Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME2114	Mechanics of Materials	4	2	ME2114 is an intermediate mechanics course on the failure and deformation of elastic structures. Common criteria for determining failure of brittle and ductile materials will be introduced and applied for the failure analyses of thin-walled pressure vessels and slender structures. Failure of slender structures due to buckling is included. The course will also present several energy based methods for determining the deformation of slender structures and show how energy methods lead to the Finite Element Method – a common tool for computational stress analysis.	• understand yield criteria, • understand combined stresses and failure. • understand yielding and residual stresses and evaluate stresses in a structure including experimental stress analysis. • understand the concept of instibilty of column with various boundary conditions and able to determine the critical load of slender structures under axial compression. • understand how to apply work-energy balance and Castigliano theorem to determine the deformation of complex structures and solve indeterminate problems.	ME2112	Nil	Nil	• Yield criteria • Combined stresses and failure • Elastoplastic behaviour and experimental stress analysis • Instability of structures • Work-energy balance and Castigliano theorem	Lab, Quiz, Final Examination	• C. Ugural, Mechanics of Materials, McGraw-Hill, Current edition • R. C. Hibbeler,Mechanics of Materials, Prentice Hall, SI 2nd Ed., 2005. • F. P. Beer, E. R. Johnston, Jr. and J. T. DeWolf, Mechanics of Materials, McGraw-Hiil, SI 3rd Ed., 2004. • J. M. Gere and S. P. Timoshenko, Mechanics of Materials, PWS Publishing Company, 4th ed., 1997. • R. R. Craig, Jr., Mechanics of Materials, McGraw-Hiil, 2nd ed., 2000.
ME2135	Intermediate Fluid Mechanics	4	2	This course aims to introduce fundamentals of fluid dynamics covering notions of the continuum hypothesis, flow kinematics, mathematical tools for flow visualization, material derivative, fluid acceleration, conservation laws, Euler and Navier-Stokes Equations, inviscid flows, potential flows, viscous flows, creeping flows and boundary layer flows. Review of relevant mathematical tools to support the theory will accompany the topics when and where it is required.	On successful completion of this course, the student will be able to: 1. Apply angular momentum principle and dimensional analysis to analyze the performance of pumps, perform pump-system matching and assess the likelihood of cavitation occurrence. 2. Understand the concepts of vorticity, circulation, irrotationality, stream function and velocity potential function, and apply these concepts to solve simple potential flow problems involving the superposition of elementary flows. 3. Identify and discuss the features of external flow past immersed bodies and calculate the lift and drag forces for typical body shapes. 4. Describe and explain the phenomenon of boundary layer on a body (at this stage, a flat plate) and estimate the drag force exerted. 5. Analyze and design an aerodynamic body with minimum drag force.	ME2134	Nil	Nil	Fluid Machinery Pump classification for dynamic and positive-displacement pumps. Basic velocity triangles and rotordynamics of centrifugal and axial-flow pumps. Use of dimensional analysis to simplify pump characteristic curves. Specific speed and pump selection. Matching of pump and system requirements. Physical phenomenon of cavitation in pumps and quantification of cavitation risk and damage. Potential Flow Ideal and irrotational flow. Continuity equation. Rotation, vorticity and circulation. Streamfunction and velocity potential of basic flows, such as a uniform flow, source, sink, vortex and doublet. Linearity of potential flow. Flow past a circular cylinder and the lift on a rotating cylinder. D'Alembert's paradox, Kutta Joukowski Theorem and Magnus Effect. Method of images. Viscous Flow Differences between Ideal(Inviscid) and Real(Viscous) Flows. Description of fluid motion and the substantive derivative. Navier-Stokes equations and some exact solutions. Prandtl's Laminar Boundary Layer Theory. Solution of laminar boundary layer flow on a flat plate (Blasius solution), Notions of boundary layer, displacement and momentum thicknesses. Drag on flat plate (von Karman integral equation). Boundary layer separation and control. Comparison between laminar and turbulent boundary layers. Turbulent flow and time averaging, equations of motion for turbulent flow, structure of the turbulent boundary layer and the law of the wall; turbulence models, velocity profiles in turbulent boundary layer and parameters of turbulent boundary layer. Boundary layer with transition. Flow around bluff and streamlined bodies. Drag reduction techniques.	100% CA - Project report, Lab report, Quiz	**Supplementary reading:** 1. "Introduction to Fluid Mechanics" by R. W. Fox, A. T. McDonald & P. J. Pritchard, John Wiley & Sons, 8th Edition, 2012. 2. "Fluid Mechanics: Fundamentals and Applications", Y. A. Cengel and J. M. Cimbala, Mcgraw-Hill, 3rd Edition, 2014. 3. "Mechanics of Fluids" by M. C. Potter, D. C. Wiggert & M. Hondzo, Prentice Hall, 4th Edition, 2012. 4. "A Physical Introduction to Fluid Mechanics", A. J. Smits, John Wiley & Sons, 1st Edition, 2000. 5. "Mechanics of Fluids" by I. H. Shames, McGraw-Hill, 4th Edition, 2003. 6. "Engineering Fluid Mechanics" by C. T. Crowe, D. F. Elger, J. A. Roberson & B. C. Williams, John Wiley & Sons, 9th Edition, 2010. 7. "Fluid Mechanics" by J. F. Douglas, J. M. Gasiorek, J. A. Swaffield & L. B. Jack, Prentice Hall, 5th Edition, 2005. 8. "Fluid Mechanics with Engineering Applications" by J. B. Franzini & E. J. Finnemore, McGraw-Hill, 10th Edition, 2002. 9. "Mechanics of Fluids" by B. S. Massey, Taylor & Francis, 9th Edition, 2012. 10. "Applied Fluid Mechanics" by R. L. Mott, Prentice Hall, 6th Edition, 2006. 11. "Elementary Fluid Mechanics" by R. L. Street, G. Z. Watters & J. K. Vennard, John Wiley & Sons, 7th Edition, 1996. 12. "Fluid Mechanics" by V. L. Streeter, E. B. Wylie & K. W. Bedford, McGraw-Hill, 9th Edition, 1997. **Compulsory reading:** 13. "Fluid Mechanics" by F. M. White, McGraw-Hill, 7th Edition, 2011. 14. "Fundamentals of Fluid Mechanics" by B. R. Munson, D. F. Young, T. H. Okiishi & W. W. Huebsch,, John Wiley & Sons, Inc., 7th Edition, 2013.
ME2143	Sensors and Actuators	4	1	This course introduces various components that are useful in the analysis, design and synthesis of mechatronic systems. The topics mainly include electronic circuits (analog and digital), sensors, actuators, etc. For the analog circuits, the operational amplifiers and its applications will be introduced. The working principles of semiconductor devices such as diodes and transistors will be explained. The digital circuits will then be introduced for digital electronics applications. For the sensors part, the basic principles and characteristics of various sensors for the measurement of physical quantities such as position, strain, temperature, etc will be introduced. The actuators section mainly covers the electric motors which include DC motors, stepper motors and AC motors.'	On successful completion of this course, the student will be able to: 1. Apply operational amplifiers circuits for analog signal processing. 2. Analyze circuit involving diodes, BJT transistors 3. Design and implement digital circuits. 4. Understand the basic principles and characteristics of DC, AC, and stepper motors. 5. Understand the basic principles and applications of various sensors.	Nil	Nil	Nil	1. Operational Amplifiers and Applications: Ideal Op-amp model. Inverting and non-inverting amplifier. Summer. Integrator. Voltage follower. Differential amplifier. Practical op-amp characteristics 3. Semiconductor Electronics: Junction Diode. Zener diodes. Rectifiers. Voltage regulators. Transistors. 4. Introduction to Digital Electronics: Boolean Algebra. Truth tables. Logic Gates. Combinational logic. Karnaugh Maps. Flip-flops and counters. Sequential logic. 5. DC Motors: Magnetic field and circuits. DC motor principle. Types of DC motors. Torque-speed characteristics. Speed regulations. 6. Review of AC Power: Single and three phase systems. Star and delta configurations. Line and phase quantities. 7. AC Motors and Stepper Motors: Principle of operation. Torque-speed characteristics. Induction motors and stepper motors. 8. Sensors and Transducers: Bridges and their applications. Variable resistance elements: potentiometers, strain gauges, thermistors, RTDs. Variable reluctance elements: differential transformers, variable reluctance transducers. Capacitive transducers. Thermal couples. Piezoelectric effect. Selection of sensors.	Lab, Online assignment/forum participation, Final Examination	**Compulsory reading:** David G. Alciatore and Michael B. Histand, "Introduction to Mechatronics and Measurement Systems", McGraw-Hill, 2007. Allan R Hambley, "Electrical Engineering, Principles & Application", Prentice Hall, 2005. **Supplementary reading:** R. Pallas-areny and J. Webster, "Sensors and Signal Conditioning", John Wiley & Sons, 2001. Ernest O. Doebelin, "Measurement Systems Application and Design", McGraw Hill, 2004. W. Bolton, "Mechatronics", Prentice Hall, 2003. Nitaigour Premchand Mahalik, "Mechatronics: Principles, concepts and applications", McGraw Hill, 2003. D. Shetty and R. A. Kolk, "Mechatronics System Design", PWS Publishing Company, 1997.
ME3000	Independent Study I	2	1 & 2	This course encourages students to become independent and self-motivated learners, and promotes students' interest in research-based work. The course may consist of a series of laboratory-based projects or other academic prescriptions for the students' independent study amounting to approximately 65 hours of work over one or two semesters. The academic scope is worked out between the student and supervisor. Topics taken under UROP and extension of FYP will not be considered for this course.	On successful completion of this course, the student will be able to: (a) Design and conduct experiments, analyse, interpret data and synthesize valid conclusions; (b) Design a system, component, or process, and synthesise solutions to achieve desired needs; and (c) Identify, formulate, research through relevant literature review, and solve engineering problem reaching substantial conclusions.	Nil	Nil	Nil	The scope is to be worked out between the student and his supervisor.	100% CA	NA
ME3001	Independent Study II	2	1 & 2	This course encourages students to become independent and self-motivated learners, and promotes students' interest in research-based work. The course may consist of a series of laboratory-based projects or other academic prescriptions for the students' independent study amounting to approximately 65 hours of work over one or two semesters. The academic scope is worked out between the student and supervisor. Topics taken under UROP and extension of FYP will not be considered for this course.	On successful completion of this course, the student will be able to: (a) Design and conduct experiments, analyse, interpret data and synthesize valid conclusions; (b) Design a system, component, or process, and synthesise solutions to achieve desired needs; and (c) Identify, formulate, research through relevant literature review, and solve engineering problem reaching substantial conclusions	Nil	Nil	Nil	The scope is to be worked out between the student and his supervisor.	100% CA	NA

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME3122	Heat Transfer	4	1	This course covers the key concepts related to the different modes of heat transfer (conduction, convection and radiation) and principles of heat exchangers. It develops the students' proficiency in applying these heat transfer concepts and principles, to analyse and solve practical engineering problems involving heat transfer processes. Topics include introduction to heat transfer; steady state heat conduction; transient heat conduction; lumped capacitance; introduction to convective heat transfer; external forced convection; internal forced convection; natural/free convection; blackbody radiation and radiative properties; radiative exchange between surfaces; introduction to heat exchangers and basic calculation of overall heat transfer coefficient.	Upon successful completion of this course, the student will be able to: 1. Identify, formulate and solve problems involving different heat transfer processes; 2. Analyse, model heat conduction in one-dimensional cases and describe two- and three-dimensional heat conduction and be able to apply them to simple heat conduction problems; 3. Analyse, model and apply appropriate empirical correlations for convection heat transfer in both internal and external flows; 4. Identify, model and calculate heat transfer through radiation and between irradiated surfaces; and 5. Understand principles and different types of heat exchangers and perform basic calculation of overall rate of heat exchange.	Cohort AY18/19 & before =PC1431	Nil	Nil	**Conduction** Fourier's law of conduction, one dimensional heat conduction through composite wall, tubes and spheres. Derivation of general transient conduction equation with a heat source. Steady state 1D conduction with and without energy generation; overall heat transfer coefficient, critical and economic thickness of insulation. Extended surfaces: derivation of equation for simpler cases, fin efficiency and effectiveness. Unsteady heat conduction: lumped system analyses. **Convection** Newton's law of cooling. Laminar flow over a flat plate, Reynolds number and its interpretation, Blasius solution, velocity profile, boundary layer thickness, wall shear stress. Momentum integral equation, similar velocity profile, boundary layer thickness. Thermal boundary layer, energy equation, energy integral equation and its solution. The Reynolds analogy between fluid friction and heat transfer. Laminar flow through a circular tube, constant heat flux, constant wall temperature conditions, concept of bulk temperature, Nusselt number for these cases. Turbulent flow through circular tubes, use of Reynolds analogy, empirical relations, Dittus-Boelter equation. Empirical relations for internal and external flows, Reynolds number, circular and non-circular geometries, hydraulic diameter. Natural convection on a vertical plate, energy integral approach to the problem, Grashof number. Use of empirical correlations for laminar and turbulent flows and for standard geometries to determine natural convection heat transfer. **Radiation** Laws of blackbody and gray body radiation; semi-transparent and opaque materials. Intensity, emissive power, emittance, absorptance, reflectance, transmittance; shape factor. Radiation exchange between blackbody and gray surfaces; radiation shields. **Heat Exchangers** Types of heat exchangers, overall heat transfer coefficients, influence of hi/o on U values. Log mean temperature method, extension to non-counter flow arrangement, correction factor charts. Effectiveness-NTU method. Application to sensible heat exchangers and condensers.	Lab, Mid-term Quiz/Project, Final Examination	**Illustrative Reading List:** Fundamentals of Heat and Mass Transfer by Incropera and DeWitt; Heat Transfer – a practical approach by Y.A. Cengel; Heat Transfer by J. P. Holman **Compulsory Reading:** Lecture Notes
EE3306/ ME3163	Introduction to Cyber Physical Systems	4	1	The course introduces recent technological developments enabling cyber-physical systems, which in turn define Industry 4.0. Topics are organized under Internet of Things, Data Analytics, Robotics and Automation, and Additive Manufacturing. The course provides a common technology foundation for students in the Industry 4.0 Specialisation programme. This course is a core course in the Industry 4.0 Specialisation.	At the end of the course the student will be able to: 1. Have a good understanding of the latest trends in Industry 4.0 topics and practices. 2. Identify industry use-case(s). 3. Develop the use case(s) for specific application(s).	Nil	Nil	Nil	The course will cover the following topics. Industry 4.0 (12 hrs): Cyber Physical Systems, Smart Manufacturing, Lights Out Industry, Digital Twin, Robotics and Automation: Robots for Smart automation, Collaborative Robotics, Sensors and Data. Internet of Things (6 hrs): Industrial Internet of Things, Data transmission, processing and storage, Cloud and Edge Analytics. Additive Manufacturing (6 hrs): 3D Printing technologies and process; Digital design, simulation and post-processing; Benefits of 3D printing in product design & development; Applications and case studies.	100% CA Essay, Indivdual, Group project, presentation	**Supplementary reading:** Industry 4.0, 1st Edition, Managing Digital Transformation Using Disruptive Technologies, Editors: Loveleen Gaur Arun Solanki Mike Hinchey, Paperback ISBN: 9780323884853
ME3211	Mechanics of Solids	4	1	The course 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 course and is intended for students in Stages 3 and 4 who have an interest in the stress analysis of isotropic and composite materials.	On successful completion of this part of the course, the student will be able to: 1. Understand the fundamentals and applications of linear elasticity: Equilibrium, Compatibility, Constitutive relations, Airy stress functions, boundary conditions, and Thermal Stresses. 2. Determine the deformations and stresses in thick-wallled cylindrical pressure vessels and rotating discs and shafts, and hence prescribe their performance limits. 3. Describe and apply the classical lamination theory of fiber-reinforced composite laminates.	ME2112	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 exercises, Final Examination	**Supplementary reading:** 1. A.C. Ugural and S.K. Fenster, "Advanced Strength and Applied Elasticity", Arnold (1987). 2. A.P. Boresi, R.J. Schmidt and O.M. Sidebottom, "Advanced Mechanics of Materials", J. Wiley (1993). 3. R.M. Jones, "Mechanics of Composite Materials", McGraw-Hill (1975). 4. R.R. Craig Jr., "Mechanics of Materials", John Wiley and Sons (2011)
ME3221	Sustainable Energy Conversion	4	2	This elective course 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 course 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.	On successful completion of this course, the student will be able to: 1. Explain how the efficiency of a power plant is improved through the use of regeneration and binary vapour systems; and compute the cycle efficiencies 2. Compute the reversible work, available energy changes and irreversibility of non-flow and flow processes. 3. Compute energy exchanges, temperature rises and apply the Second Law to combusting systems in the absence of and accounting for dissociation of the products of combustion. 4. Compute energy transformations and efficiencies in reciprocating and rotary compressors. 5. 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	1. 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 2. 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 3. 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 4. Reciprocating Compressors Machine cycle analysis, work and heat transfer; performance parameters of compressors: volumetric efficiency, isothermal efficiency, intercooling, intercooling pressure; reciprocating expanders. 4 hours 5. 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 6. Nozzles Isentropic flow in convergent and convergent-divergent nozzles; critical pressure ratio; effects of varying back pressure.3 hours 7. 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 8. Group project: A mini project on energy conversion equivalent 6 lecture-hours. 6 hours	Toturial/Seminar, Lab, Mid-Term Quiz/project, 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
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.	1. Able to represent number in various bases and explain the different type of common codes used in industries.2. Explain various error detection and correction techniques3. To solve problem using combinatorial logic and/or sequential logic.4. To explain the basic structure of a microprocessor.5. To do assemble programming for a microprocessor.	Nil	Nil	Nil	1. 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. 2. Digital Electronics Flip-flops, digital arithmetic circuits, counters and registers, encoders, decoders, multiplexers, demultiplexers, integrated-circuit logic families, memory devices. 9 3. Microcomputer ArchitectureCentral processing unit, arithmetic logic unit, registers, processor microarchitecture, instruction set architecture, PIC18 microcontroller. 4. Machine and Assembly LanguagesPIC18 instruction set, addressing modes, assembly language programming, subroutine, stack and stack pointer, interrupt facilities. 5. Microcontroller Interfaces and ApplicationsInterface chips, parallel I/O, timer related I/O, analogue/digital converter.	Tutorial assignment, Quiz, Project, Final Examination	**Compulsory reading:**RJ Tocci, "Digital systems: Principles and applications", 11th edition, 2014, 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.

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ME3242	Automation	4	1	In this course 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.	(1) Have a good appreciation of practical industrial pneumatic and electromechanical logic components. (2) Able to read and understand pneumatic circuits and electromechanical ladder diagrams. (3) Able to design and implement such circuits for any sequencing problem. (4) Explain major functions of a programmable logic controller (5) Able to program a PLC.	Nil	Nil	Nil	1. Review of Boolean Algebra: Theorem, Synthesis of Logic Functions and Karnaugh Maps. 2. Switching Elements: Pneumatic and Electromechanical Devices 3. Design of Sequential Control Systems: Sequence Chart Approach, Cascade Method 4. Purely Pneumatic Circuits: Cascade Method, Lucas Method, Miscellaneous topics 5. Systems with Random Inputs: Huffman Method, Sequential System with Random Inputs 6. Programmable Logic Controllers: Basic architecture of PLC, Programming PLC, differences from hardwired circuits	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.
EE3305 /ME3243	Robotics System Design (Robotics)	4	1	This course will introduce the mobile robot systems' architecture and key components such as various sensor and actuator technologies. Various locomotion mechanisms adopted by robotic systems will be discussed. The course will also introduce basic principles of robot motion control. Robot Operating System (ROS) will be utilized for simulation in virtual environments.	At the end of the course the student will be able to 1. Analyse motion of different locomotion mechanisms. 2. Understand key working principles of selected sensors and actuators used in robots; and select appropriate sensors and actuators for a robot system to achieve a given task. 3. Apply basic robot motion control principles. 4. Utilize ROS for mobile robot simulation in a virtual environment.	Nil	Nil	Nil	The course will cover the following topics. Introduction to Robotics (2 hr): Definitions and history of robotics, robot components, robot Applications. Robot Sensors and Actuators (6 hr): Various sensor principles and actuation technologies, degrees of freedom. Robot Locomotion (8 hr): Types of locomotion, Examples: legged, wheeled, flying, swimming. Mobile robot kinematics. Robot Motion Control (8 hr): Types of controls (proportional, integral and derivative), localization, path planning and navigation. Robot Operating System (8 hr): Simulation of mobile robot(s) in a virtual environment.	100%CA-Lab/Tests/ProjectS	**Compulsory reading: NIL** **Supplementary reading:** 1. Matarić, Maja J. The robotics primer. Mit Press, 2007. 2. Siegwart, Roland, Illah R. Nourbakhsh, and Davide Scaramuzza. "Autonomous mobile robots." Massachusetts Institute of Technology (2004). 3. Joseph, L. (2018). "Robot Operating System (ROS) for Absolute Beginners: Robotics Programming Made Easy", Apress Berkely, CA, USA.
ME3252 (Combined of ME2151 & ME3151)	Materials Engineering Principles for Engineers	4	1	This course equips students with basic knowledge and unique properties of materials useful in engineering design selection. Commonly used materials in different engineering designs and emerging materials and processes, and life cycle assessment will be taught. Introductory concepts on surface engineering, strengthening and hardening techniques, hardenability, heat treatment, friction and wear properties will be provided. Key material properties and testing such as tensile testing, compression testing, torsion test, 3-point bending test will be introduced along with their specific relevance. Finally, students will be introduced to the different ways of degradation of materials when it reacts with environment.	- Describe the mechanical properties of metals and its alloys, polymers, ceramics, and composites - Correlate the microstructures of materials to their mechanical properties - Explain the mechanics of failure in materials - Apply the knowledge of phase equilibria and transformations to predict microstructures and properties	Nil	Nil	ME2151 & ME3251	- Classification of engineering materials and their applications - Processing-structure-property relationship - materials failure such as fracture, creep, wear, corrosion - phase equilibria and transformations	Mid-term test Project-based case study	**Compulsory reading:** - Donald R Askeland and Wendelin J Wright, The Science and Engineering of Materials, SI Edition, 7th Edition, Cengage Learning, 2016 - K.G. Budinski and M.K. Budinski, Engineering Materials: Properties and Selection (6th edition), Prentice Hall, Upper Saddle River, 1999 **Supplementary reading:** - William D Callister Jr. and David G. Rethwisch, Materials Science and Engineering, 9th Edition, SI Version, John Wiley and Sons, 2013 - James F. Shackelford, Introduction to Materials Science for Engineers, 7th Edition, Pearson Prentice Hall, 2009 - William F. Smith and Javad Hashemi, Foundations of Materials Science and Engineering, 5th Edition in SI Units, Mc-Graw Hill, 2011 - J.A. Charles, F.A.A. Crane and J.A.G. Furness, Selection and Use of Engineering Materials (3rd edition), Butterworth-Heinemann, Oxford, 1997 - Michael F. Ashby, Materials and the environment: eco-informed material choice, 2nd ed. 2013 Elsevier Inc., ISBN 978-0-12-385971-6 - 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 part 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 course is targeted at students specializing in manufacturing engineering.	1. Students learn the basics of the mathematical models that form the tools for curve and surface construction in CAD packages. 2. 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. 3. 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. 4. 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. 5. An independent study project is assigned to each student and reports are graded. Students are required to work independently on their projects. 6. 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	**CAD: Geometric Modeling**, Curve segment models, Composite curve construction, Surface patch models, Composite surface construction, Solid model data structure and techniques. 19.5 hours **CAM: Fabrication of Part by CNC Machining based on Geometric Model: Basics of CNC Turning and Milling**, Tool path generation in CAD/CAM. 10 hours **CAM: Verification of Fabricated Part by CNC Measurement based on Geometric Model**: Geometric Dimensioning and Tolerancing, Basics of Computer-automated Measurement. 9.5 hours	CA components: CAD/CAM independent study project involving CAD, CNC machining and computer-aided measurement. Final Examination	**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.

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME3263	Design for Manufacturing and Assembly	4	1	This course 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 course is targeted at students majoring in manufacturing.This is an elective for Mechanical Engineering students specializing in Precision Engineering	1. Understand and apply the principles of design for material forming processes2. Understand and apply the principles of basic machining practice and principles of design for machining3. Apply the knowledge in selecting material forming and additive manufacturing processes for specific jobs. 4. Understand the principles of assembly planning, and the ability to identify the assembly design bottlenecks.5. Able to apply design for assembly techniques to determine the average assembly time and cost6. Understanding the principles of rapid prototyping, rapid tooling and able to apply rapid prototyping and tooling in design7. Understand how rapid prototyping has evolved into a direct manufacturing process and system selection can influence final part quality	Nil	ME3162	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
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 course 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.	On successful completion of this course, the student will be able to: 1. Understand the advantages of microsystems and their application areas. 2. Understand the fundamentals of microelectromechanical systems (MEMS) based actuators for translational and rotational motions. 3. Understand the basics of optical microsystems including micro-mirrors, micro-mirror arrays, and micro-gratings. 4. Understand the basics of microsystems-based sensors, including micro-accelerometers, micro-gyroscopes, and pressure sensors. 5. Understand the basics of microfluidic devices, including micro-pumps, micro-channels, micro-valves, and micro-flow sensors.	Nil	Nil	Nil	1. Introduction (3hrs) Overview of Microsystems Technology and Applications; Scaling law and performance; Markets for MEMS devices; Information resources 2. Microfabrication fundamentals (5hrs) Photolithography; Thin film deposition and etching; Surface-micromachining; Bulk-micromachining; SOI processes; Bonding 3. Materials for microsystems (2hrs) 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 4. Beams and diaphragms for microsystems (2hrs) Introduction to static behavior of elementary beams and membranes 5. Microactuators (6hrs) 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 6. Microsensors (6hrs) Piezoresistive sensing and signal processing; Capacitive sensing and signal processing; Force feedback; Micromachined microaccelerometers; MEMS gyroscopes; MEMS pressure sensors 7. Optical MEMS (6hrs) 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 8. Microfluidics and Bio-MEMS (6hrs) 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 assignments, Final Examination	**Compulsory reading:** 1. 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) 2. K. E. Petersen, "Silicon as a mechanical material", Proc. IEEE, vol.70, no.5, p.420, 1982. **Supplementary reading:** 3. Fundamentals of Microfabrication, by Madou, CRC Press, 1997. 4. Micromachined Transducers Sourcebook, by Kovacs, McGraw-Hill, 1998. 5. 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 a wide variety of engineering problems. The topics covered include numerical solution of linear systems of algebraic equations, numerical solution of nonlinear algebraic equations and systems of equations, elementary unconstrained optimization techniques, regression and interpolation techniques, numerical differentiation and integration, as well as the numerical solution of Ordinary Differential Equations (ODE). Applications are drawn from a broad spectrum of diverse disciplines in Mechanical Engineering. The course will also introduce the use of scientific computing software packages for the numerical solution of practical engineering problems.	On successful completion of this course, the student will be able to: 1. numerically solve linear systems of algebraic equations using techniques such as Gaussian Elimination and LU Decomposition. 2. numerically solve nonlinear algebraic equations using iterative techniques such as the Bisection Method, the Method of False-Position, Simple Fixed-Point Iteration Method, the Newton-Raphson Method, and the Secant Method. 3. apply elementary unconstrained optimization techniques such as the method of line searches, Newton's Method, and Gradient Methods. 4. perform regression and interpolation of numerical data using techniques such as Linear and Polynomial Regression, Lagrange Interpolating Polynomials, Inverse Interpolation, and Spline Interpolation. 5. perform numerical integration using techniques such as the Trapezoidal Rule, Simpson's Rule, and Gauss Quadrature. 6. numerically solve Ordinary Differential Equations (ODE) using techniques such as the Runge-Kutta Method (RK23, RK45).	MA1505 or MA1512 & MA1513	Nil	Nil	Introduction Round-off error and computer arithmetic Machine accuracy LU Decomposition and Matrix Inversion Gaussian Elimination and LU Decomposition, pivoting and Matrix Inverse Roots of Equations (Bracketing Methods) Bisection Method, Methods of False-Position, Simple Fixed-Point Iteration The Newton-Raphson Method, The Secant Method, Systems of Nonlinear Equations Unconstrained Optimization Methods of line searches, Newton's Method Gradient Methods Least-Squares Regression & Interpolation Linear and Polynomial Regression Lagrange Interpolating Polynomials, Inverse Interpolation, Spline Interpolation Numerical Differentiation and Integration The Trapezoidal Rule, Simpson's Rules, Gauss Quadrature, Runge-Kutta Methods (RK23, RK45)	Homework assignments, Final Examination	**Compulsory reading:** Numerical Methods for Engineers, 3rd., SC Chapra & RP Canale, McGraw-Hill, 1998 **Supplementary reading:** Numerical solution of partial differential equations: finite difference, Oxford University Press, G.D. Smith. Numerical Methods for Scientific and 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

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ME4105	Specialisation Study Course (Offshore Oil & Gas Technology)	4	1	This course 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 course comprises structured programme of lectures, seminars, term papers and mini-projects.	Upon completing the course, student will have an overview and understanding of the following: 1. how oil & gas exist in a reservoir 2. the process of oil & gas exploration, i.e. seismic exploration, etc 3. 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. 4. the various phases of oil & gas production, Improved Oil Recovery (IOR), Enhanced Oil Recovery (EOR) and production equipment used 5. the various fixed platforms, floating production platforms, Floating Production Storage & Offloading (FPSO), etc. used in offshore production 6. the oil, water & gas processing technologies used during oil & gas production 7. the processes involved in Subsea Processing 8. Use and design of process equipment, e.g. pumps, separators, compressors, etc. for oil and gas production	Nil	Nil	Nil	1. Introduction to Oil & Gas Technology 2. Basic Petroleum Geology – a. Organic theory & Inorganic theory b. Oil & Gas Reservoirs 3. Exploration – a. Geographical surveys b. Seismic surveys 4. Drilling Technology – a. Cable tool drilling b. Rotary drilling – procedures and equipments involved c. Types of drill bits d. Drilling mud e. Casing f. Offshore drilling – procedures and equipment involved g. Offshore drill rigs h. Directional drilling & equipment i. Horizontal drilling j. Underbalanced Drilling 5. Well Completion – a. Casing b. Cementing c. Well completion methods d. Offshore completion e. Well testing f. Well stimulation techniques 6. Production – a. Natural drive mechanism b. Artificial Lift Methods c. Improved Oil Recovery – i. Secondary recovery ii. Tertiary recovery iii. Enhanced oil recovery (EOR) 7. Floating Production System - FPS and FPSO 8. Surface/Topside Processing of Well Fluids 9. Subsea Processing	100% CA	Course notes handed out by course lecturers.
ME4212	Aircraft Structures	4	2	This course covers torsion of open and closed non-circular thin-walled sections; bending of unsymmetric thin-walled beams; idealized beams; multi-cell torque boxes and beams; tapered beams; introduction to mechanics of fiber-reinforced composites; classical lamination theory; failure theories for composites. This is an elective course and is intended for students who are interested in the design and analysis of thin-walled structures, especially aircraft structures.	On successful completion of this part of the course, the student will be able to: 1. Correctly apply the formulae for bending of thin-walled beams of unsymmetric sections, and determine the bending stresses and resultant shear flow. 2. Describe and explain the difference in shear stress distribution for torsion of open and closed thin-walled members. 3. Apply the approximation of idealized beams with stringers and sheets to beams of various cross-sectional and multi-cell configurations. 4. Analyze stresses in circular and rectangular plates subjected to transverse loadings. 5. Apply the energy method to buckling and understand the limitations of the energy method	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. (19.5hrs) **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 buckling of columns and plates (19.5hrs)	Quiz, Homework assginments, Final Examination	**Compulsory reading:** 1. S.P. Timoshenko and S. Woinowsky-1. Krieger, "Theory of Plates and Shells", McGraw-Hill, 2nd Ed. (1984). 2. T.H.G. Megson, "Aircraft Structures for Engineering Students", Butterworth-Heinemann, 5th Ed. (2013). **Supplementary reading:** 3. S.P. Timoshenko and J.M. Gere, "Theory of Elastic Stability", McGraw-Hill, 2ed. (1985). 4. M.H. Jawad, "Theory & Design of Plates & Shell Structures". Chapman & Hall (1994). 5. C.R. Calladine, "Theory of Shell Structures". Cambridge University Press (1983). 6. A.P. Boresi, R.J. Schmidt and O.M. Sidebottom, "Advanced Mechanics of Materials", J. Wiley (1993). 7. T.H.G. Megson, "An Introduction to Aircraft Structural Analysis", Butterworth-Heinemann, (2010). 8. C.T. Sun, "Mechanics of Aircraft Structures", John Wiley & Sons, 2nd Ed. (2006). 9. J. Cutler, "Understanding Aircraft Structures", Blackwell, 4th Ed. (2005).
ME4223	Thermal Environmental Engineering	4	1	This course 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 course 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.	On successful completion of this course, the student will be able to:1. Apply heat transfer principles in estimating the thermal loads of building and other spaces.2. Apply principles of thermodynamics, heat transfer and fluid mechanics in designing and simulating air-conditioning systems. 3. Estimate the energy requirements of buildings and other spaces.4. Analyze the energy performance of buildings and other spaces.5. Improve the energy performance of buildings and other spaces6. Evaluate feasibility of alternative energy sources for buildings and other spaces	ME2121	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 Quiz/Project, 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: 2D steady state heat conduction; transient heat conduction; turbulent heat transfer, boiling; condensation; heat exchangers with phase change; mass transfer	On successful completion of this course, the student will be able to: 1. Analyse problems involving 2D steady state and transient heat conduction. 2. Understand the analogy between heat and mass transfer and calculate mass transfer rates. 3. Analyse heat transfer problems involving change of phase. 4. Analyse problems involving turbulent heat transfer.	ME3122	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, evaporative cooling.	Quiz, Assignment, Final Examination	**Compulsory reading:** Lecture notes. **Supplementary reading:** 1. A.F. Mills, "Heat Transfer", Prentice Hall, New Jersey 1999. 2. F.P. Incropera, D.P. Dewitt, T.L. Bergman and A.S. Lavine, "Fundamentals of Heat and mass transfer", 6 Ed, John Willey, 2007.

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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 course 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	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 analyses of biomass cogeneration system.	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 course 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.	1. The students will acquire a sound knowledge of the working principles of all kinds of internal combustion engines 2. They will know the structure of IC engines 3. They will understand the design of IC engines 4. 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 5. They will learn to test and analyze the emissions of IC engine and the methods to improve it 6. They will learn the analytical methods to estimate the performance of IC engines, and understanding the methods to optimize it.	Nil	Nil	Nil	1. The structure, major components and working principle of internal combustion (IC) engine. 2. Internal combustion engine performance parameters and characteristics 3. Ideal Air-standard cycles and their analysis 4. Fuel-air cycles and actual cycles 5. Fuel supply system and their effect on the performance of IC engines 6. Ignition system and ignition timing 7. Combustion process and combustion chambers design 8. Energy losses and cooling system 9. Engine emissions and their control 10. Two stroke engines 11. Biofuels and applications in IC engine	Test, Others(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.

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME4231	Aerodynamics	4	2	This course introduces to students the basic concepts/ theories/ applications in aerodynamics. 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. The course 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.	On successful completion of this course, the student will be able to: 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.	ME2134	Nil	Nil	0	Quiz, Final Examination	**Compulsory reading:** Course notes handed out by course lecturers. **Supplementary reading:** General References 1. Anderson, Jr., J.D. "Fundamentals of Aerodynamics", McGraw Hill International Editions, 1985. 2. Anderson, Jr., J.D. "Introduction to Flight", McGraw Hill International Editions, 3rd edition, 1989. 3. Bertin, J.J. and Smith, M.L., "Aerodynamics for Engineers", Prentice-Hall International Editions, 3rd edition, 1998. 4. Kermode, A.C. "Mechanics of Flight", Longman Scientific and Technical, 10th edition, 1996. 5. Keuthe, A.M. and Chow, C.Y., "Foundations of Aerodynamics, Bases of Aerodynamic Design", John Wiley and Sons, 4th edition, 1986. 6. Shevell, R.S., "Fundamentals of Flight", Prentice Hall Internationl Editions, 2nd edition, 1989. 7. Philip G. Hill & Carl R. Peterson "Mechanics and Thermodynamics of Propulsion" Addison Wesley, 2nd Edition. Additional References 1. Ashley, H. and Landahl, M., "Aerodynamics of Wings and Bodies, Chapter 5 and 7", Addison Wesley. 2. Duncan, W. J., Thom, A. S. and Young, A. D., "Mechanics of fluids, Chapter 2, 3 and 11", Edward Arnold. 3. Houghton, E.L. and Boswell, R.P., "Further Aerodynamics for Engineering Students, Chapter 8", Edward Arnold. 4. Moran, J., "An Introduction to Theoretical and Computational Aerodynamics", John Wiley and Sons, 1984. 5. Panton, R.L., "Incompressible flow", Wiley. 6. Tritton, D. J., "Physical fluid dynamics, Chapter 12", Van Nostrand Reinhold. 7. Ian G. Currie, "Fundamental Mechanics of Fluids", McGraw-Hill International. 8. Roger D. Schaufele, "The Elements of Aircraft Preliminary Design", Aries Publications, 2000. 9. Gordon Oates, "Aero-thermodynamics of Gas Turbine and Rocket Propulsion", American Institute of Aeronautics and Astronautics, 1985.
ME4232	Small Aircraft and Unmanned Aerial Vehicles	4	2	This course introduces the concepts of small aircraft, unmanned aerial vehicles, related systems (UAS) and their applications. Students will learn to apply basic concepts from aerodynamics, aircraft design, structures, propulsion, guidance, control, navigation, sensors, communications, vision technology, mission planning, multi-agent operations, UAS application, anti-drone technology, the latest R&D in UAS with integration of artificial intelligence and related systems to UAS. There will be a problem-based design project for this course. There will be involvement and collaboration with the industry. There will be a combination of lectures, tutorials, case studies, seminars and project activities.	The learning objectives of this course are as follows:• To understand and apply fundamental engineering concepts related to UAS design and operation;• To design the UAS platform suited for the mission and job requirements;• To understand the working principles, scopes and limitations of sensors and communications sufficiently to choose the right equipment sets for missions;• To understand and use the current technology in guidance and navigation applicable to UAS;• To understand and perform trajectory, mission and path planning, including multi-agent operations;• To understand and apply the latest drone technology including AI-related technology to UAS and anti-drone technology;• To design the holistic UAS system for specific applications in both aerospace and non-related industries;• To gain awareness of the current law and regulations applicable to UAS in Singapore in order to practice safe flight operations• To prepare students for pursuing further graduate studies or advanced R&D in UAS.	Nil	Nil	Nil	1- Conceptual small aircraft and UAS design (fixed-wing, rotary-wing, flapping wing, unconventional). (3 hr)'- Unsteady aerodynamics and flapping wing micro aerial vehicle. (3 hr)'- Aircraft performance & Propulsion system of small aircraft and UAS. (3 hr).'- Guidance, navigation and control for UAS. (3 hr)- Sensors & communication system for UAS. (4 hr)- Visual & inertial odometry, vision-based navigation, computer vision and perception for UAS. (4 hr)- Trajectory planning & obstacle avoidance. (4 hr)- Multi-UAV and swarm operations. (4 hr)- Integration of artificial intelligence (AI) to UAS. (4 hr)- Detection and Anti-drone technology. (4 hr)- Applications & current R&D in UAS. (2 hr) - Law & regulations related to UAS in Singapore. (1 hr)Total number of contact hours = 39 hrs.	CA, Final Examination	**Supplementary reading:**1. Small Unmanned Aircraft: Theory & Practice, Randal W.Beard & Timothy W. McLain2. Unmanned Aircraft System, Reg Autin3. Autonomous Flying Robots: Kenzo Nonami et al4. Aerodynamics of Low Reynolds Number Flyers: Wei Shyy et al
ME4233	Computational Methods in Fluid Mechanics	4	1	This course 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.	On successful completion of this part of the course, the student will be able to: 1. Understand the fundamental issues of finite difference discretization. 2. Generate finite difference schemes and apply them to reduce a partial differential equation to a coupled set of ordinary differential equations or algebraic equations. 3. Do stability and accuracy analysis by the matrix method. 4. Do stability analysis by Von Neumann method. 5. Solve Poisson and elliptic-type equations arising from incompressible fluid flows. 6. Formulate and discretize equations of incompressible viscous fluid flow (differential and finite-volume form). 7. Gain basic skills / experience for solving incompressible fluid flow through implementing a typical methodology in a 2D problem.	ME2134	Nil	Nil	1. 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. (19.5 hrs) 2. 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 o Streamfunction-vorticity formulation o Projection methods o Finite-volume methods: SIMPLE/R/C including implementation of boundary conditions. (19.5hrs)	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.

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME4241	Aircraft Performance, Stability and Control	4	1	Aircraft range, endurance, level and gliding flight, climb, takeoff and landing, static longitudinal and lateral stability, dynamic stability and control, flying qualities	1. Appreciate the interplay of aerodynamics, propulsion, structures and control on flight performance, stability and control. 2.Know the standard atmospheric models and the effect of atmospheric conditions on flight performance, stability and control. 3. Ability to estimate aircraft performance metrics for a given aerodynamic configuration. 4. Ability to assess flight stability and flying qualities via the use of stability derivatives. 5. Apply and interpret industrial specifications e.g. Federal Air Regulations and MIL specifications for conventional commercial and military aircrafts. 6. Understand the performance, stability and control characteristics for experimental and research flight vehicles.	Nil	Nil	Nil	**Aircraft Performance (18 hrs)** 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 (18 hrs)** 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	Toturial/Seminar, Lab, 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
ME4242	Nanomaterials for Energy Engineering	4	2	Soft Robotics introduces the usage of soft materials to construct and design integral parts of a robot like soft actuators and soft sensors. This course will introduce different types and genre of soft robots, mechanics of soft robots and the design, kinematics of control and applications of soft robots. The objective of this course is to introduce students to a new field of robotics that are made up of, in-part or as a whole, with soft materials and systems.	1. Define soft robots and the different classifications of soft robots 2. Describe the different kinds of soft materials used for robotic mechanisms and components. 3. Model the physical (e.g, electrical and mechanical) behaviour of such materials in response to different energy sources. 4. Explain how soft materials can be used as sensors 5. Explain how soft materials can be used as actuators 6. Design and realize active robotic components (e.g, sensors and actuators) based on soft materials. 7. Develop a mathematical model that describes the kinematic response of robotics mechanisms with soft materials 8. Develop a mathematical model that describes the kinematic response of robotics mechanisms with soft materials. 9. Build a soft robot system that is capable of fast locomotion and overcoming obstacle	Nil	Nil	Nil	1. Introduction to Soft Robotics and recent developments. Define soft robotics and the different types of soft robots developed in the recent years. 2. Biomimetics Introduce bio-inspired concept and designs of soft robots, including muscular hydrostat, growing/evolving structures etc 3. Soft Fluidic Robot Systems Introduce the concept of fluid-based inflation and associated material designs and electronics setup for fluidic control. 4. Electrical Driven Dielectric Elastomer. 5. Polymers Describe new types of magnetic/thermos/electrosensitive actuation materials, such as soft resins,shape memory alloys; polymers and resins 6. Mathematical Modeling Describe basic models for relating the pressure kinematics relationship of soft actuators. 7.Manufacturing methods Describe silicone mold-casting, direct 3D-printing, fabric welding methods, including their advantages and disadvantages. 8. Control of soft robots Explain fluidic PID control in detail 9. Example applications Introduce soft wearable robots, manipulation robots and locomotion robots	CA & Final Exam	**Supplementary reading:** Liyu Wang, Surya G. Nurzaman, and Fumiya Iida. 2017. Soft-Material Robotics. Now Publishers Inc., Hanover, MA, USA. Alexander Verl, Alin Albu-Schäffer, Oliver Brock, Annika Raatz, 2016, Soft Robotics: Transferring Theory to Applications, Springer, Berlin, Germany.
ME4245	Robot Mechanics and Control	4	1	The course 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 course is targeted at upper level undergraduates who have completed fundamental mathematics, mechanics, and control courses. 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	1. Able to mathematically describe the position and orientation of a rigid object. 2. Given the mathematical model of the kinematics and dynamics of a robot, be able to physically visualize the robot's motion capabilities 3. Able to develop the kinematic models of the robotic manipulators 4. Able to derive the dynamic models of the robotic manipulators using Lagrangian and/or Newton-Euler formulations 5. Able to implement joint-based motion planning for robotic manipulators 6. Able to synthesize control algorithms for motion control of robotic manipulators	ME2142 for ME students. EE2010 for ECE students	ME2142	Nil	1. Introduction, Spatial Descriptions and Transformations 5 Robot definition. Robot classification. Robotics system components. Notations. Position definitions. Coordinate frames. Different orientation descriptions. Free vectors. Translations rotations and relative motion. Homogeneous transformations. 2. Manipulator Forward and Inverse Kinematics 6 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. 3. Mechanics of Robot Motion 6 Translational and rotational velocities. Velocity Transformations. The Manipulator Jacobian. Forward and inverse kinematics of velocity. Singularities of robot motion. 4. Static Forces and Compliance 3 Transformations of static forces and moments. Joint and End-Effector force/torque transformations. 5. Robot Dynamics and Trajectory Planning 10 Lagrangian formulation. Model properties. Newton-Euler equations of motion. Joint-based motion planning. 6. Robot Control 9 Independent joint control. Feedforward control. Inverse dynamics control. Robot controller architectures. Implementation problems.	Quiz, Project, Final Examination(open book)	**Compulsory reading:** 1. Sciavicco L. and Siciliano B., Modeling and Control of Robot Manipulators. Second Edition (ISBN 1-85233-221-2), Springer Verlag, London, 2000 **Supplementary reading:** 2. Fu K.S.,, Gonzalez R.C., and Lee C.S.G. Robotics: Control, Sensing, Vision and Intelligence. McGraw-Hill, NY, 1987. (Recommended for purchase) 3. Sciavicco L. and Siciliano B., Modeling and Control of Robot Manipulators. McGraw Hill, 1996. 4. Craig, J.J., Introduction to Robotics, Mechanics, and Control. 2nd Edition. Addison Wesley, MA, 1989. (3rd Edition, if available) 5. Spong, M.W. and Vidyasagar, M., Robot Dynamics and Control, Wiley, New York, 1989. 6. Paul, Richard P., Robot Manipulators : Mathematics, Programming, and Control : the Computer Control of Robot Manipulators, MIT Press, Cambridge, Mass., 1981. 7. Lewis F.L., Abdallah C.T., and Dawson D.M., Control of Robot Manipulators, Maxwell Macmillan International, 1993.
ME4248	Manufacturing Simulation and Data Communication	4	1	This course covers fundamental concepts and techniques related to the simulation of (discrete) manufacturing systems and data transfer between machines and devices in such systems. Topics covered in the course include concepts of discrete-event modelling and simulation, elements in modelling, design and implementation of manufacturing simulation models, petri-nets, input information collection and analysis, interpretation of outputs, data communication standards, communication topology, medium access control, and real-time data communication protocols.	Upon successful completion of this model, students will (1) be able to set up and conduct simulation of small-scale manufacturing systems in order to analyze their performance, and (2) have a good understanding of the basic principles underlying various protocols of data communication in a manufacturing setting.	Nil	Nil	Nil	Introduction. Examples of simulation. Event-scheduling/Time-advance algorithm. Statistical models. Selection of distribution. Random numbers. Random-variate generation. Queueing models. Petri-net models. Output analysis. ISO/OSI model. Medium access protocols. Medium access protocols. Token-bus. CAN bus.**Part 1:Introduction:** Examples of simulation; components of a simulation; manual method with simulation table**Event-scheduling/Time-advance algorithm:** Event notices, activities, imminent events, future event list; effect of event on state; bootstrapping**Statistical models:** Typical distributions, i.e., uniform, normal, exponential, empirical, distributions; Poisson distribution and Poisson processesSelection of distribution: Histogram; parameter estimation; quantile-to-quantile plots**Random numbers:** Definition and characteristics of random numbers; linear congruential method; computational issues**Random-variate generation:** Inverse transform method; acceptance-rejection method**Queueing models:** Characteristics of queueing system; performance measures; Conservation equation; steady-state behaviour; performance of M/M/1 systems**Petri-net models:** Elements and structure of Petri nets; enablement and execution of transitions**Output analysis:** Point estimate and standard error; confidence interval and t-distributionPart 2:**ISO/OSI model:** Scale and transmission technology; network topology; 7-layer structure of data communication**Medium access protocols**: Pure and slotted ALOHA; persistent, non-persistent and p-persistent CSMA; MACA; bit-map; binary countdown; token ring**Token-bus:** Logical ring; token passing and timing; logical ring management; modified binary countdown algorithm; error recovery mechanism**CAN bus:** Message format; broadcast and request-and-reply operation; CSMA+AMP arbitration; exception handling; timing considerations	CA & Final Exam	**Compulsory reading:** Teaching material provided by lecturer**Supplementary reading:**Discrete-Event System Simulation, J. Banks, J. Carson, B. Nelson, and D. Nicol, Prentice-Hall, 2001.Computer Networks, A. Tanenbaum, 3ed., Prentice-Hall, 1996.

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME4252	Nanomaterials for Energy Engineering	4	1	This course starts with a brief introduction on semiconductors, ionic conductors and mixed conductors. Various transport measurements, with an emphasis on impedance studies, will be introduced. After a brief discussion of methods for the synthesis and characterization of nanomaterials, the importance of nanomaterials in the context of thermodynamics, electrical conduction and thermal conduction will be highlighed. Various energy systems (solar cells, fuel cells, thermoelectrics, batteries, and supercapacitors) using nanomaterials focusing on energy conversion and storage will be covered. Course will end with remarks on the engineering aspects such as safety issues and development of miniaturised energy devices using nanomaterials.		Nil	Nil	Nil	1. Introduction to semiconductors, ionic conductors and mixed conductors. 2. Synthesis and characterisation of single crystals, polycrystalline materials and nanomaterials. 3. Transport measurements: DC method and AC method – specific focus on impedance studies. 4. Physical and chemical aspects of nanomaterials 1.1 Thermodynamics 1.2 Electrical conductivity 1.2.1 Nano-ceramics 1.3 Thermal properties 1.3.1 Thermal conductivity 5. Energy conversion and storage using nanostructured materials a. Solar energy conversion: Dye-sensitized solar cells, perovskite solar cells and quantum-dot solar cells. b. Rechargeable batteries and supercapacitors c. Fuel cells d. Thermoelectrics 6. Engineering aspects of nanomaterials a. Designing miniaturised devices: fuel cells and batteries b. Associated safety issues	CA & Final Exam	**Compulsory reading:** Downloadable lecture notes **Supplementary reading:** 1. J. Maier, *Physical Chemistry of Ionic Materials: Ions and Electrons in Solids*, John Wiley & Sons (2004) 2. H. Rickert, *Electrochemistry of Solids: An Introduction*, Springer (1982) 3. Ryan P. O'hayre, F.B. Prinz and S-W. Cha, *Fuel cell Fundamentals*, John Wiley & Sons (2005) 4. Z. L. Wang, *Handbook of Nanophase and Nanostructured Materials*, Springer (2003) *5. Nanomaterials for Next-Generation Energy Sources,* Technology Tracking Report, IOP Publishing Ltd, (2005). 5. Related published articles.
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 introduces students to life science topics. Students gain an appreciation of multidisciplinary approach to problem solving. Topics include metals, polymers, ceramics and composites use as implants, host-tissue response, materials selection, relationship between structure-composition-manufacturing process, evaluation of implants, sterilization and packaging, regulatory approvals, and suitable case studies. Video presentations and lectures complement the breadth covered in this course. Students enjoy project-based case studies which provoke curiosity, peer evaluation and group dynamics.	On successful completion of this course, the student will be able to: 1. Know the different classes of biomaterials 2. Understand regulatory processes for medical implants 3. Understand biocompatibility, wear, stress shielding and corrosion issues in implants 4. Apply materials selection principles in development of medical devices 5. Understand the need to integrate different disciplines to solve biomaterials problems 6. Develop the techniques of good writing and communication skills	Nil	Nil	Nil	1. Introduction: Requirements of biomaterials, Classification of biomaterials, Mechanical properties of biomaterials, Effects of processing on properties of biomaterials 2. Biological Materials: Structure of proteins, collagen, elastic proteins, polysaccharides, chitin and chitosan, structure properties relationships 3. 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 4. 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 5. 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). 6. 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. 7. 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).	100% CA Term Project Take-Home Assignment	**Compulsory reading:** 1. BD Ratner, AS Hoffman, FJ Schoenm JE Lemons (Eds.), Biomaterials Science: An Introduction to Materials in Medicine, Academic Press, 2nd Edition, 2004 2. JB Park, RS Lakes (Eds.), Biomaterials - An Introduction, Plenum Press, 1992 **Supplementary reading:** 3. JS Temenoff, AG Mikos (Eds.), Biomaterials: The Intersection of Biology and Materials Science, Pearson, 2008 4. LL Hench, J Wilson (Eds.), An Introduction to Bioceramics, World Scientific, 1993 5. D Hill (Ed.), Design Engineering of Biomaterials for Medical Devices, John Wiley & Sons, 1998 6. M Jenkins (Ed.), Biomedical Polymers, Woodhead Publishing, 2007 7. R Seeram et al. (Eds.), Biomaterials: A Nano Approach, CRC Press, 2010
ME4255	Materials Failure	4	2	This course addresses the failure of engineering systems governed by the end service conditions. Commonly encountered service conditions are introduced in this course, including their impact on the service life of the individual components as well as the assembly of components. This course 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.	On successful completion of this course, the student will be able to: 1. Analyze various mechanical and environmental related failure mode of engineering materials 2. Explain the basics of the theories behind each failure mode (ductile and brittle fracture, fatigue, impact, wear, corrosion, creep) and their mechanisms 3. Use mathematical tools to predict life of a component subjected to fatigue or creep modes of failure 4. Outline failure prevention methods for engineering materials subjected to different service conditions (static and cyclic stress, environment, friction/wear, high temperature etc.) 5. Conduct failure analysis through fractography and materials property tests 6. 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	Cohort AY18/19 & before = ME2151	Nil	Nil	1. Introduction to Materials Failure: Introduction, Examples of engineering disasters, Failure investigation procedure, Modes of failure, Case study. 2. 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. 3. 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. 4. 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. 5. 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. 6. 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. 7. 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. 8. 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.	Quiz, 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, 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 course provides the fundamental understanding of metal machining and tool design.	On successful completion of this course, the student will be able to: – 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	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:** 1. E.G Hoffman, "Jig and fixture design", Delmar Publishers, 1996 2. C. Donaldson, C.H. LeCain and V.C. Gould, "Tool Design", Tata McGraaw Hill, 1994. 3. G. Boothroyd and W.A. Knight, Fundamentals of Machining and Machine Tools, Second Edition, MARCEL DEKKER, INC. 1989. **Supplementary reading:** 4. Boyes WE (ed)., "Handbook of jigs and fixture design", Society of Manufacturing Engineers, 1989 5. S.C. Salmon, Modern Grinding Process Technology, McGraw-Hill, Inc., 1992 6. T.H.C. Childs, K. Maekawa, T. Obikawa and Y. Yamane, Metal Machining, Arnold, 2000.

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME4262	Automation in Manufacturing	4	2	This course 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.	1. Able to analyze and evaluate the investment alternatives and production cost breakeven. 2. Apply the knowledge in the design and selection of various components needed in automated materials handling, storage/retrieval and layout. 3. Understand the principles of GT, decision making in process planning, RP and how it is applied to process automation. 4. Evaluate the performance measures (average production rate, yield of good assembly, etc) of both multi-station and single-station assembly machines.	Nil	ME3162	Nil	1. Economic justification of automated systems; 2. Fixed and transfer automation; 3. Automated material handling 4. Automated storage/retrieval systems, 5. Flexible manufacturing systems, 6. Internet-enabled manufacturing, 7. Automated assembly, 8. Group technology, 9. CA Process planning, 10. 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 Internation Ed., 1991. Web e-learning
ME4263	Fundamentals of Product Development	4	3	This is an intensive full-time two-week course 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.	On successful completion of this course, the student will be able to:1.Students will be able to work on a group project on product development by attending interactive classroom sessions. 2. Students will be able to carry out the group project with a final presentation.	Nil	Nil	Nil	Introduction & Global Design PerspectivesOverview of techniques and tools to facilitate and shorten product design and development; emerging trendsIdentifying Customer NeedsScoping; data gathering and interpretation; prioritizing needs; specificationConceptual DesignConcept generation and selectionIndustrial DesignVisualization and communication methods; form design basics; aesthetics; usabilityDesign for Reliability and Product TestingRobust design; related US and Singapore standardPrototyping and Design for ManufacturingTypes and uses of prototypes; rapid prototyping technologies; understanding impact of design on manufacturing; basic manufacturability evaluation;Product Design EconomicsProduct economics; net present value base case; sensitivity and trade-off analysis for development decisions; consideration of other quality factors	100% CA - fieldwork, projects	**Supplementary reading:**"Product Design and Development" by Karl T. Ulrich and Steven D. Eppinger
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 course 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** **On successful completion of this part of the course, the student will be able to:** 1. Understand how energy principles are used to formulate the finite element method for solids and structures. 2. Apply the FEM procedure to formulate truss element, beam element, frame element, 2D and 3D solid elements. 3. Use of special elements for fracture problems and problems of infinite domain. **Modeling techniques** **On successful completion of this part of the course, the student will be able to:** 1. Create a FEM model for a given solid and structure, including geometry modeling, meshing, applying boundary conditions, and job execution. 2. Understand the precautions in the actual practice of FE analysis such as mesh design, modeling and verification of solutions. **Heat Transfer Problems** **On successful completion of this part of the course, the student will be able to:** 1. Understand how the weighted residual method is used to formulate the finite element equations for field problem including heat transfer problems. 2. Understand the procedure to treat different types of boundary conditions in heat transfer problems. 3. Apply the FEM procedure to solve 2D and 3D heat transfer problems. **Hands-on Session, use of software package and project** **On successful completion of this part of the course, the student will be able to:** 1. 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. 2. Carry out a FEA assignments and writing analysis reports.	MA1505	Nil	Nil	1. Course Overview (2 hour) Physical problems, mathematical model, numerical methods, computational implementation procedures. 2. Review of solid and structural mechanics (2 hours) Governing equations for solids, truss, beam, and plates. 3. Fundamentals of FEM (4 hours) Hamilton's principle, minimum potential energy principle, shape functions, discretized system equations. 4. Formulation Techniques (3 hours) Shape functions for elements, strain matrix, FE equations, coordinate transformation, global equation assembly, reproducing property of FEM. 5. FEM in structural dynamics (1 hour) Solving eigen-value problems for natural frequencies, transient and harmonics responses. 6. FEM 1D structural elements (4 hours) FE equations for truss, beam and frame elements. 7. Use of FEM packages (5 hours) Hands-on session using a commercial software package. 8. 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. 9. 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. 10. FEM FOR 3-D SOLIDS (1 hour) Shape functions for 3-D solids, FE equations. 11. 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. 12. 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. Total (41.5)	- 100% CA -Quiz/Test, Others(assignment, fieldwork, project etc)	**Compulsory reading:** Lecture notes. **Supplementary reading:** A First Course in Finite Element Method, Daryl L. Logan, Global Engineering. An introduction to The Finite Element Method. J. N. Reddy, McGraw-Hill. The finite element method - a practical course, Liu GR and Quek SS, Elsevier (Butterworth-Heinemann).