**MECH-647 Combustion & Emissions 4 Credits**

Prerequisites: None

Introduction to the basic principles of combustion and how to apply them to basic engineering problems. Various technologies of this field will be explored. However, a large portion of the course will cover the fundamentals of combustion. Topics relating to flame speed, flame thickness, flame spread, flame quenching, blow-off, stabilization, ignition energy, flammability limits, and flashback will be presented. Laminar and turbulent premixed and diffusion flames will be discussed. These topics will be related to combustion and emissions in spark-ignition and diesel engines.

Lecture: 3, Lab 0, Other 1

**MECH-650 Automotive Bioengineering: Occupant Protection and Safety 4 Credits**

Prerequisites: None

Terms Offered: Winter, Spring

A discussion and application of the following fundamental concepts:

(1) an overview of Federal Motor Vehicle Safety Standards; (2) basic anatomy and physiology of the overall human body; (3) introduction to injury biomechanics including rate, load, and acceleration dependent injury mechanisms; (4) overview of injury prevention strategies including a variety of air bags, multipoint restraint systems, and occupant sensing methodologies; (5) the basic structure and function of anthropomorphic test devices; (6) introduction to experimental crash simulation; (7) virtual occupant simulation; (8) develop the necessary algorithms to filter crash sensor data using the appropriate CFC per SAEJ211; (9) develop a simulation of a pretensioner; (10) develop a method to determine the relevant due care criteria from a crash simulation in addition to the mandated criteria.

Lecture: 4, Lab 0, Other 0

**MECH-682 Mechanics and Design Simulation of Fiber-Reinforced Composite Materials 4 Credits**

Prerequisites: None

The properties, mechanics, and design simulation aspects of fiber-reinforced composite materials are covered in this course. Topics include: constituents and interfacial bonding, microstructure and micromechanics, theory of anisotropy, classical laminate theory, material characterization, failure and damage, manufacturing techniques, composite structure design, and introduction of nanocomposite.

Lecture: 4, Lab 0, Other 0

**MECH-697 ME Elective Credit 4 Credits**

Prerequisites: None

Lecture: 4, Lab 0, Other 0