Module Code	Module Title	Modular Credits [MC]	Semester	Module Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Cross Listing	Syllabus	Assessment	Illustrative Reading List
ME3211	Mechanics of Solids	4	1	The module covers topics on: Linear elasticity in which the general equations of equilibrium and compatibility are derived and its applications are illustrated for complex problems; Theory of thermal stresses; Stresses in pressurized thick-walled cylinders in the elastic and elastic-plastic regions; Stresses in rotating members; and Introduction to mechanics of composite materials. This is an elective module and is intended for students in Stages 3 and 4 who have an interest in the stress analysis of isotropic and composite materials.	Understand the fundamentals and applications of linear elasticity: Equilibrium, Compatibility, Constitutive relations, Airy stress functions, boundary conditions, and Thermal Stresses.; Determine the deformations and stresses in thick-walled cylindrical pressure vessels and rotating discs and shafts, and hence prescribe their performance limits.; Describe and apply the classical lamination theory of fiber-reinforced composite laminates.	ME2114	Nil	Nil	Nil	Basic equations of force equilibrium, compatibility and constitutive relations. Airy stress functions. Boundary conditions. Solutions of elasticity equations. Theory of thermal stresses. Thick-walled cylinders subjected to pressure loading, and their elastic-plastic behaviour. Compound cylinders. Rotating discs and shafts, interference fits, critical speeds. Introduction to composite materials. Classical lamination theory. Residual and fabrication stresses. Failure of composites.	Homework Assignments, Hands-on exercise, Final Examination	**Supplementary Reading:** A.C. Ugural and S.K. Fenster, "Advanced Strength and Applied Elasticity", Arnold (1987).; A.P. Boresi, R.J. Schmidt and O.M. Sidebottom, "Advanced Mechanics of Materials", J. Wiley (1993).; R.M. Jones, "Mechanics of Composite Materials", McGraw-Hill (1975).; R.R. Craig Jr., "Mechanics of Materials", John Wiley and Sons (2011)
ME3221	Sustainable Energy Conversion	4	2	This elective module provides an introduction to intermediate level topics in engineering thermodynamics and their applications to engineering thermal processes. The following topics are covered: Efficiency improvement of steam power cycles through the use of regeneration and the introduction of binary vapour power cycle. Reversible work and available energy and available energy changes in thermal processes, Second Law efficiency; Combustion processes; Analysis of energy and work interactions of basic mechanical engineering thermal processes such those of reciprocating and centrifugal compressors and axial flow turbines. ; This module is for students who wish to extend their understanding of engineering thermodynamics beyond the first course, and understanding and appreciation of the operation, efficiency and energy conversion of mechanical engineering thermal processes.	Explain how the efficiency of a power plant is improved through the use of regeneration and binary vapour systems; and compute the cycle efficiencies; Compute the reversible work, available energy changes and irreversibility of non-flow and flow processes; Compute energy exchanges, temperature rises and apply the Second Law to combusting systems in the absence of interaction with environment; reversible work; availability; irreversibility.; Compute energy transformations and efficiencies in reciprocating and rotary compressors; Compute the energy transformations and efficiencies of gas and steam flows through the nozzles and rotary blade passages of axial flow turbine systems.	ME2121	Nil	Nil	Nil	**Vapour Power Cycle:** Criteria for the comparison of cycles; overall efficiency of a plant: combustion efficiency, mechanical efficiency, generator efficiency; work ratio; specific steam consumption; development of vapour power cycles ; improvement of Carnot cycle: Rankine cycle, Reheat cycle, Regenerative cycle - with open and closed heaters; binary vapour cycle. (3 hours); **Second Law Analysis for Sustainable Energy Systems:** Analysis of flow and non-flow processes: with and without thermal interaction with environment; reversible work; availability; irreversibility.(3 hours); **Analysis of Combustion Processes:** Fuels; conservation of mass; First Law applied to combustion processes; calorific value of fuels; efficiency of power plant and combustion processes; dissociation; Second law analysis of combustion processes;Third Law analysis for combustion processes and absolute entropy. (6 hours); **Reciprocating Compressors:** Machine cycle analysis, work and heat transfer; performance parameters of compressors: volumetric efficiency, isothermal efficiency, intercooling, intercooling pressure; reciprocating expanders. (4 hours); **Centrifugal compressors:** Velocity diagram, torque, work, power and general heat expression; total or stagnation pressure ratio; mass flow ratio; special considerations: no prewhirl, radial exit effect of blade shape on performance, pressure ratio and volume flow.(3 hours); **Nozzles:** Isentropic flow in convergent and convergent-divergent nozzles; critical pressure ratio; effects of varying back pressure. (3 hours); **Axial Flow Turbines:** Velocity diagram; impulse and reaction turbines; h-s diagram for a stage; frictionless one dimensional flow impulse stage; diagram efficiency, blade speed ratio, optimum blade speed ratio; velocity compounded stage. Reaction Turbine: temperature drop across turbines; isentropic efficiency and expansion ratio; degree of reaction and its expression in term of velocity diagram parameters; 50% reaction turbine; multi-staging; losses in turbines. (5 hours); **Group project:** A mini project on energy conversion equivalent 6 lecture-hours (6 hours)	Mid-Term Quizzes/ Project Assignment and Final Examination	**Compulsory Reading:** Engineering Thermodynamics by G.F.C. Rogers and Y.R. Mayhew; **Supplementary Reading:** Fundamentals of Classical Thermodynamics by Gordon J. Van Wylen and Richard E. Sonntag
ME3232	Compressible Flow	4	2	This module introduces students to some of the physical phenomena in compressible flow. The theories in one- and two-dimensional flow will be described, explained and analysed in this module. Topics include subsonic and supersonic flow, converging–diverging nozzle, normal and oblique shock waves, Prandtl-Meyer flows, flow with friction and heat exchange, Fanno line, Rayleigh line, two-dimensional compressible flows, thin airfoils in supersonic flow, method of characteristics, hypersonic and high temperature gas dynamics, and optical methods in compressible flow measurements. Real-life applications, such as sonic boom, gas turbine, ramjet and scramjet combustion, supersonic nozzle design, space shuttle re-entry will be discussed.	Analyze the characteristics of isentropic flow of a perfect gas, normal and oblique shock waves, and Prandtl-Meyer flow; Assess the performance of a converging-diverging nozzle and explain the characteristics of underexpanded and overexpanded nozzles. Apply shock-expansion theory to predict the lift and drag of two-dimensional bodies in supersonic flow; Analyze subsonic and supersonic flow in a constant-area or a variable area duct with friction, heat addition or heat loss; Solve problems in two-dimensional isentropic supersonic flow using the method of characteristics, and apply the linearized theory to flow over wavy walls and thin aerofoils; Analyze some aspects of hypersonic and high-temperature gas dynamics; Apply various techniques to measure the properties of a compressible flow, and explain the working principles of schlieren system, shadowgraph and interferometry.	ME2135	Nil	Nil	Nil	Fundamental aspects of compressible flow; speed of sound; Mach waves; basic equations of steady one-dimensional compressible flow.; Subsonic and supersonic isentropic flow through varying area channel; converging nozzle; converging-diverging nozzle.; Normal shock waves: Formation of a normal shock wave; equations of motion for a normal shock wave; normal shock wave relations; moving normal shock waves; reflected normal shock waves.; Oblique shock waves: Equations of motion for a straight oblique shock wave; oblique shock relations; reflection of oblique shock waves. ; Prandtl-Meyer flows: Flow equations for a Prandtl-Meyer expansion fan; reflections of expansion waves.; Performance of converging-diverging nozzle; Underexpanded and overexpanded supersonic nozzles; Shock-expansion theory; supersonic airfoils.; Flow with friction: One-dimensional adiabatic flow in a constant-area duct with friction. Fanno line. Adiabatic flow with friction in a variable-area duct.; Flow with heat addition or extraction: One-dimensional frictionless flow with heat transfer in a constant-area duct; Rayleigh line; frictionless flow in a variable-area duct with heat addition; frictional flow with heat exchange in a constant-area duct; isothermal flow with friction in a constant area duct with friction. Application example: gas turbine, ramjet and scramjet combustion.; Linearized flow: Velocity potential equation; linearized velocity potential equation; linearized pressure coefficient; linearized subsonic flow; linearized supersonic flow; similarity laws. Application example: linearized subsonic and supersonic flow over a wavy wall and an aerofoil.; Method of characteristics for two-dimensional supersonic flows: Determination of characteristic lines, compatibility equations, regions of influence, domain of dependence. Application example: supersonic nozzle design.; Introduction to hypersonic and high-temperature gas dynamics: Characteristics of hypersonic flows; Newtonian theory; modified Newtonian theory; forces on a body; effect of temperature on specific heats; dissociation and ionization; non-equilibrium effects. Application example: space shuttle re-entry.; Measurements in compressible flow: pressure measurement, temperature measurement, velocity measurement. Optical methods: Schlieren, shadowgraphy and interferometry.	Term paper/Assignments/Quiz, Final Examination	**Compulsory Reading:** Saad, M.A., Compressible Fluid Flow, 2nd edition, Prentice-Hall, Englewood Cliffs, N.J. 1993.: **Supplementary Reading:** Anderson, J.D., Modern Compressible Flow with historical perspective. 3rd Edition, McGraw Hill, 2003.; John, J.E.A., Gas Dynamics, 2nd edition, Allyn and Bacon, Boston, 1984.; Liepmann, H.W. and Roshko, A., Elements of Gas Dynamics, John Wiley, New Yeok, 1957.; Oosthuizen, P.H. and Carscallen, W.E., Compressible Fluid Flow, 1st edition, McGraw-Hill, 1997.; Shapiro A.H., The Dynamics and Thermodynamics of Compressible Fluid Flow, Vols. 1& 2. Ronald Press, 1953.; Thompson P.A., Compressible Fluid Dynamics. McGraw-Hill, 1972.
ME3233	Unsteady Flow in Fluid Systems	4	2	This course introduces to students the unsteady fluid flow systems typical encountered in Mechanical Engineering applications. Unsteady flow fluid theories, real-life unsteady flow problems and practical design solutions will be described, explained and analysed in this course. These include Analysis and Designs of Thermal Power Stations, Water pumping stations and their distribution systems, petroleum products (i.e. crude oil and natural gas) transportation pipelines systems, Oil and Gas flow systems, Fuel injection systems in automobile and aircraft applications; Modelling of Artificial Heart-Blood flow systems etc.	Describe and explain the fundamental phenomena and causes of unsteady flow problems (extreme pressure surges, column separation etc) in fluid systems and their significances in engineering practice; Describe, explain and analyse the unsteady fluid flow systems with various simple and complex system characteristics (Reservoirs, multi-pipe branching, unsteady mode of multiple pumps operations, problematic system elevation profiles, etc; Describe and apply the working principles of the various fluid devices used in controlling extreme adverse flow conditions (pressure surges, column separation, air entrainment etc) in the fluid systems under unsteady fluid flow operations; Analyze and design a fluid system with suitable fluid engineering devices for the control and protection of the fluid system from extreme adverse flow conditions.	ME2135	Nil	Nil	Nil	Concepts of unsteady flows in fluid systems and the associated problems. What is waterhammer? Pressure transients in instantaneous valve closure. Frictionless flow and Effects of Friction. Friction Recovery in theory and in practice. Wave speed and Effects of Air Entrainment. Column separation and Gas release. Causes of unsteady flow problems. Methods of Analysis. Scope and Ranges of Problems in Unsteady Fluid Flow systems. Basic Governing Equations and Boundary Conditions. Single pipeline applications. Reservoirs, pumps, pipelines, valves, orifices, dead-end pipe etc. Complex Fluid System Boundary conditions. Valve closure functions, system with multi-connections, series and branch connections, in-line valves. Fluid transients caused by operation of fluid machineries. Pumps failure in a fluid system. Fluid machinery characteristics in unsteady flow systems. Centrifugal and non-centrifugal pump characteristics in unsteady flow systems. Pumps run down characteristics. Characteristics of partial pump trip in unsteady fluid flow systems. Controlling of extreme flow conditions in unsteady flow systems. Effects of Flywheel and pump-set inertia on unsteady flow systems. Characteristics of unsteady fluid flow operations of surge tanks, air vessels (pressure surge chambers), by-pass systems, air valves etc. Fluid transients in complex systems with elevation profiles. Special topics. Introduction to gas pipeline transients. Sample case studies of unsteady fluid flow problems and their design solutions with computer simulations.	Essays: Term paper, Final Examination	**Compulsory Reading:** Wyle, E.B., Streeter, V.L. and Suo, L., "Fluid Transient in Systems", Prentice Hall, 1993.; **Supplementary Reading:** Chaudhry, M. Hanif, "Applied Hydraulic Transient", Van Nostrad Rainhold Co. Inc., 1997.; Fox, J.A., "Hydraulic Analysis of Unsteady Flows", Macmillan Press. London. 1984.; Thorley, A.R.D., "Fluid Transients in Pipeline Systems", D & L George Ltd, United Kingdom (2004)

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ME3241	Microprocessor Applications	4	2	To provide a basic understanding of microprocessor or microcontroller and its related i/o interfaces for mechanical systems. This includes topics like numbering system and codes, microprocessor architecture, programming and digital electronics associated with the input/output of a microprocessor system. Also, its application to mechanical systems.	Able to represent number in various bases and explain the different type of common codes used in industries.; Explain various error detection and correction techniques; To solve problem using combinatorial logic and/or sequential logic.; To explain the basic structure of a microprocessor.; To do assemble programming for a microprocessor.	ME2143	Nil	Nil	Nil	**Numbering System and Codes**: Binary, octal and hexidecimal numbering systems. One's and two's complement represetation. ASCII, BCD, Excess-3 and Gray Codes. Parity. Digital Arithmetic Operations.; **Digital Electronics**: Flip-flops, digital arithmetic circuits, counters and registers, encoders, decoders, multiplexers, demultiplexers, integrated-circuit logic families, memory devices. ; **Microcomputer Architecture:** Central processing unit, arithmetic logic unit, registers, processor microarchitecture, instruction set architecture, PIC18 microcontroller.; **Machine and Assembly Languages:** PIC18 instruction set, addressing modes, assembly language programming, subroutine, stack and stack pointer, interrupt facilities.; **Microcontroller Interfaces and Applications:** Interface chips, parallel I/O, timer related I/O, analogue/digital converter.	Marked Tutorial Assignments, Mid-Term Quiz, Mini Project Assignment, Final Examination	**Compulsory Reading:** RJ Tocci, "Digital systems: Principles and applications", 6th edition, 1995, Prentice-Hall, Inc. ; H-W Huang, "PIC microcontroller : an introduction to software and hardware interfacing", Clifton Park, NY : Thomson/Delmar Learning, 2005. **Supplementary Reading:** LD Jones, "Principles and applications of digital electronics", Macmillan, 1986. ; TF Bogart, Jr., "Introduction to digital circuits", McGraw-Hill International Student Edition, 1992.; RL Tokheim, "Digital electronics: Principles and applications", 7th edition, 2008, McGrawHill.
ME3242	Automation	4	1	In this module the student will learn the approaches used in the design of sequencing circuits applied to machine-level industrial automation. Special emphasis is given to electromechanical and pneumatic systems. After a quick review of input sensing, pneumatic actuators, basic switching logic and elements, the design of sequential control systems using electromechanical ladder diagrams, purely pneumatic circuits and programmable logic controllers are introduced. Upon successful completion of the course, the student should be able to read and understand pneumatic circuits and electromechanical ladder diagrams and be able to quickly design and implement such circuits for any sequencing problem. This is a technical elective course with the main target audience being mechanical engineering students in their third year of study.	Have a good appreciation of practical industrial pneumatic and electromechanical logic components; Able to read and understand pneumatic circuits and electromechanical ladder diagrams; Able to design and implement such circuits for any sequencing problem; Explain major functions of a programmable logic controller; Able to program a PLC.	Nil	ME2143	Nil	Nil	**Review of Boolean Algebra:** Theorem, Synthesis of Logic Functions and Karnaugh Maps.; **Switching Elements:** Pneumatic and Electromechanical Devices; **Design of Sequential Control Systems:** Sequence Chart Approach, Cascade Method; **Purely Pneumatic Circuits:** Cascade Method, Lucas Method, Miscellaneous topics; **Systems with Random Inputs:** Huffman Method, Sequential System with Random Inputs; **Programmable Logic Controllers:** Basic architecture of PLC, Programming PLC, differences from hardwired circuits	Lab1: Electro-mechanical Lab, Lab2: Pneumatic Lab, Lab3: PLC Lab, Final Examination	**Compulsory Reading:** D W Pessen, "Industrial Automation", 1989, John Wiley & Sons, Inc.; **Supplementary Reading:** FD Petruzella, "Programmable logic controllers", 4th ed., McGraw-Hill, 2011.
ME3251	Materials for Engineers	4	2	This module equips students with basic knowledge in materials selection for mechanical design. The major topics are: classification of engineering materials; materials properties in design using case studies; ferrous alloys (carbon and low-alloy steels, tool steels, stainless steels, cast irons); non-ferrous alloys (Cu-, Al-, Mg-, Ti-, Zn-, Ni-alloys, etc.); engineering plastics and composites; engineering ceramics; surface engineering and coating techniques; joining processes; material selection in design; product costing. An appreciation is given of the merits and demerits of commonly used materials in different engineering designs as well as emerging materials and processes. A considerable portion of the time is allocated to case studies in materials selection in engineering design, during which the students are exposed to multi-facets of the material selection process before making their choices.	Be familiar with the salient properties, advantages and limitations of various important engineering materials including ferrous and non-ferrous metals and alloys, commodity and engineering plastics, polymeric matrix composites and technical ceramics; Be familiar with established applications of the various engineering materials including case studies on both sound and unsound designs and applications; Have the ability to quickly spot good and/or bad selection of materials in an mechanical design/device and make appropriate correction; Make sound decision, both engineering and economic, on life cycle assessment and the selection of materials for new mechanical designs/devices he/she is working on.	ME2151	Nil	Nil	Nil	**Materials properties in engineering designs:** Classification of engineering materials and their applications; cost of a product; design for dimensional stability/accuracy; design against fracture/fatigue; other relevant aspects in design.; **Metals and alloys:** Ferrous alloys – carbon steels; low alloy steels, tool steels, stainless steels, cast irons; non-ferrous alloys – copper alloys, aluminum alloys, magnesium alloys, titanium alloys, zinc alloys, etc.; surface treatments and coatings; joining of metals and alloys; case studies.; **Engineering ceramics and their applications**: Advanced structural/engineering ceramics; important property considerations; toughening mechanisms in ceramics; major applications of engineering ceramics; case studies.; **Polymers:** Review of polymer types, synthesis and structures; structure-property relationships; processing; commodity vs. engineering plastics; case studies.; **Polymeric matrix composites:** Types and properties of fiber reinforced composites; multiplied laminated composites; applications of fiber-reinforced polymeric matrix composites; case studies.; **Design and materials selection:** Review of properties of engineering materials, heat treatments/coatings; process of design and materials selection; economy aspects in materials selection; case studies.	Mid term Quiz, project based assessment and Final Examination	**Compulsory Reading:** Michael F. Ashby, Materials and the environment: eco-informed material choice, 2nd ed. 2013 Elsevier Inc., ISBN 978-0-12-385971-6; K.G. Budinski and M.K. Budinski, Engineering Materials: Properties and Selection (6th edition), Prentice Hall, Upper Saddle River, 1999.; **Supplementary Reading:** J.A. Charles, F.A.A. Crane and J.A.G. Furness, Selection and Use of Engineering Materials (3rd edition), Butterworth-Heinemann, Oxford, 1997.; M.F. Ashby, Materials Selection in Mechanical Design (2nd edition), Butterworth-Heinemann, Oxford, 1999.; M.F. Ashby and D.R.H. Jones, Engineering Materials: An Introduction to Their Properties and Applications, Pergamon Press, Oxford, 1980.; R.A. Flinn and P.K. Trojan, Engineering Materials and Their Applications (4th Edition), Houghton Mifflin Co., Boston, 1990.
ME3261	Computer-Aided Design and Manufacturing	4	1	This course covers the principles of computer-aided tools: CAD and CAM, which are widely used in modern design and manufacturing industry. By introducing the mathematical background and fundamental tool programming of CAD/CAM, this course provides the basics for students to understand the techniques and their industrial applications. The topics are: CAD: geometric modelling methods for curves, surfaces, and solids; CAM: part fabrication by CNC machining based on given geometric model; Basics of CNC machining; Tool path generation in CAD/CAM (Option to introduce a CAM software to generate a CNC program for the machining of a part); Verification of fabricated part by CNC measurement based on given geometric model. The module is targeted at students specializing in manufacturing engineering.	Students learn the basics of the mathematical models that form the tools for curve and surface construction in CAD packages; Students are required to demonstrate ability to apply mathematics through matrix and vector algebra to model free-form curves and surfaces from discrete data points; They learn basic principles and programming techniques of computer-aided manufacturing (CAM) in relation to computer-aided fabrication of parts by machining and computer-aided verification of dimensions/tolerance by measurement; Students are able to learn and demonstrate their ability in integrating CAD modeling and different techniques of computer-aided machining and measurement through applications in a CAM environment; An independent study project is assigned to each student and reports are graded. Students are required to work independently on their projects; The study projects are designed to broaden the vision of students on the state-of-the-art CAD/CAM applications in manufacturing industry.	Nil	ME3162	Nil	Nil	**CAD: Geometric Modeling**, Curve segment models, Composite curve construction, Surface patch models, Composite surface construction, Solid model data structure and techniques.; **CAM: <u>Fabrication</u> of <u>Part</u> by <u>CNC</u> <u>Machining</u> <u>based</u> <u>on</u> <u>Geometric</u> <u>Model</u>:** Basics of CNC Turning and Milling, Tool path generation in CAD/CAM.; **CAM: <u>Verification</u> of <u>Fabricated</u> <u>Part</u> by <u>CNC</u> <u>Measurement</u> <u>based</u> <u>on</u> <u>Geometric</u> <u>Model</u>:** Geometric Dimensioning and Tolerancing, Basics of Computer-automated Measurement.	CAD/CAM independent study project involving CAD, CNC machining and computer-aided measurement.; Final Examinations	**Supplementary Reading:** B. K. Choi, 1991, Surface modelling for CAD/CAM, Elsevier Science Publishers B. V., Amsterdam, The Netherlands.; M. E. Mortenson, 1985, Geometric modelling, John Wiley & Sons, Inc.; H.B. Kief and T.F. Waters, 1992, Computer numerical control, Macmillan/McGraw-Hill, U.S.A.
ME3263	Design for Manufacturing and Assembly	4	1	This module introduces the students to the concept of product design for manufacture and assembly. It covers the details of design for manufacture and assembly (DFMA) methods for practicing engineers and also allows for learning of concurrent or simultaneous engineering. The topics covered: Introduction, Selection of materials and processes; Product design for manual assembly; Design for automatic assembly and robotic assembly; Design for machining; Design for rapid prototyping and tooling (rapid mould making); Design for injection moulding. The module is targeted at students majoring in manufacturing. This is an elective for Mechanical Engineering students specializing in Precision Engineering.	Understand and apply the principles of design for material forming processes; Understand and apply the principles of basic machining practice and principles of design for machining; Apply the knowledge in selecting material forming and additive manufacturing processes for specific jobs; Understand the principles of assembly planning, and the ability to identify the assembly design bottlenecks; Able to apply design for assembly techniques to determine the average assembly time and cost; Understand the principles of rapid prototyping, rapid tooling and able to apply rapid prototyping and tooling in design; Understand how rapid prototyping has evolved into a direct manufacturing process and system selection can influence final part quality	Nil	ME3162	Nil	Nil	Introduction to material forming and additive manufacturing processes; design for material forming processes; design for additive manufacturing, design for machining; design for rapid tooling; parts design for manufacturing and assembly material selection; design for manual assembly and automated assembly.	Term Paper, Final Examination	**Compulsory Reading:** Geoffrey Boothroyed, Peter Dewhurst, and Winston Knight, "Product design for manufacturing and assembly" Marcel Decker, Inc., 1994. **Supplementary Reading:** Web e-learning.

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ME3281	Microsystems Design and Applications	4	2	Microsystems technology has demonstrated powerful capabilities and become increasingly popular in many areas of science and engineering. Microsystems-based products are already in the market, replacing existing technology, or creating new possibilities. This module will give a broad introduction to microsystems technology, and will cover the principles, fabrication techniques and system-level design and applications of microsystems to a variety of engineering fields such as aerospace, mechanical, electrical, telecommunications and bioengineering. Major topics include properties of semiconductors, fundamentals of dynamics and vibration, microfabrication techniques, piezoresistivity and applications in sensors, thermal sensors, electrostatics and capacitance, microsensors and microactuators, microfluidics and lab-on-a-chip, and optical microsystems.	Understand the advantages of microsystems and their application areas.; Understand the fundamentals of microelectromechanical systems (MEMS) based actuators for translational and rotational motions.; Understand the basics of optical microsystems including micro-mirrors, micro-mirror arrays, and micro-gratings.; Understand the basics of microsystems-based sensors, including micro-accelerometers, micro-gyroscopes, and pressure sensors.; Understand the basics of microfluidic devices, including micro-pumps, micro-channels, micro-valves, and micro-flow sensors.	Nil	Nil	Nil	Nil	**Introduction:** Overview of Microsystems Technology and Applications; Scaling law and performance; Markets for MEMS devices; Information resources; **Microfabrication fundamentals:** Photolithography; Thin film deposition and etching; Surface-micromachining; Bulk-micromachining; SOI processes; Bonding; **Materials for microsystems:**Overview of materials used in microsystems; Material properties of single crystalline silicon; Miller indices and wafer identification; Mechanical, thermal, and electrical properties of other commonly used materials; **Beams and diaphragms for microsystems:** Introduction to static behavior of elementary beams and membranes ; **Microactuators:** Overview of actuation methods; Electrostatic actuation; Parallel-plate microactuator; Comb-drive microactuator; Pull-in and stable travel range; Fundamentals of dynamics and vibration; Damping in microactuators; Thermal actuation; Basic motion control in microsystems; **Microsensors:** Piezoresistive sensing and signal processing; Capacitive sensing and signal processing; Force feedback; Micromachined microaccelerometers; MEMS gyroscopes; MEMS pressure sensors; **Optical MEMS:**Basic building-blocks for optical microsystems; Microhinges and free-space micro optical bench; Micromirrors and micromirror arrays; MEMS optical switches, attenuators, and tunable lasers for fiber optical communication; MEMS based projection displays; Optical MEMS for adaptive optics; **Microfluidics and Bio-MEMS:**Basic fluidic concepts; Laminar flow; Micro-valves, micro pumps and micro mixers; Micro-channels; Soft lithography; Electro-wetting; Droplet generators; Micro flow sensors; Lab-on-a-chip;	Lab, Term Paper, Quizzes	**Compulsory Reading:** Richard P. Feynman, "There's plenty of room at the bottom", Dec. 28, 1959 (Journal of Microelectromechanical systems, vol.1, no.1, p.60, 1992); K. E. Petersen, "Silicon as a mechanical material", Proc. IEEE, vol.70, no.5, p.420, 1982. **Supplementary Reading:** Fundamentals of Microfabrication, by Madou, CRC Press, 1997.; Micromachined Transducers Sourcebook, by Kovacs, McGraw-Hill, 1998.; Microsystem Design, by Stephen D. Senturia, Kluwer Academic Publishers, 2001.
ME3291	Numerical Methods in Engineering	4	2	This elective course introduces students to fundamental concepts of numerical analysis as a powerful tool for solving engineering problems. Basic concepts of erros arising from discretization, Taylor series, von-Neumann stability analysis, and curve-fitting techniques will be introduced, with emphasis on simple examples andapplications derived from engineering disciplines. Solution methods in terms of direct or indirect approach will be discussed. Brief introductions to the finite difference and finite element methods will be given. The treatment will primarily use the Laplace and Diffusion equations as illustrations of analysis familiar to mechanical engineers. The course will also introduce the use of software Matlab as a tool for the solution of numerical problems.	Describe and understand the importance of numerical simulation for engineering design and development; Understand the different numerical approaches for the simulation in the different engineering fields; Understand and implement numerical discretization of continuous governing equations in the finite difference and finite element spaces; Understand and implement the different solution approaches via direct integration and iterative methods; Understand the relationship between the discretized variables (both independent and dependent) and accuracy of the computed solution; Understand the properties and issues related to solution convergence; Translate a typical engineering problem into system of algebraic equations for numerical implementation.	MA1505/ MA1506	Nil	Nil	Nil	**Classification of PDE; Discretization of differential equations; Consistency/Compatibility of a numerical scheme; Parabolic PDE:** Explicit scheme, Stability Analysis, Implicit scheme, Types of boundary conditions; **Elliptic differential equations; Solution of system of linear algebraic equations:** Direct methods, Iterative methods – Jacobi, Gauss-Seidel, SOR, SSOR; **Hyperbolic differential equations:** Use of method of characteristics for 1st order equation, Use of method of characteristics for 2nd order equation, Finite difference method for 1st order equation; **Finite Element Analysis:** Direct approach – truss analysis, Green-Gauss theorems, Strong & weak formulations: 1D heat flow, Strong & weak formulations: 2D heat flow, Weighted residual method, Approximating functions, FEM for 1-D heat flow, FEM for 2-D & 3-D heat flow	Homework Assignment, Final Examinations	**Compulsory Reading:** "Numerical Methods for Engineers", 3rd Ed., SC Chapra & RP Canale, McGraw-Hill, 1998. **Supplementary Reading:** "Numerical solution of partial differential equations: finite difference method", Oxford University Press, G.D. Smith.; "Numerical Methods for Scientific aand Engineering", Wiley Eastern Ltd, M.K. Jain, S.R. Klyengar, R.K. Jain; "Applied Numerical Analysis", Addison-Wesley Publishing Company, G.F Gerald, P.O. Wheatley.; "Linear Algebra and its Applications", Academic Press, G. Strang.
ME4105	Specialisation Study Module - Offshore Oil & Gas Technology	4	1	This module is designed for students interested in offshore oil & gas industry. Its contents are focused on giving an overview of the upstream oil & gas industry. Contents to cover reservoir basics, seismic, exploration, onshore & offshore drilling, mud management, well completion, production, well stimulation, artificial lift methods, improved oil recovery (IOR) & enhanced oil recovery methods (EOR), equipment, floating production systems (FPS), etc. This module comprises structured programme of lectures, seminars, term papers and mini-projects.	How oil & gas exist in a reservoir; The process of oil & gas exploration, i.e. seismic exploration, etc; The process of onshore and offshore oil-well drilling and completion and the equipment used, i.e. drill rig, jack-up rig, semis, drill ship, etc; The various phases of oil & gas production, Improved Oil Recovery (IOR), Enhanced Oil Recovery (EOR) and production equipment used; The various fixed platforms, floating production platforms, Floating Production Storage & Offloading (FPSO), etc. used in offshore production; The oil, water & gas processing technologies used during oil & gas production; The processes involved in Subsea Processing; Use and design of process equipment, e.g. pumps, separators, compressors, etc. for oil and gas production	Nil	Nil	Nil	Nil	**Introduction to Oil & Gas Technology; Basic Petroleum Geology:** Organic theory & Inorganic theory, Oil & Gas Reservoirs; **Exploration:** Geographical surveys, Seismic surveys; **Drilling Technology:** Cable tool drilling, Rotary drilling – procedures and equipments involved, Types of drill bits, Drilling mud, Casing, Offshore drilling – procedures and equipment involved, Offshore drill rigs, Directional drilling & equipment, Horizontal drilling, Underbalanced Drilling; **Well Completion:** Casing, Cementing, Well completion methods, Offshore completion, Well testing, Well stimulation techniques; **Production:** Natural drive mechanism, Artificial Lift Methods, Improved Oil Recovery, Secondary recovery, Tertiary recovery, Enhanced oil recovery (EOR); **Floating Production System - FPS and FPSO; Surface/Topside Processing of Well Fluids; ubsea Processing**	Term paper, mini projects	Gerding, Fundamentals of Petroleum, 3rd Ed; Giuliano, Introduction to Oil and Gas Technology; Berger, Anderson, Modern Petroleum - A Basic Primer of the industry, 3rd Ed.; Dawe, Modern Petroleum Technology, Vol 1, Upstream **Compulsory** : Course notes handed out by course lecturers
ME4212	Aircraft Structures	4	2	The module deals mainly with torsion and bending of thin-walled beams, idealized beams, analysis of plate structures subjected to static loading; and the application of energy methods to instability problems in columns and frames. This is an elective module and is intended to accommodate the needs of students who have an interest in the design and analysis of thin-walled structures, especially aircraft structures. The materials in this module are also applicable to the chemical, civil, mechanical, aeronautical engineering and engineering mechanics curricula.	Correctly apply the formulae for bending of thin-walled beams of unsymmetric sections, and determine the bending stresses and resultant shear flow.; Describe and explain the difference in shear stress distribution for torsion of open and closed thin-walled members.; Apply the approximation of idealized beams with stringers and sheets to beams of various cross-sectional and multi-cell configurations.; Analyze stresses in circular and rectangular plates subjected to transverse loadings.; Apply the energy method to buckling and understand the limitations of the energy method.	ME2114	Nil	Nil	Nil	**Torsion and Bending of Thin-Walled Beams, Idealized Beams and Membrane:** Basic equations. Torsion of non-circular sections. Warping functions. Stress functions. Membrane analogy. Shear stress distribution in a thin-walled member under torsion. Shear stress in open sections. Shear stress and shear flow in closed sections. Bending of unsymmetric sections. Bending stresses. Shear flow due to bending. Shear center. Idealized beams with stringers and sheets. Equations of bending and torsion for idealized beams. ; **Small Deflection of Thin Plates:** Slope and curvature of plates. Equilibrium equations and boundary conditions. Bending of circular plates. Navier and Levy solutions for rectangular plates.; **Instability:** Energy methods applied to bucklingof columns and plates.	Quizzes and homework assignments, Final Examination	**Compulsory Reading:** S.P. Timoshenko and S. Woinowsky-Krieger, "Theory of Plates and Shells", McGraw-Hill, 2nd Ed. (1984). ; T.H.G. Megson, "Aircraft Structures for Engineering Students", Butterworth-Heinemann, 5th Ed. (2013). **Supplementary Reading:** S.P. Timoshenko and J.M. Gere, "Theory of Elastic Stability", McGraw-Hill, 2ed. (1985).; M.H. Jawad, "Theory & Design of Plates & Shell Structures". Chapman & Hall (1994).; C.R. Calladine, "Theory of Shell Structures". Cambridge University Press (1983).; A.P. Boresi, R.J. Schmidt and O.M. Sidebottom, "Advanced Mechanics of Materials", J. Wiley (1993).; T.H.G. Megson, "An Introduction to Aircraft Structural Analysis", Butterworth-Heinemann, (2010).; C.T. Sun, "Mechanics of Aircraft Structures", John Wiley & Sons, 2nd Ed. (2006).; J. Cutler, "Understanding Aircraft Structures", Blackwell, 4th Ed. (2005).
ME4213	Vibration Theory and Applications	4	2	This course introduces the principles of vibration for linear discrete and continuous systems.; Major topics in linear SDOF discrete systems: Free and forced vibration of one degree-of-system including damping. Transient vibration and response spectra.; Major topics in MDOF discrete systems: Lagrange equations of motion, mass and stiffness matrices, natural frequencies and modes. Method of mode summation ; Major topics in continuous systems: transverse vibration of strings, axial vibration of rods, torsional vibration of rods, transverse vibration of beams, D'Alembert's solutions for wave equation.	Analyze and solve one degree of freedom vibration problems; Analyze and solve multiple degree of freedom vibration problems.; Analyze and solve transverse vibration of strings.; Analyze and solve axial vibration of rods.; Analyze and solve torsional vibration of rods.	Nil	Nil	Nil	Nil	**SDOF systems:** Free and forced vibration of one degree-of-system including damping. Transient vibration and response spectra.; **MDOF systems:** Lagrange equations of motion. Mass and stiffness matrices, natural frequencies and modes, Mode summation. **Continuous systems:** Axial vibration of rods, Transverse vibration of beams, assumed modes	Assignments, Final Examination	**Compulsory Reading:** Singiresu S. Rao Mechanical vibrations; **Supplementary Reading:** William T. Thomson Theory of Vibration with Applications; Cyril M. Harris, Shock and vibration handbook

Module Code	Module Title	Modular Credits [MC]	Semester	Module Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Cross Listing	Syllabus	Assessment	Illustrative Reading List
ME4214	Vehicle Dynamics	4	1	This module covers the topics for analysis of vehicle dynamics. These include forces acting on a vehicle and the resulting dynamics and motions. Forces from tires, brakes, steering and power train will be discussed. Students will learn how to analyze the longitudinal and turning motions as well as the vibration of a vehicle.	Describe and explain the forces acting on a vehicle and analyze its resulting motion; Understand the roles of tire, power-train and brakes and aerodynamic forces acting on a vehicle; Describe and analyze the longitudinal dynamics of a vehicle; Describe and understand the vehicle coordinate system and rigid vehicle dynamics; Use a two-wheel model to analyze the turning motion of a vehicle; Use a quarter/half vehicle model to analyze the vibration of a vehicle.	ME3112	Nil	Nil	Nil	External forces acting on a vehicle: gravity forces, tire forces due to acceleration/braking/cornering/rough roads and aerodynamic forces.; Longitudinal Vehicle Dynamics: equations of motion to define vehicle acceleration and braking. Equations of motion of a vehicle on an inclined plane.; Power-train and brake system parameters that control vehicle acceleration and braking performance.; Quarter/half vehicle model and corresponding equations of motion which control bounce/pitch/roll motion of a vehicle.; Vehicle coordinate system. Revision of kinematic relations. Fixed frame vs rotating frame. Coordinate transformation. Pitch, roll and yaw motions. Forces and moments. 2D planar motion. Rigid body dynamics. Tire and body forces; Two wheel vehicle model. Front wheel steering and rear wheel steering. Wheel velocity. Sideslip angles. Lateral forces and moments. Force coefficients. State-space equations. Input-output form.; Two wheel vehicle dynamics. Steady state turning. Radius of curvature. Yaw rate. Lateral acceleration. Stability factor. Oversteer, understeer and neutral steer. Critical speed. Transient response. Eigenvalue problem. Free response. Step input response. Roll dynamics.	Others (eg. fieldwork, projects), Final Examination	**Compulsory Reading:** "Vehicle dynamics: theory and applications" by Reza N. Jazar
ME4223	Thermal Environmental Engineering	4	1	This module aims to integrate knowledge in thermodynamics, heat transfer and fluid mechanics to design and simulate air-condition-ing systems, as well as to estimate and analyze the energy performance of buildings and other spaces. Major topics discussed include applications of refrigeration and air conditioning, thermal basics, psychrometrics, comfort and health, heat gains through building envelopes, cooling load calculations, air conditioning design calculations, air-conditioning systems, air-conditioning plants and equipment, energy estimation and energy performance analysis. The module is designed for third and final-year students who are interested in the air conditioning and improvement of energy efficiency of buildings and other spaces.	Apply heat transfer principles in estimating the thermal loads of building and other spaces; Apply principles of thermodynamics, heat transfer and fluid mechanics in designing and simulating air conditioning systems; Estimate the energy requirements of buildings and other spaces; Analyze the energy performance of buildings and other spaces; Improve the energy performance of buildings and other spaces; Evaluate feasibility of alternative energy sources for buildings and other spaces.	ME2121 and ME3122	Nil	Nil	Nil	**Applications and Basics**: Applications of Air Conditioning and Refrigeration. Review of Thermal Principles. (3 hrs); **Psychrometrics, Comfort and Health**: Properties of moist air. Humidity measurement. Psychrometric chart. Psychrometric processes. Comfort. Indoor Air Quality. (6 hrs); **Heat gains through building envelopes**: Solar heat gain, fenestration and shading coefficient, Thermal performance of building envelopes, the Overall Thermal Transmittance Value, Green-mark incentive scheme (6 hrs) ; **Cooling load calculations**: Manual and computerized methods of load estimation. (6 hrs); **Air-conditioning design calculations**: Sensible and latent loads. Room load ratio line. Supply air quantity. Cooling capacity. (3 hrs); **Air-conditioning systems**: All-air, all-water, air-water, heat pump and solar-assisted systems (3 hrs); **Air-conditioning plants, equipment and systems**: Vapour-compression refrigeration. Chillers. Cooling and dehumidifying coils, Cooling towers, district cooling (6 hrs); **Energy Estimation and Energy Performance analysis**: Computer-aided energy estimation. Energy performance measurement and analysis. (6 hrs)	Mid Term Quizzes/ Project Assignment and Final Examination	**Compulsory Reading:** Stoecker, W.F. and Jones, J.W., "Refrigeration and Air Conditioning", McGraw-Hill Book Company, 2nd Edition, 1982. ; **Supplementary Reading:** ASHRAE Handbook of Fundamentals. ; Kreider, J.F., Curtiss, P.S. and Rabl, A., "Heating and Cooling of Buildings", McGraw-Hill Inc., 2002.
ME4225	Applied Heat Transfer	4	2	The main topics include: boiling; condensation; heat exchangers; combined heat and mass transfer; cooling of electronic equipment using conduction, convection and radiation.	Analyse heat flows through various components in a thermal system; Analyse heat transfer problems involving change of phase; Understand the analogy between heat and mass transfer and calculate mass transfer rates; Design heat exchangers for heating and cooling systems.	ME3122	Nil	Nil	Nil	Introduction and review of modes of heat transfer. 2D steady heat conduction: analytical and numerical solutions. Conduction shape factors. Transient heat conduction: analytical solutions for a semi-infinite solid, slab, long cylinder and sphere, numerical solution of 1D system.; Turbulent heat transfer: Prandtl's mixing length, Reynolds and Colburn analogies, universal velocity profile.; Heat exchangers with phase change: pool boiling, flow boiling; film condensation; heat exchanger analyses, application to boiler and condensers.; Mass transfer: diffusion, convection; heat and mass transfer analogy, applications in the industrial mass transfer.	Quizzes, Assignments, Final Examination	**Compulsory Reading:** Lecture Notes. **Supplementary Reading:** D.S. Steinberg, "Cooling Techniques for Electronic Equipment", 2e. J. Wiley & Sons, 1991; A.F. Mills, "Heat Transfer", Prentice Hall, New Jersey 1999.; F.P. Incropera, D.P. Dewitt, T.L. Bergman and A.S. Lavine, "Fundamentals of Heat and mass transfer", 6 Ed, John Willey, 2007.
ME4226	Energy and Thermal Systems	4	1	This course covers a number of topics beginning with a treatment the properties, heat and work transfers of real gases vapours. The module focuses on the sub-systems related to energy efficient systems such as cogeneration. The major topics are the design procedure of heat exchangers, performance of absorption refrigeration systems. Two main topics under cogeneration are introduced. These are microturbine cogeneration and biomass cogeneration. The students are provided with the status of these technologies, and provided with the technical, financial and environmental performance. Case studies of cogeneration plants found locally and regionally provide students with actual operating experience.	**Real gas properties and Processes:** Students are able to describe the behavior and determine the measureable properties of real gases through the use of equations sf state and the generalized compressibility chart. He is also able to make use of the basic thermodynamic properties and laws to deduce simple general thermodynamic equations, able to make use of the Bridgman Table of equations to derive more complex relations. Able to use of the generalized charts to compute the work and heat exchanges of real gas processes; **Design of Heat Exchangers:** The student is able to carry out the design process of across-flow shell and tube and flat finned heat exchangers, based upon selection of material and internal core geometries; **Absorption Refrigeration:** The student is able to describe the principle of operation and performance determination of a single-stage Li-Br absorption system. Explain the cause of and avoidance of operational problems such as crystallization and capacity control. Explain the operation of a two-stage system and other absorption system such as ammonia water system; **Microturbine Cogeneration:** Student is able to describe the principle of operation and applications of microturbines, their advantage and disadvantages as compared to other distributed power systems. Describe the design, installation and operating characteristics of a microturbine cogeneration system. Conduct the financial analysis of such an application and describe the factors affecting the financial performance; **Biomass Cogeneration:** The student is able to describe the basic features of biomass cogeneration systems and their subcomponents. Able explain the technical, financial and environmental benefits of biomass cogeneration using local and regional installations as examples. He is able to describe the procedure involved in the performance monitoring (energy auditing) procedures of a typical biomass cogeneration plant, and give examples of problems that may be expected in such an exercise. He is able to make simple efficiency calculations, and estimation of carbon dioxide mitigations for the plant.	ME2121 and ME3122	Nil	Nil	Nil	**Real Gas Properties and Processes**: Compressibility factor z and behaviour of real gases as depicted on specific compressibility chart; Van Der Waals, Beatty-Bridgeman, Redlich-Kwong, Virial equations of state; generalized compressibility chart, z-critical,Obert-Nelson reduced isometrics; determination of p,v,T values. Exact differential, +1, -1 rules, differentials of u, h, g and a, Tds equations; Maxwell relations; determination of non-measurable properties using measurable properties, cp, cv, β, κ and μ. du, dh, ds expressed in terms of measurable properties and their partial derivatives. Computational procedures. The fugacity factor. Derivation and construction of enthalpy, entropy and fugacity charts, use of these charts for thermodynamic processes.; **Absorption Refrigeration**: Vapour compression and absorption cycles, p-c-T and h chart for Li-Br water system. Representation as source –sink system, ideal COP. Simple cycle, inclusion of heat exchanger, performance calculation. Crystallization and capacity control. Two-stage Li-Br system and ammonia water systems.; **Design of Heat Exchanger**: Types of heat exchanger core geometries. Nomenclature and geometric properties of circular and finned flat tube heat exchangers, free flow area, frontal area, hydraulic radius, surface and volumes ratios and relationships. Efficiency of fins and finned tubes, overall heat transfer coefficients, pressure drop. Step-by-step design and verification procedures for circular and finned flat tube heat exchangers. Pressure loss computations. Comparison of different design outcomes.; **Microturbine Technology and Application**: Types of microturbines in the market and their applications, advantages and disadvantages compared with other technologies such as fuel cells and Stirling engines. Basic principles of operation of microturbines. Installation and performance testing of a microturbine system for power and cooling applications. Environmental effects on power output and efficiency. Industrial and commercial applications. Thermo-economic performance of microturbine applications.; **Biomass cogeneration:** Global and regional biomass resources and supply. Economic and environmental benefits of biomass utilization. Biomass cogeneration, regional and local installations, Biomass cogeneration systems and subcomponents design, operation and selection. Large-medium and small scale systems, plant flow processes, emission control, condensing systems. Waste heat applications.Performance monitoring procedure. Properties and characteristics of biomass fuels, moisture content, gravimetric analysis, HHV and LHV. Exhaust gas flow rates and properties. Technical performance, boiler and cogeneration efficiencies. Financial (IRR and payback period) and simple environmental impact	Design exercise (Heat exchanger), Performance testing of microturbine cogeneration system/ Industrial case study, Final Examination	**Compulsory Reading:** Lecture Notes; Gordon J. Van Wylen and Richard E. Sonntag, "Fundamentals of Classical Thermodynamics", John Wiley and Sons, Second Edition (SI); Wilbert F. Stoecker and Jerold W. Jones, "Refrigeration and Air Conditioning", McGraw-Hill, Second Edition; W. M. Kays and A.L. London, "Compact Heat Exchangers", Kreiger, Third Edition.
ME4227	Internal Combustion Engines	4	2	This module provides a detailed introduction to the working principle of all kinds of internal combustion (IC) engines, the major components and their functions of spark-ignition and compression-ignition engines, the parameters and characteristics used to describe IC engine operation, the necessary thermodynamics and combustion theory required for a quantitative analysis of engine behavior, the measurement of IC engine performance, the design of combustion chamber and its effect on the performance of IC engines, the formation of emissions and their control, supercharging, heat transfer and heat losses, friction and lubrication etc.	The students will acquire a sound knowledge of the working principles of all kinds of internal combustion engines; They will know the structure of IC engines; They will understand the design of IC engines; They will learn to test the performance of IC engines and understand the methods to detect and solve the potential problems may faced in practice; They will learn to test and analyze the emissions of IC engine and the methods to improve it; They will learn the analytical methods to estimate the performance of IC engines, and understanding the methods to optimize it.	Nil	Nil	Nil	Nil	The structure, major components and working principle of internal combustion (IC) engine.; Internal combustion engine performance parameters and characteristics; Ideal Air-standard cycles and their analysis; Fuel-air cycles and actual cycles; Fuel supply system and their effect on the performance of IC engines; Ignition system and ignition timing; Combustion process and combustion chambers design; Energy losses and cooling system; Engine emissions and their control; Two stroke engines; Biofuels and applications in IC engine	Tests, Others (eg. fieldwork, projects), Final Examination	**Compulsory Reading:** Internal Combustion Engine, by V Ganesan, published by the McGraw-Hill companies, ISBN 10:0-07-064817-4.; **Supplementary Reading:** Internal Combustion Engine Fundamentals, by John B. Heywood, Published by McGraw-Hill book company, ISBN 0-07-028637-X.

Module Code	Module Title	Modular Credits [MC]	Semester	Module Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Cross Listing	Syllabus	Assessment	Illustrative Reading List
ME4231	Aerodynamics and Propulsion	4	2	This module introduces to students the basic concepts/theories/applications in aerodynamics and propulsion. Major topics are: Characteristics and parameters for airfoil and wing aerodynamics; Incompressible flow past thin airfoils and finite-span wings; Aerodynamic design considerations; Compressible subsonic, transonic and supersonic flows past airfoils and supersonic flow past thin wings; Propulsion. The module is targeted at students who are interested in aerodynamics, especially those who intend to work in the aviation industry or those who intend to conduct R & D work in the aerodynamics area.	Understand various aerodynamics principles which include relation between lift acting on and circulation around an airfoil, starting vortex, Kutta condition etc.; Understand the function, principle and design of various components of an aircraft which include control surfaces and drag reduction/lift enhancement devices etc.; Apply the Thin Airfoil Theory to calculate the aerodynamic parameters of an airfoil.; Apply the Prandtl Lifting Theory to calculate the aerodynamic parameters of a wing.; Understand various CFD schemes like Panel Method and Vortex Lattice Method.; Understand the corrections for applying the incompressible results to subsonic flow conditions. Learn the fundamental principles governing aerodynamics in the transonic regime. Understand the theory and of supersonic flow around thin airfoils and how to obtain the corresponding values of lift, drag and moment.; Learn about propeller, jet, and rocket propulsion systems. Understand the propulsion requirements of different aircraft and the appropriate choice of propulsion system. Be knowledgeable on propulsive systems based on the gas-turbine engine cycle. Learn the working principles of inlets and nozzles and how these are designed.	ME2135	Nil	Nil	Nil	**Characteristics Parametric for Airfoil and Wind Aerodynamics:** Basic components of an aeroplane. Airfoil nomenclature and geometric parameters. Wing geometric parameters. Characterization of aerodynamic forces. Aerodynamic force and moment coefficients.; **Two-dimensional Incompressible Flows around Thin Airfoils:** Circulation and generation of lift. Kutta-Joukowski Theorem. Thin airfoil theory and its application to symmetric, cambered and flapped airfoil. Panel method.; **Incompressible Flow around Finite-span Wings:** Biot- Savart Law and Helmholtz's Vortex Theorems. Prandtl's Lifting Line Theory, general and elliptical lift distribution. Vortex Lattice Method.; **Aerodynamic Design Considerations:** The ideal airfoil. High lift devices including single and multi-flap systems, power augmented lift, rippled trailing edge and vortex lift. Drag reduction devices including laminar flow control, ribblets and winglets.; **Compressible Subsonic and Transonic Flows around Airfoils:** Compressible subsonic flows. Linearized thin aerofoil theory for compressible flow. Transonic flow past unswept airfoils. Design considerations to overcome transonic flow problems. Swept wings at transonic speeds. Transonic aircraft.; **Two-dimensional, Supersonic Flows around Thin Airfoils:** Linear theory. Busemann's theory. Shock-expansion technique.; **Aircraft Propulsion:** Theory of propulsion. Principles and design considerations of turbo-prop, turbo-fan and turbo-jet engines. Engine performance parameters. Ramjet and scramjet engines. Rocket propulsion. Design calculation and thermodynamic cycle analysis of various engines.	Quizzes, Final Examination	**Compulsory Reading:** Course Notes; **Supplementary Reading:** Anderson, Jr., J.D. "Fundamentals of Aerodynamics", McGraw Hill International Editions, 1985.; Anderson, Jr., J.D. "Introduction to Flight", McGraw Hill International Editions, 3rd edition, 1989.; Bertin, J.J. and Smith, M.L., "Aerodynamics for Engineers", Prentice-Hall International Editions, 3rd edition, 1998.; Kermode, A.C. "Mechanics of Flight", Longman Scientific and Technical, 10th edition, 1996.; Keuthe, A.M. and Chow, C.Y., "Foundations of Aerodynamics, Bases of Aerodynamic Design", John Wiley and Sons, 4th edition, 1986.; Shevell, R.S., "Fundamentals of Flight", Prentice Hall International Editions, 2nd edition, 1989.; Philip G. Hill & Carl R. Peterson "Mechanics and Thermodynamics of Propulsion" Addison Wesley, 2nd Edition. Ashley, H. and Landahl, M., "Aerodynamics of Wings and Bodies, Chapter 5 and 7", Addison Wesley.; Duncan, W. J., Thom, A. S. and Young, A. D., "Mechanics of fluids, Chapter 2, 3 and 11", Edward Arnold.; Houghton, E.L. and Boswell, R.P., "Further Aerodynamics for Engineering Students, Chapter 8", Edward Arnold.; Moran, J., "An Introduction to Theoretical and Computational Aerodynamics", John Wiley and Sons, 1984.; Panton, R.L., "Incompressible flow", Wiley.; Tritton, D. J., "Physical fluid dynamics, Chapter 12", Van Nostrand
ME4233	Computational Methods in Fluid Mechanics	4	1	This module introduces students to the application of numerical methods for solving incompressible viscous fluid flow and convective heat transfer problems. Students will acquire an understanding of the basic principles of fluid flow simulation, a basic working knowledge of numerical implementation and an appreciation of the power of computational methods in solving complex problems.; Major topics covered are: Basic theory of numerical discretization; Finite difference discretization; Stability and accuracy analysis; Solution methods for Poisson and elliptic type equations arising from incompressible flows.; Conservation laws and finite volume discretization.; Formulation and solution methods for viscous incompressible fluid flows by (1) Stream function-Vorticity method for 2D flows, (2) Projection method for Navier-Stokes equations, (3) Finite-volume discretization and SIMPLE/R-based procedures and (4) Others methods as time allows. Assignments on (1) an elliptic equation problem and (2) a 2D fluid flow problem (by a method of their choice) allow students to acquire generic skills and experience in implementing their own codes.	Understand the fundamental issues of finite difference discretization; Generate finite difference schemes and apply them to reduce a partial differential equation to a coupled set of ordinary differential equations or algebraic equations; Do stability and accuracy analysis by the matrix method; Do stability analysis by Von Neumann method; Solve Poisson and elliptic-type equations arising from incompressible fluid flows; Formulate and discretize equations of incompressible viscous fluid flow (differential and finite-volume form); Gain basic skills / experience for solving incompressible fluid flow through implementing a typical methodology in a 2D problem.	ME2135	Nil	Nil	Nil	**Fundamentals of Finite Difference Discretization:** Governing equations and boundary conditions for incompressible viscous flows; Three solution structures of Navier-Stokes equations.; Basic issues of finite-difference discretization (consistency, stability, convergence, Lax equivalence theorem); Finite difference approximation of derivatives; Reducing a partial differential equation (PDE) into a set of ordinary differential equations (ODEs).; Isolation theorem for ODEs and finite difference equations.; Matrix method for stability and accuracy analysis; Stability analysis of convection and diffusion equations.; Implicit and alternating direction methods; Factorization technique for multi-dimensional problems.; Von-Neumann stability analysis. **Solution of Incompressible Viscous Fluid Flow and Energy Equations:** Navier-Stokes equations in primitive-variables and streamfunction-vorticity form.; Iterative methods for Poisson / elliptic equations – point methods and line methods. A brief review of time-integration schemes.; Conservation laws, finite-volume discretization and flux evaluation.; Solution methodologies for incompressible viscous fluid flow via: Streamfunction-vorticity formulation, Projection methods, Finite-volume methods: SIMPLE/R/C; including implementation of boundary conditions.	CA, Final Examination	**Compulsory Reading:** Anderson, D. A., Tannehill, J. C. and Pletcher, R. H., "Computational Fluid Mechanics and Heat Transfer", McGraw-Hill, 1998.; Hirsch, C., "Numerical Computation of Internal and External Flows", Wiley - Interscience, 1988.; Roach, P. J., "Computational Fluid Dynamics", Hermann, 1969.; **Supplementary Reading:** Fletcher, C.A.J., "Computational Techniques for Fluid Dynamics: Fundamental and General Techniques", Springer-Verlag, 1991.; Versteg, H.K., Malalasekeva, W., "An Introduction to computational Fluid Dynamics: the finite volume Method", Longman Scientific & Technical, 1995.; Anderson, J. D., "Computational Fluid Dynamics: The Basics with applications", Mc Graw-Hill, 1995.
ME4234	Experimental Methods in Fluid Mechanics	4	1	This module teaches students various techniques and skills in carrying out fluid mechanics experiment and data analysis. Major topics are: Similitudes and modeling; Wind tunnel design; Mean and fluctuating velocity measurement; Mean and fluctuating pressure measurement; Shear stress measurement; Wind tunnel blockage correction; End plate configurations; Flow visualization; Signal analysis: data acquisition, probability theory, correlation studies, spectral analysis. This module is primarily targeted at students who are working on their final year project which involves conducting fluid mechanics experiments and those who have interest in experimental fluid mechanics.	Conduct fluid mechanics related experiments accurately and properly; Have sufficient knowledge in: Dimensional analysis, similitude and modeling, wind tunnel design and blockage correction, end plate design; Conduct experiments in laminar and turbulent flow fields and be able to measure mean and fluctuating flow related quantities like velocity, pressure and shear stress; Understand flow visualization techniques, and data analysis which include data acquisition, probability theory, correlation theory and spectral analysis of fluctuating signals; Have sufficient knowledge in carrying out analog to digital signal conversion of signal and subsequent signal processing and statistical analysis.	ME2135	Nil	Nil	Nil	**Similitude and Modeling - Quick Revision:** Dimensional analysis. Principle of Dimensional Homogeneity. Rayleigh's method. Buckingham's pi Theorem. Important dimensionless groups in Fluid Mechanics. Modeling. Distorted models.; **Wind Tunnel Design:** Open and closed-loop wind tunnel. Design procedure and consideration. Various components of a wind tunnel. Generation of shear flow.; **Mean and Fluctuating Velocity Measurement:** Pitot static tube. Hot wire anemometry. Laser Doppler Velocimetry. Particle Image Velocimetry.; **Mean and Fluctuating Pressure Measurement:** Different definitions of pressure. Measurement of static (differential and absolute) pressure. Different types of pressure transducer. Tubing systems, its frequency response and compensation methods. The pressure averager.; **Shear Stress Measurement:** Different types of shear stress measurement technique including those using Preston tune, near wall hot wire and hot film probe, liquid crystal and interferometry.; **Wind Tunnel Blockage Correction:** Classification of blockage type and body shape. Different types of blockage correction. Selection criteria for suitable blockage correction method(s).; **End Plates:** Use and effectiveness of end plates. Selection on shapes and sizes of end plate.; **Flow Visualization:** Different types of flow visualization methods including the tracer category and the optical method category. Analysis of flow visualization results.; **Data Acquisition:** Aliasing and Nyquist frequency.; **Probability Theory:** Probability distribution and probability functions. Goodness-of-fit tests. Central Limit Theorem.; **Correlation Studies:** Independent and dependent processes. Auto- and cross-correlations.; **Spectral Analysis:** Fourier series representation of a complex signal. Fourier transformation and FFT. Power spectra and cross power spectra of signals.	Quizzes, Final Examination	**Compulsory Reading:** Course Notes; **Supplementary Reading:** Bendat, J.S. and Piersol, A.G., "Random Data: Analysis and Measurement Procedures", John Wiley, 1971.; Bradshaw, P., "An Introduction to Turbulence and Its Measurement", Pergamon Press, 1975.; Collett, C.V. and Hope, A.D., "Engineering Measurement", Longman, 2nd edition, 1983.; Dally, J.W., Riley, W.F. and McConnell, K.G., "Instrumentation for Engineering Measurements", John Wiley and Sons, 1984.; Doebelin, E.O., "Measurement Systems Application and Design", McGraw Hill, 4th edition, 1990.; Engineering Science Data Unit 80024, "Blockage Corrections for Bluff Bodies in Confined Flows", 1980.; Hamming, R.W., "Numerical Methods for Scientists and Engineers", McGraw Hill, 1973.; Merzkirch, M., "Flow Visualization", Academic Press International, 2nd edition, 1987.; Oppenheim, A.V. and Schaefer, R.W., "Discrete-time Signal Processing", Prentice Hall International, 1989.; Barlow, J.B., Rae, W.H. Jr. and Pope, A., "Low Speed Wind Tunnel Testing", Wiley Interscience, 3rd edition, 1999.; Brunn, H.H., "Hot-wire Anemometry – Principles and Signal Analysis", Oxford University Press, 1995.
ME4235	Introduction to Aeroelasticity	4	1	This is an introductory course on aeroelasticity as applied to aerospace specialization. Aeroelasticity is defined as the interactions of the deformable elastic structures in free airstream and the resulting aerodynamic force, which broadly falls under fluid-structure interaction. After introducing the basic terminology and a classification, the basics of statics and dynamics of fluid-structure interaction will be given. Topics covered include static aeroelasticity (divergence, control surface reversal), dynamic aeroelasticity (flutter, buffeting, and gust response), aeroservoelasticity (fluid-structure-control interaction), unsteady aerodynamics over lifting surfaces, and experimental methods for flutter prediction.	Understand the physical, theoretical, and mathematical aspects of aeroelasticity and aeroservoelasticity; Acquire the fundamental understanding of aeroelastic phenomena such as static divergence, control surface reversal, flutter instability, buffeting, gust response; Learn the fundamentals of structural dynamics including the principle of minimum energy, Lagrange equations, eigenvalues and modes, free and forced responses; Be able to perform preliminary design calculations to estimate the static divergence and flutter instability for simple two-dimensional airfoils, three-dimensional wing configurations; Be able to analyze and compute relevant critical parameters and incorporate the aeroelastic phenomena during aircraft design, analysis, and testing.	ME2134 and ME2114	Nil	Nil	Nil	**Overview and Preliminaries:** A general and historical overview of aeroelasticity; illustration of some fluid-structure interaction problems in mechanical, civil and aerospace engineering; preliminary information on the theory of elasticity, mechanical vibrations, and aerodynamics.; **2D Typical Section Example:** A simple demonstration of static and dynamic aeroelasticity using a 2D airfoil model; divergence and flutter.; **Structural Dynamics:** Principle of minimum energy, Lagrange equations of motion, beam and plate theory, finite elements, eigenvalues and eigenmodes, free and forced vibrations, Rayleigh-Ritz method, Galerkin's approximation.; **Aerodynamic Tools:** Airfoils and wings in unsteady subsonic and supersonic flows; Strip Theory, Wagner & Kussner functions, Vortex Lattice, Doublet Lattice, Piston Theory; Generalized Aerodynamic Forces.; **Coupled Aero-Structure Systems:** Coupling of the structure with aerodynamics; mixed frequency/time domain, state-space time-domain formulations of the aeroelastic equations of motion.; **Static Aeroelasticity:** Deformation of airplane structures under static loads, static divergence, control surface reversal.; **Flutter Prediction:** Estimation of critical flutter speeds using the k method, p method, p-k method, eigenvalue analysis, V-g plot.; **Analysis of Dynamic Responses:** Transient responses and loads due to gust; modeling of gust aerodynamics; buffeting due to turbulence.; **Active Aeroelastic Control (Aeroservoelasticity):** Use of control surfaces and control algorithms for ride quality improvement, damping enhancement, flutter suppression.; **Advanced Topics:** Computational Aeroelasticity; nonlinear aeroelasticity; aeroelastic tailoring by composites; experimental methods for flutter testing	Homework & Mini-projects, Quizzes (in class and take home), final examinations	**Compulsory Reading:** Lecture notes, Hodges, D.H and Pierce, G.A., Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002. Y.C. Fung, An Introduction to the Theory of Aeroelasticity, Dover, 1994. **Supplementary reading:** Wright, J.R. and Cooper, J.E., Introduction to Aircraft Aeroelasticity and Loads, John Wiley & Sons, 2008.; Bisplinghoff, R.L., Ashley, H. and Halfman, H., Aeroelasticity. Dover Science, 1996.; Dowell, E. H., A Modern Course on Aeroelasticity, Kluwer Academic Publishers, 1989

Module Code	Module Title	Modular Credits [MC]	Semester	Module Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Cross Listing	Syllabus	Assessment	Illustrative Reading List
ME4241	Aircraft Performance and Stability	4	2	Aircraft range, endurance, level and gliding flight, climb, takeoff and landing, static longitudinal and lateral stability, dynamic stability and control, flying qualities	Appreciate the interplay of aerodynamics, propulsion, structures and control on flight performance, stability and control; Know the standard atmospheric models and the effect of atmospheric conditions on flight performance, stability and control; Ability to estimate aircraft performance metrics for a given aerodynamic configuration; Ability to assess flight stability and flying qualities via the use of stability derivatives; Apply and interpret industrial specifications e.g. Federal Air Regulations and MIL specifications for conventional commercial and military aircrafts; Understand the performance, stability and control characteristics for experimental and research flight vehicles.	Nil	Nil	Nil	Nil	**Aircraft Performance:** Straight and Level Flight, Climbing and Gliding, Power Requirement Curve, Take off and Landing Field Length, Range estimates, Breguet's equation, Endurance estimates, Turning Performance, Generation of flight envelopes. **Aircraft Stability and Control:** Static longitudinal stability, static margin, Static directional stability, Longitudinal dynamic stability, phugoid and short period modes, Lateral dynamic stability, roll, spiral and Dutch roll modes, Flying qualities assessment	Tutorials/ Seminars, Laboratories, Final Examination	**Compulsory Reading:** R.C. Nelson, "Flight Stability and Automatic Control"; B.W. McCormick, "Aerodynamics, Aeronautics and Flight Mechanics"; WF Phillips, Mechanics of Flight, John Wiley & Sons, 2004.; M. Saarlas, Aircraft Performance, John Wiley & Sons, 2007. (for Performance part of the course only). **Supplementary Reading:** Federal Air Regulations – Part 23, 25, US military specifications MIL-8785
ME4245	Robot Mechanics and Control	4	1	The module facilitates the learning of the fundamentals of robotic manipulators for students who are interested in their design and applications. Successful completion allows students to formulate the kinematics and dynamics of robotic manipulators consisting of a serial chain of rigid bodies, and design, analyze and implement control algorithms with sensory feedback. The module is targeted at upper level undergraduates who have completed fundamental mathematics, mechanics, and control modules. Students will also gain a basic appreciation of the complexity in the control architecture and manipulator structure of new-generation robots. Topics covered include: Introduction, Spatial Descriptions and Transformations, Manipulator Forward and Inverse Kinematics, Mechanics of Robot Motion, Robot Dynamics, Static Forces and Torques, Trajectory Planning, Robot Control	Able to mathematically describe the position and orientation of a rigid object; Given the mathematical model of the kinematics and dynamics of a robot, be able to physically visualize the robot's motion capabilities; Able to develop the kinematic models of the robotic manipulators; Able to derive the dynamic models of the robotic manipulators using Lagrangian and/or Newton-Euler formulations; Able to implement joint-based motion planning for robotic manipulators; Able to synthesize control algorithms for motion control of robotic manipulators	MA1506/ ME2142 for ME students, EE2010 for ECE students	Nil	Nil	Nil	**Introduction, Spatial Descriptions and Transformations:** Robot definition. Robot classification. Robotics system components. Notations. Position definitions. Coordinate frames. Different orientation descriptions. Free vectors. Translations rotations and relative motion. Homogeneous transformations.; **Manipulator Forward and Inverse Kinematics:** Link coordinate frames. Denavit-Hartenberg convention. Joint and end-effector Cartesian space. Forward kinematics transformations of position. Inverse kinematics of position. Solvability. Trigonometric equations. Closed-Form Solutions. Workspace.; **Mechanics of Robot Motion:** Translational and rotational velocities. Velocity Transformations. The Manipulator Jacobian. Forward and inverse kinematics of velocity. Singularities of robot motion.; **Static Forces and Compliance:** Transformations of static forces and moments. Joint and End-Effector force/torque transformations.; **Robot Dynamics and Trajectory Planning:** Lagrangian formulation. Model properties. Newton-Euler equations of motion. Simulations. Joint-based motion planning. Cartesian-based path planning.; **Robot Control:** Independent joint control. Feedforward control. Inverse dynamics control. Robot controller architectures. Implementation problems.	Assignment fieldwork/projects, Final Examinations	**Compulsory Reading:** Sciavicco L. and Siciliano B., Modeling and Control of Robot Manipulators. Second Edition (ISBN 1-85233-221-2), Springer Verlag, London, 2000; **Supplementary Reading:** Fu K.S,, Gonzalez R.C., and Lee C.S.G. Robotics: Control, Sensing, Vision and Intelligence. McGraw Hill, NY, 1987. (Recommended for purchase); Sciavicco L. and Siciliano B., Modeling and Control of Robot Manipulators. McGraw Hill, 1996.; Craig, J.J., Introduction to Robotics, Mechanics, and Control. 2nd Edition, Addison Wesley, MA, 1989. (3rd Edition, if available); Spong, M.W. and Vidyasagar, M., Robot Dynamics and Control, Wiley, New York, 1989.; Paul, Richard P., Robot Manipulators : Mathematics, Programming, and Control : the Computer Control of Robot Manipulators, MIT Press, Cambridge, Mass., 1981.; Lewis F.L., Abdallah C.T., and Dawson D.M., Control of Robot Manipulators, Maxwell Macmillan International, 1993.
ME4246	Modern Control System	4	2	This is a second module on control of linear dynamical systems. It focuses on analysis and synthesis of controllers in the time domain. The module introduces students to the techniques and analysis of dynamical systems using state-space models. The major topics covered are: Introduction to State-Space Model; Solution of State-Space Model; Canonical Forms of State-Space Model; Controllability and Observability; State Feedback and State Estimation; Linear Quadratic Optimal Control, Stability; Discrete Time Systems; Controller Design of Discrete-Time Systems. Students are required to have knowledge of basic classical control theory and linear algebra.	Derive mathematical models of physical systems; Analyze models of the system; Understand the relation between state-space and transfer function representation; Understand the concepts of state-space realizations, controllability, and observability; Design state feedback controllers and observers; Design Linear Quadratic Optimal Controllers; Understand digital systems, discrete time systems, difference equations, z-transforms and sampled-data systems; Design and analyze digital controllers for discrete-time system; Use tools such as MATLAB to analyze control systems and/or design controllers for systems	ME2142	Nil	Nil	Nil	**Review of Classical Control and Linear Algebra:** Review of Classical Control Theory. Review of Linear Algebra. **Introduction to State-Space Model:** Motivation for space-space model. Examples of state-space representation of dynamical systems. Linearization of non-linear systems. Concept of state of a system and definitions. **Solution of State-Space Model:** Time solution of linear-invariant state-space model. Properties of state-transition matrix. Methods to compute state-transition matrix. Relation to transfer function representation. Review of matrix and linear algebra. **Canonical Forms of State-Space Model:** Similarity transformation. Controllable and Observable canonical forms and their realisations. **Controllability and Observability:** Definitions of Controllability and Observability. Algebraic conditions for controllability and observability of systems. Stabilisability and detectability. Minimality of realisation. Duality. **Stability:** Introduction to Lyapunov stability theorem. BIBO stability. Lyapunov equation for linear time-invariant systems. **Simulation Tools - MATLAB:** Introduction to MATLAB simulation language. **Overview of Digital Control Systems:** Difference equations and z-transforms. Discrete models of sampled-data systems. Transfer functions with z-transforms. State-space model. **State Feedback and State Estimation:** Pole-placement design for SISO system. Design of linear observer. Compensator design by separation principle. **Linear Quadratic Optimal Control:** Introduction and formulation of the LQR problem. Derivation of Ricatti equation solution to the LQR problem. Steady-state solution. Effects of choices of Q and R matrices. Properties of the LQR **Digital Control System Design:** Control design specifications. Dynamic responses. Design using emulation and discrete equivalents of continuous-time controllers. Direct digital design in state-space (combined with continuous time)	Tutorial/Seminar, Test, Final Examination	**Compulsory Reading:** K.Ogata, "Modern Control Engineering," Fourth Edition, Prentice-Hall, Inc.; Franklin, Powell, and Workman, "Digital Control of Dynamic Systems", 3rd Edition.; Addison Wesley; K. Ogata, "Discrete-Time Control Systems", 2nd Edition, Prentice Hall; **Supplementary Reading:** B. Briedland, "Control System Design - An Introduction to State-Space Methods," McGraw-Hill, Inc., 1987.; John S. Bay, "Fundamentals of Linear State Space Systems", McGraw-Hill
ME4253	Biomaterials Engineering	4	2	Biomaterials involve the integration of engineering materials with biological entities in the body. The success of any implant or medical device depends very much on the biomaterial used. This course targets students who wish to develop broad based knowledge. The course introduces students to life science topics. Students gain an appreciation of multidisciplinary approach to problem solving. Topics include biological materials, metals, polymers, ceramics and composites use as implants, host-tissue response, materials selection, relationship between structure-composition-manufacturing process, mechanical testing and evaluation of implants, sterilization and packaging, regulatory approvals, and suitable case studies. Video presentations and lectures from invited clinicians complement the breadth covered in this course. Students enjoy project-based case studies which provoke curiosity, peer evaluation and group dynamics.	Know the different classes of biomaterials; Understand regulatory processes for medical implants; Understand biocompatibility, wear, stress shielding and corrosion issues in implants; Apply materials selection principles in development of medical devices; Understand the need to integrate different disciplines to solve biomaterials problems; Develop techniques of good writing and communication skills.	ME2151 or equivalent background in materials science is helpful. Students without basic physics, biology and chemistry will find this course hard to follow initially. Some basics in physics, biology and chemistry (O-A level) are therefore essential.	Nil	Nil	Nil	**Introduction:** Requirements of biomaterials, Classification of biomaterials, Mechanical properties of biomaterials, Effects of processing on properties of biomaterials; **Biological Materials:** Structure of proteins, collagen, elastic proteins, polysaccharides, chitin and chitosan, structure properties relationships; **Metallic Implant Materials:** Some common examples and properties of metals used as implants: stainless steel, titanium and titanium alloy, cobalt chrome alloys. Problem of corrosion, corrosion behavior and the importance of passive films for tissue adhesion, wear, stress shielding. Host tissue reaction with metals; **Polymeric Implant Materials:** Some common examples and properties of polymers used as implants: PE, PMMA, silicon rubber, polyester, acetals, biodegradable polymers. (Classification according to thermosets, thermoplastics and elastomers). Viscoelastic behavior: Tg, creep-recovery, stress relaxation, strain-rate sensitivity. Host tissue reaction: importance of molecular structure, hydrophilic and hydrophobic surface properties; **Ceramics Implant Materials:** Definition of bioceramics. Common types of bioceramics (inert and bioactive types) and their properties (importance of wear resistance and low fracture toughness). Host tissue reactions: importance of interfacial tissue reaction (e.g. ceramic/bone tissue reaction).; **Composite Implant Materials:** Mechanics of improvement of properties by incorporating different elements. Composites theory of fiber reinforcement (short and long fibers, fibers pull out). Polymers filled with osteogenic fillers (e.g hydroxyapatite). Textile composites. Host tissue reactions.; **Testing of Biomaterials:** In-vitro testing. Mechanical test: wear, tensile, corrosion studies and fracture toughness. Effect of physiological fluid on the properties of biomaterials. In-vivo testing (animals).	MCQ, Project-Based Case Studies, Final Examination	**Compulsory Reading:** BD Ratner, AS Hoffman, FJ Schoenm JE Lemons (Eds.), Biomaterials Science: An Introduction to Materials in Medicine, Academic Press, 2nd Edition, 2004; JB Park, RS Lakes (Eds.), Biomaterials - An Introduction, Plenum Press, 1992.; **Supplementary Reading:** JS Temenoff, AG Mikos (Eds.), Biomaterials: The Intersection of Biology and Materials Science, Pearson, 2008; LL Hench, J Wilson (Eds.), An Introduction to Bioceramics, World Scientific, 1993; D Hill (Ed.), Design Engineering of Biomaterials for Medical Devices, John Wiley & Sons, 1998; M Jenkins (Ed.), Biomedical Polymers, Woodhead Publishing, 2007; R Seeram et al. (Eds.), Biomaterials: A Nano Approach, CRC Press, 2010

Module Code	Module Title	Modular Credits [MC]	Semester	Module Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Cross Listing	Syllabus	Assessment	Illustrative Reading List
ME4255	Materials Failure	4	2	This module addresses the failure of engineering systems governed by the end service conditions. Commonly encountered service conditions are introduced in this module, including their impact on the service life of the individual components as well as the assembly of components. This module enables students to understand the deterioration of materials due to service conditions and how to minimize them. The topics are covered: introduction to failure of materials; service failure analysis practice; failure due to overloading; failure due to cyclic loading; failure due to corrosion; failure due to friction and wear; failure at elevated temperatures; failure of weld joints; inspection and remaining life prediction techniques; and case studies.	Analyze various mechanical and environmental related failure mode of engineering materials; Explain the basics of the theories behind each failure mode (ductile and brittle fracture, fatigue, impact, wear, corrosion, creep) and their mechanisms; Use mathematical tools to predict life of a component subjected to fatigue or creep modes of failure; Outline failure prevention methods for engineering materials subjected to different service conditions (static and cyclic stress, environment, friction/wear, high temperature etc.); Conduct failure analysis through fractography and materials property tests; Take corrective measures such as changes in the design and safety factor, or recommendation of appropriate inspection schedule or quality control procedure to avoid failure of engineering components.	ME2151	Nil	Nil	Nil	**Introduction to Materials Failure**: Introduction, Examples of engineering disasters, Failure investigation procedure, Modes of failure, Case study.; **Failure due to overload**: 3-dimensional stress state and principal stresses, Failure criterion for both yielding and fracture, Ductile and brittle fracture, Plastic deformation mechanism, Yielding in polymers, Factors affecting yield stress of polymers, Case study.; **Failure due to cracking**: brief introduction of fracture mechanics, stress concentration, stress intensity factor and their application in design and analysis, fracture toughness, R-curve behaviors, plastic zone correction, energy principle of fracture, fracture toughness measurement.; **Failure due to friction and wear**: Definitions, Type applications involving wear failure, Types of wear, abrasive wear, adhesive wear, fatigue wear, fretting, wear failure preventions, Empirical model for zero wear.; **Failure due to cyclic loading**: Definitions in cyclic loading, Fatigue fracture surface marks, Types of fatigue, S-N curve, Fatigue life prediction, Mechanism of fatigue failure in metals and polymers, Statistical nature of fatigue failure, Factors affecting fatigue life, Variable amplitude fatigue, strain-based fatigue approaches, Fatigue crack growth under constant amplitude and variable amplitude loading, fatigue of welded members, fretting fatigue. Case study.; **Failure at elevated temperatures**: Introduction and definitions, Creep, Mechanisms of creep, Creep behaviour predictions, Creep fracture mechanisms, Creep in polymers, Dynamic and cyclic loading, Time-temperature superposition, Creep failure mechanisms in polymers, Long-term creep life prediction, Case study.; **Failure due to environmental effects**: Important environmental effects, Principles of corrosion, Corrosive conditions, Different forms of corrosion, Theory of aqueous corrosion, Pitting, Crevice corrosion, Stress-corrosion cracking, Corrosion fatigue, Hydrogen damage failures and preventions.; **Flaw detection**: Use of non-destructive testing, Visual examination, Microscopy, Dye penetrant test, Magnetic particle testing, Eddy current testing, Ultrasound testing, Radiographic testing, Acoustic emission testing, general principle of fractography, and case studies.	Mid Term Quiz, Term Paper, Final Examination	**Compulsory Reading:** A.J. McEvily, "Metal Failures", John Wiley & Sons, Inc, 2002.; J. A.Collins, "Failure of Materials in Mechanical Design" , John Wiley & Sons, Inc, 1993.; N. E. Dowling, "Mechanical Behavior of Materials - Engineering Methods for Deformation, Fracture, and Fatigue", Prentice Hall, 2007. **Supplementary Reading:** D.R.H.Jones, "Engineering Materials 3", Pergamon Press, 1993.; V. J. Colangelo and F. A. Heiser, "Analysis of Metallurgical Failures", John Wiley & Sons, Inc, 1987.; G. E. Dieter, "Mechanical Metallurgy", McGraw-Hill International Edition, 2000.
ME4261	Tool Engineering	4	2	All mechanical engineering students need the basic knowledge of metal machining and tool design for mass production and the design of cutting tools. This module provides the fundamental understanding of metal machining and tool design.	Identify the types of locators and supports used for jigs and fixtures; Design a Jig and a fixture; Understand the nomenclature of cutting tools; Design single point cutting tools, drills and milling cutters	Nil	ME3162	Nil	Nil	**Jigs and Fixtures**: Work holding principles. Locating principles. Clamping devices. Design of jigs and fixtures for conventional and CNC machines. Inspection jigs and fixtures. Modular fixtures.; **Mechanics of metal cutting:** Chip formation, forces acting on the cutting tool and their measurement, the apparent mean shear strength of the work material, chip thickness, friction in metal cutting, tool life and tool wear.; **Design of Cutting Tools:** Nomenclature of cutting tools, Optimization of tool shape and design features of special single-point cutting tools. Conventional drills and milling cutters. Grinding wheels and dressing of grinding wheels.	Term Paper, Final Examination	**Compulsory Reading:** E.G Hoffman, "Jig and fixture design", Delmar Publishers, 1996.; C. Donaldson, C.H. LeCain and V.C. Gould, "Tool Design", Tata McGraw Hill, 1994.; G. Boothroyd and W.A. Knight, Fundamentals of Machining and Machine Tools, Second Edition, MARCEL DEKKER, INC. 1989. **Supplementary Reading**: Boyes WE (ed)., "Handbook of jigs and fixture design", Society of Manufacturing Engineers, 1989; S.C. Salmon, Modern Grinding Process Technology, McGraw-Hill, Inc., 1992.; T.H.C. Childs, K. Maekawa, T. Obikawa and Y. Yamane, Metal Machining, Arnold, 2000.
ME4262	Automation in Manufacturing	4	2	This module provides a comprehensive introduction to automation technologies applied in discrete part manufacturing. It also introduces essential principles and provides analytical tools for manufacturing control. Major topics covered include: Economic justification of automated systems; Fixed and transfer automation; Automated material handling and automated storage/retrieval systems, Flexible manufacturing systems, Internet-enabled manufacturing, Group technology, Process planning, Automated assembly and Automated operation planning for layered manufacturing processes.	Able to analyze and evaluate the investment alternatives and selection of various components needed in automated materials handling, storage/retrieval and layout; Understand the principles of GT, decision making in process planning, RP and how it is applied to process automation; Evaluate the performance measures (average production rate, yield of good assembly, etc) of both multi-station and single-station assembly machines.	Nil	ME3162	Nil	Nil	Economic justification of automated systems; Fixed and transfer automation; Automated material handling; Automated storage/retrieval systems,; Flexible manufacturing systems,; Internet-enabled manufacturing,; Automated assembly,; Group technology,; CA Process planning,; Automated operation planning for layered manufacturing processes.	Term Paper, Final Examination	**Compulsory Reading:** Mikell P. Groover, "Automation, Production system, and computer integrated manufacturing" Prentice Hall International, Inc., 1987. **Supplementary Reading:** William W. Luggen, "Flexible Manufacturing Cells & Systems" Prentice Hall International Ed., 1991.; T.C. Chang, Richard A. Wysk & H.P. Wang, "Computer aided manufacturing, Prentice Hall International Ed., 1991.; Web e-learning
ME4263	Fundamentals of Product Development	4	3	This is an intensive full-time two-week module held during the Special Term covering the following topics relating to the basic product development process: global design perspectives, identifying customer needs and conceptual design, industrial design, design for reliability and product testing, prototyping and design for manufacturing, and product testing economics. Students will propose a product to be developed and work in a team to go through the process via a series of guided exercises relating to the above topics.	Students will be able to work on a group project on product development by attending interactive classroom sessions.; Students will be able to carry out the group project with a final presentation.	Nil	Nil	Nil	Nil	**Introduction & Global Design Perspectives:** Overview of techniques and tools to facilitate and shorten product design and development; emerging trends; **Identifying Customer Needs:** Scoping; data gathering and interpretation; prioritizing needs; specification; **Conceptual Design:** Concept generation and selection; **Industrial Design:** Visualization and communication methods; form design basics; aesthetics; usability; **Design for Reliability and Product Testing:** Robust design; related US and Singapore standard; **Prototyping and Design for Manufacturing:** Types and uses of prototypes; rapid prototyping technologies; understanding impact of design on manufacturing; basic manufacturability evaluation; **Product Design Economics:** Product economics; net present value base case; sensitivity and trade-off analysis for development decisions; consideration of other quality factors	Others (eg Fieldwork, projects)	**Supplementary Reading**: "Product Design and Development" by Karl T. Ulrich and Steven D. Eppinger

Module Code	Module Title	Modular Credits [MC]	Semester	Module Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Cross Listing	Syllabus	Assessment	Illustrative Reading List
ME4264	Automobile Design & Engineering	4	1	This module will help students learn to make engineering decisions regarding power-train, braking, suspension, steering and body systems in order to meet acceleration, braking, ride & handling, safety, durability and NVH performance specifications.	Design engine, transmission and driveline system properties to meet vehicle acceleration specifications; Design brake system properties to meet vehicle braking specifications; Design suspension system properties to meet vehicle ride, durability and noise/vibration/harshness specifications; Design suspension, steering and tire properties to meet vehicle handling and roll-over specifications; Design body system properties to meet vehicle crash safety specifications; Understand suspension and steering mechanisms; Understand systems engineering approach to design.	ME 2113	Nil	Nil	Nil	Vehicle specifications such as acceleration requirement, deceleration requirement, ride comfort, ability to manage road irregularities, noise & vibration levels, handling response, anti-roll-over capability, crash safety, etc.; Design of power-train system properties including torque/power, transmission gear ratios, drive line and wheel/tires in order to meet acceleration requirement; Design of brake system properties including brake torque & gains, master cylinder pressure, proportional valve and wheel/tires in order to meet deceleration requirement (FMVSS).; Design of suspension system properties such as spring, damper and tire to meet ride comfort specifications.; Design of suspension system properties such as jounce/rebound clearances, jounce bumper, damper and tire to meet suspension load specifications.; Frequency alignment and vibration isolation strategies to meet NVH specifications.; Design of suspension/steering system properties such as tires, springs, anti-roll bar, linkages, bushings to meet handling specifications.; Design of suspension system properties such as tires, springs, dampers and anti-roll bar to meet roll-over specifications.; Study of currently popular suspension & steering system mechanisms and architectures.; Design of body front rail section to absorb energy during frontal crash in order to meet crash safety specification (FMVSS).; Study of body system architectures, sub-systems/parts, materials, manufacturing methods and requirements.	Tests, Fieldworks/Projects	**Supplementary Reading:** Fundamentals of vehicle dynamics, by Thomas D. Gillespie
ME4265	Automotive Body & Chassis Engineering	4	2	This module will help students understand the specifications for the design of body and chassis systems, design architectures, methods of component engineering, material selection, and manufacturing methods.	Understand body system architecture, lay-out and function of sub-system and components.; Learn body component design and performance evaluation.; Understand body system assembly process.; Understand suspension/steering system architectures.; Learn design of suspension/steering mechanisms.	ME 2113	Nil	Nil	Nil	Discussion on body system performance specifications: strength & stiffness, durability, frequencies, crashworthiness, function, cost/weight and manufacturing feasibility.; Discussion on body sub-systems and panels, such as, front end sheet metal, dash & cowl, under body structure, body side panels, roof panel and closure system (doors, hood, deck lid and lift gate).; Discussion on materials used for different body panels and material properties important for strength, stiffness, energy absorption and stamping.; Method of designing body panels and assembling them to form a section/system for stiffness and strength improvement. ; Methods of performance evaluation of body panel assembly including finite element analysis and testing.; Description of spot welding process for body panels & assembly sequence followed in a typical assembly plant.; Suspension system architectures, such as SLA, Macpherson strut, 3-link, 5-link, twist beam solid axle, Hotchkiss, etc. Linkage geometry design to provide required toe, camber and vertical movement of wheel. Calculation of roll-center.; Design of suspension linkages for vehicle handling, anti-squat and anti-dive performance.; Calculation of suspension component loads as longitudinal, lateral and vertical loads are transferred from wheel to the body through suspension links.; Design of suspension components to withstand loads.; Discussion on the factors affecting design of tires and on the tire properties essential for vehicle acceleration, braking and cornering.; Design of steering system mechanism	Tutorials/ Seminar, Tests, Fieldwork/Projects	**Compulsory Reading:** Fundamentals of Automobile Body Structure Design by Donald E Malen. **Supplementary Reading:** Automotive Body Manufacturing Systems by Mohammad Omar; The Automotive Chassis by Jornsen Reimpell, et al.
ME4291	Finite Element Analysis	4	1	This course introduces the fundamental concepts of the finite element method, practical techniques in creating an FEM model, and demonstrates its applications to solve some important stress and thermal analysis problems in Mechanical Engineering. Some necessary background in mechanics will be briefed before the foundations of the FEM theory, concept and procedures are covered. Various formulations and applications to one- two- and three-dimensional problems in solid mechanics and heat transfer will be covered to reinforce the theory and concepts. The precautions in the actual practice of FE analysis such as mesh design, modeling and verification will also be covered. Some instruction in the use of a commercial FEM software package will be given and students are expected to carry out one or more projects with it independently. This module should give students a good foundation for numerical simulation, and basic skills for carrying out stress and thermal analysis for a mechanical system.	**Structural and Solid Mechanics Problems:** Understand how energy principles are used to formulate the finite element method for solids and structures; Apply the FEM procedure to formulate truss element, beam element, frame element, 2D and 3D solid elements; Use of special elements for fracture problems and problems of infinite domain; **Modeling techniques:** Create a FEM model for a given solid and structure, including geometry modeling, meshing, applying boundary conditions, and job execution; Understand the precautions in the actual practice of FE analysis such as mesh design, modeling and verification of solutions; **Heat Transfer Problems:** Understand how the weighted residual method is used to formulate the finite element equations for field problem including heat transfer problems; Understand the procedure to treat different types of boundary conditions in heat transfer problems; Apply the FEM procedure to solve 2D and 3D heat transfer problems; **Hands-on Session, use of software package and project:** Understand the basic procedures in using a commercial software package, including geometry creation/importing, meshing, use of different types of elements, analysis execution, post-processing of results; Carry out a FEM project and write a report independently in teams of students.	MA1505	Nil	Nil	Nil	**INTRODUCTION** (1.5 hours): Physical problems, mathematical model, numerical methods, computational implementation procedures.; **BRIEFING ON MECHANICS FOR SOLIDS AND STRUCTURES (reading material for students, but give 1 hours briefing in class):** System equations for solids, truss, beam, and plates; **THE FUNDAMENTALS OF FINITE ELEMENT METHOD** (4 hours): Hamilton's principle, minimum potential energy principle, shape functions, discretized system equations.; **FEM FOR TRUSSES (3 hours):** Shape functions for truss elements, strain matrix, FE equations, coordinate transformation, global equation assembly, reproducing property of FEM.; **FEM FOR BEAMS (3 hours):** Shape functions for beams, strain matrix, FE equations, reproducing and convergence property of FEM.; **FEM FOR FRAMES (2 hours):** FE equations for frames, superimposition techniques. Coordinate transformation in three dimensions.; **FEM FOR 2-D SOLIDS (5 hours):** Triangular element, rectangular element, high order elements, Gauss integration, coordination transformation, isoperimetric element, crack tip elements, infinite elements.; **FEM FOR PLATES AND SHELLS (4.5 hours):** Shape function for plates, FE equations for plates and shells, superimposition techniques. Coordinate transformation in three dimensions.; **FEM FOR 3-D SOLIDS (1 hour):** Shape functions for 3-D solids, FE equations.; **Modeling techniques (4 hours):** Geometry creation, multi-point constraints, modeling of rigid body, loading, boundary condition, mesh design, mesh distortion, compatibility issues, assessment of results, adaptive analysis.; **FEM FOR heat transfer problems (6 hours):** Weighted residual method, divergence theorem, one-dimensional heat conduction fin, composite wall, 2D problems, boundary conditions, case studies.; **Use of FEM packages (4 hours):** Hands-on session using a commercial software package.	Tutorial Presentations, Mid-Term Quiz, Independent Group Project, Final Examinations	**Compulsory Reading:** The finite element method - a practical course (2nd edition), Liu GR and Quek SS, Elsevier (Butterworth-Heinemann), 433 pages, ISBN: 978-0-08-098356-1, 2013. ; **Supplementary Reading:** Zienkiewicz OC, Taylor RL (2000) The finite element method (Fifth edition). Butterworth Heinemann, Oxford.; An introduction to The Finite Element Method. J. N. Reddy, McGraw-Hill, 1993. 2nd ed.; Introduction to The Finite Element Method. N. Ottosen and H. Peterson. Prentice Hall, 1992.; Applied Finite Element Analysis. L. J. Segerlind. John Wiley, 1984. 2nd ed.