Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
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 analyse 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. Analyse and design an aerodynamic body with minimum drag force.	ME2134	Nil	TME2135	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. Stream function 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 – Online Assignment, 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.
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 half or one semester. 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 half or one semester. 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	ME3000	NIL	The scope is to be worked out between the student and his supervisor.	100% CA	NA
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 Cohort AY19/20 & after =ME1102	Nil	ME3122E/ TME3122	**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.	Mid Term, Quiz, Final Examination	**Supplementary reading:** Fundamentals of Heat and Mass Transfer by T.L Bergman. Heat transfer by Yunus Ali Cengel Heat Transfer by Jack Philip Holman
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.	The course will cover the following topics: 1. 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. 2. Internet of Things (6 hrs): Industrial Internet of Things, Data transmission, processing and storage, Cloud and Edge Analytics. 3. 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.	Nil	Nil	EE3306	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.		

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
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; Unsymmetrical bending of beams; Stresses in pressurised thick-walled cylinders in the elastic and elastic-plastic regions; Stresses in rotating members; and Introduction to mechanics of composite materials; and Experimental stress analysis with particular emphasis on optical methods. 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. The materials in this course are applicable to chemical, civil, mechanical and aeronautical engineering.	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-walled 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.	Essays/ 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 advanced 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 binary fluids processes; Real gases; equation of state, enthalpy and entropy; 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.		ME2121	Nil	Nil		Mid-Term/ Final Examination	
ME3241	Microprocessor Applications	4	2	In this course, students are taught how the logic circuits and microcontrollers are applied as the brain of a mechatronic system. Major topics include: Digital Electronics; Basic operations of the microprocessor; Introductory assembly language programming; Basic interfacing with external devices. Upon successful completion, students will be able to design, analyse, and explain logic circuits, describe the inner workings of a microprocessor and microcontroller, and programme in ARM assembly language. Examples of applications, tailored specifically to mechanical engineers, are used to illustrate these principles.	1. Represent number in various bases and explain the different type of common codes used in industries. 2. Explain various error detection and correction techniques 3. Solve problem using combinatorial logic and/or sequential logic. 4. Explain the basic structure of a microprocessor. 5. Code programs in assembly language for a microprocessor.	Nil	Nil	Nil	1. Numbering System and Codes • Review of numbering systems, signed number representation and binary arithmetic • ASCII, BCD, Excess-3 and Gray Codes • Parity and data correction 2. Digital Electronics • Integrated circuit logic • Logic gates • Flip-flops and latches • Counters and registers • Encoder and decoder • Multiplexer and de-multiplexer 3. Microprocessor Architecture • Review of digital circuits, memory devices, data busing, data bus operation • Central processing units: arithmetic logic unit, registers, instruction decoder, timing and control, memory instruction cycle 4. Assembly Programming • Instruction set of a microprocessor • Use of instructions to programmes • Addressing Modes, Flags • Stack and stack pointer • Subroutines 5. ARM7 TDMI Specifics • Interrupts • Timers • Memory Map and Structure • Direct Memory Accesses	Project Assignment 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.
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) Boolean Algebra Review Theorem, Synthesis of Logic Functions and Karnaugh Maps 2) Actuators and Switching Elements Pneumatic and Electromechanical Devices 3) Design of Sequential Control Systems Sequence Chart, Cascade Method, etc 4) Purely Pneumatic Circuits Pneumatic implementation of various automation approaches and its related issues 5) System with Random Inputs Huffman Method, Sequential System with Random Inputs 6) Programmable Logic Controllers Architecture of PLC, Programming of PLC and its differences from hardwired circuits	Lab, Final Examination	
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	EE3305	The course will cover the following topics. Introduction to Robotics : Definitions and history of robotics, robot components, robot Applications. Robot Sensors and Actuators : Various sensor principles and actuation technologies, degrees of freedom. Robot Locomotion : Introduction to legged and wheeled mobile robots. Wheeled Mobile robot kinematics. Robot Motion Control: Types of controls (proportional, integral and derivative), localization, path planning and navigation. Robot Operating System : Simulation of mobile robot(s) in a virtual environment.	Group Projects/ Quizzes/ Assignments	**Compulsory reading: NIL** **Supplementary reading:** 1. Matarić, Maja J. The Robotics Primer. Mit Press, 2007. 2. Siegwart, Roland, Illah R. Nourbakhsh, and Davide Scaramuzza. "Introduction to Autonomous mobile robots." 3. Joseph, L. (2018). "Robot Operating System (ROS) for Absolute Beginners

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME3252 (Combined of ME2151 & ME3151)	Materials Engineering Principles for Engineers	4	1	This course equips students with knowledge on the 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. 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	Essays, Project, Mid Term Tests	
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 programme for the machining of a part); Verification of fabricated part by CNC measurement based on given geometric model. The course is targeted at students specialising in manufacturing engineering.	1. Understanding the basics of the mathematical models that form the tools for curve and surface construction in CAD packages. 2. Apply mathematics through matrix and vector algebra to model free-form curves and surfaces from discrete data points. 3. Understanding 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. Integrate CAD modeling and different techniques of computer-aided machining and measurement through applications in a CAM environment. 5. Complete an independent study project related to CAD/CAM.	Nil	ME2162	Nil	**CAD: Geometric Modeling** • Curve segment models • Composite curve construction • Surface patch models • Composite surface construction • Solid model data structure and techniques **CAM: Fabrication of Part by CNC Machining based on Geometric Model** • Basics of CNC Turning and Milling • Tool path generation in CAD/CAM **CAM: Verification of Fabricated Part by CNC Measurement based on Geometric Model** • Geometric Dimensioning and Tolerancing • Basics of Computer-automated Measurement.	Essays 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.
ME3263	Design for Manufacturing and Assembly	4	1	This course teaches 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 sustainable product design and manufacturing. The topics covered include DFMA Introduction, Selection of materials and manufacturing processes; Product design for manual assembly; Design for automatic assembly and robotic assembly; Design for manufacturing, including machining and injection molding; Design for Additive Manufacturing. The course is targeted at students majoring in manufacturing.	1. Understand and apply the principles of design for material forming processes 2. Understand and apply the principles of basic machining practice and principles of design for machining 3. 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. Apply design for assembly techniques to determine the average assembly time and cost 6. Understand the principles of additive manufacturing and able to apply additive manufacturing in design 7. Understand how additive manufacturing has evolved into a direct manufacturing process and system selection can influence final part quality	Nil	ME2162/ME3162	Nil	• DFMA Introduction • Selection of materials and manufacturing processes • Product design for manual assembly • Design for automatic assembly and robotic assembly • Design for manufacturing, including machining and injection molding • Design for Additive Manufacturing	Project Final Examination	
ME3281	Microsystems Design and Applications	4	2	The course generates an appreciation of the interdisciplinary nature of microsystems and their impact on various application domains, including but are not limited to, consumer electronics, healthcare, and manufacturing. Secondly, it enables students to learn and apply science and technology of miniaturisation. The major topics include: An overview of the principles, Semiconductor materials and processes, System-level design and applications of microsystems; Properties of semiconductor; Fundamentals of dynamics and vibration; Micro flexural suspension designs; Piezoresistivity and applications in sensors; Electrostatics and Capacitance; Electrostatic micro actuators; Micro optics and miniaturised imaging systems; Thermal actuators and sensors; Biosensors; Fabrication in MEMS. The target students are those having a keen interest in both mechanical and electrical engineering subjects as well as material processing topics.	On successful completion of this course, the student will be able to: 1. Understand the advantages of microsystems and their application areas. 2. Design basic microelectromechanical systems (MEMS) based actuators for translational and rotational motions. 3. Design basic optical MEMS devices including micro-mirrors and micro-mirror arrays for optical microsystems. 4. Design 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. 6. Understand the basics of microfabrication processes.	Nil	Nil	Nil	1. Introduction and Overview of Microsystems Technology 2. Microfabrication Fundamentals 3. Materials for Microsystems 4. Beams and Diaphragms for Microsystems and Micro Suspension Designs 5. Microactuators 6. Microsensors 7. Optical Microsystems 8. Microfluidics and Bio-MEMS	Project Quizzes/Tests	

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
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 optimisation 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.	1. Perform numerical integration using techniques such as the Trapezoidal Rule, Simpson's Rule, and Gauss Quadrature. 2. Numerically solve Ordinary Differential Equations (ODE) using techniques such as the Runge-Kutta Method (RK23, RK45). 3. Numerically solve linear systems of algebraic equations using techniques such as Gaussian Elimination and LU Decomposition 4. Apply elementary unconstrained optimisation techniques such as the method of line searches, Newton's Method, and Gradient Methods 5. Perform regression and interpolation of numerical data using techniques such as Linear and Polynomial Regression, Lagrange Interpolating Polynomials, Inverse Interpolation, and Spline Interpolation 6. 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.	MA1505 & 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 Optimisation Methods of Line Searches • Newton's Method • Gradient Methods • Least-Squares Regression and Interpolation Linear • 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)	Project Mark Tutorial Final Examination	
ME4105	Specialisation Study Course (Offshore Oil & Gas Technology)	4	1	This module is designed to link staff research to teaching in the selected areas of specialisation offered by the Department. The module comprises a structured programme of seminars, term papers, and mini-projects to be given by a group of faculty members based on their current research interests in the specialisation area. The programme content differs for different specialisation areas. The module is intended for students pursuing a specialisation.		Nil	Nil	Nil		100% CA	
ME4212	Aircraft Structures	4	2	This course covers torsion of open and closed non-circular thin-walled sections; bending of unsymmetric thin-walled beams; idealised 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. 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. Understand basic elastic constants in fiber-reinforced composite materials at lamina level. 5. Apply classical lamination theory to determine effective laminate stiffness and load-deformation relations. 6. Apply failure criteria in analysis of laminated composite plates and structures.	Nil	Nil	Nil	**Torsion and Bending of Thin-Walled Beams, Idealised 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 • Idealised beams with stringers and sheets • Equations of bending and torsion for idealised beams **Mechanics of Fiber-Reinforced Composite Materials and Structures** • Elastic constants and constitutive relations for anisotropic and orthotropic materials • On-axis and off-axis stiffness and compliance of a fiber-reinforced composite lamina • The composite laminate • Classical Lamination Theory • The laminate stress-strain relations • Special laminates • Fabrication stresses • Hygrothermal behaviour of composites • Failure of composite structures	Assignments/ Final Examination	**Compulsory reading:** 1. Ronald F. Gibson, "Principles of Composite Material Mechanics" 2. T.H.G. Megson, "Aircraft Structures for Engineering Students", Butterworth-Heinemann, 5th Ed. (2013). **Supplementary reading:** 3. David W A Rees, "Mechanics Of Solids And Structures (2nd Edition)" 4. T.H.G. Megson, "An Introduction to Aircraft Structural Analysis", Butterworth-Heinemann, (2010). 5. C.T. Sun, "Mechanics of Aircraft Structures", John Wiley & Sons, 2nd Ed. (2006). 6. J. Cutler, "Understanding Aircraft Structures", Blackwell, 4th Ed. (2005) 7. M. W. Hyer; Scott R. White, "Stress Analysis of Fiber-reinforced Composite Materials". 8. Bhagwan D. Agarwal; Lawrence J. Broutman; K. Chandrashekhara, "Analysis and Performance of Fiber Composites" 9. Carl T. Herakovich, "Mechanics of Fibrous Composites".
ME4223	Thermal Environmental Engineering	4	1	This course aims to integrate knowledge in thermodynamics, heat transfer and fluid mechanics to design and simulate air-conditioning 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 6. Evaluate feasibility of alternative energy sources for buildings and other spaces	ME2121	Nil	TME4223	Applications and Basics: Applications of Air Conditioning and Refrigeration. Review of Thermal Principles. Psychrometrics, Comfort and Health: Properties of moist air. Humidity measurement. Psychrometric chart. Psychrometric processes. Comfort. Indoor Air Quality. Heat gains through building envelopes: Solar heat gain, fenestration and shading coefficient, Thermal performance of building envelopes, Overall Thermal Transmittance Value, Green-mark incentive scheme calculations: Manual and computerized methods of load estimation. Air-conditioning Cooling Load CG Design Calculations: • Sensible and Latent Loads • Room Load Ratio Line • Supply Air Quantity • Cooling Capacity Air-conditioning Systems: • All-air• All-water• Air-water• Heat Pump and Solar-assisted Systems Air-conditioning Plants, Equipment and Systems: • Vapour-Compression Refrigeration• Chillers• Cooling and Dehumidifying Coils• Cooling Towers • District Cooling Energy Estimation and Energy Performance Analysis: • Computer-aided Energy Estimation• Energy Performance Measurement and Analysis	Quizzes Mid Term 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.

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
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.	Describe real gas behavior using equations of state and compressibility charts, derive thermodynamic equations. Compute work and heat exchanges for real gas processes using generalized charts. Design crossflow shell and tube heat exchangers and flat finned heat exchangers, considering material selection and core geometries. Explain single-stage and two-stage absorption systems, and address operational problems. Detail the operation, advantages, and financial analysis of microturbines cogeneration systems. Describe biomass cogeneration systems, their benefits, performance monitoring, and calculate efficiency and carbon dioxide mitigation.	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.	Assignment Mid Term Final Examination	**Compulsory reading:** 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. Know the structure of IC engines 3. Understand the design of IC engines 4. Test the performance of IC engines and understand the methods to detect and solve the potential problems faced in practice 5. Test and analyze the emissions of IC engine and the methods of improvement 6. Understand the analytical methods to estimate the performance of IC engines, and appreciate 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	Project Mid Term Test 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.
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: 1. Apply the fundamental principles governing aerodynamics in different flow regimes 2. Apply the theory of supersonic flow around thin airfoils to obtain the corresponding values of lift, drag and moment. 3. Understand various aerodynamics principles which include relation between lift acting on and circulation around an airfoil, starting vortex, Kutta condition etc. 4. Understand the function, principle and design of various components of an aircraft which include control surfaces and drag reduction/lift enhancement devices etc. 5. 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. 6. Understand various CFD schemes such as the Panel Method and Vortex Lattice Method and the corrections for applying the incompressible results to subsonic flow conditions.	ME2134	Nil	Nil	**Characteristics Parametric for Airfoil and Wind Aerodynamics:** • Basic components of an aeroplane • Airfoil nomenclature and geometric parameters • Wing geometric parameters • Characterisation of aerodynamic forces • Aerodynamic force and moment coefficients **Two-dimensional Incompressible Flows Around Thin Airfoils:** • Circulation and generation of lift • KuttaJoukowski Theorem • Thin airfoil theory and its application to symmetric, cambered and flapped airfoil • Panel method **Incompressible Flow Around Finite-span Wings:** • Biot- Savart Law and Helmholtz's Vortex Theorems • Prandlt's Lifting Line Theory • General and elliptical lift distribution • Vortex Lattice Method **Aerodynamic Design Considerations:** • The ideal airfoil • High lift devices, including single and multi-flap systems, power augmented lift, rippled trailing edge and vortex lift • Drag reduction devices, including laminar flow control, ribblets and winglets **Compressible Subsonic and Transonic Flows Around Airfoils:** • Compressible subsonic flows • Linearised thin airfoil theory for compressible flow • Transonic flow past unswept airfoils • Design considerations to overcome transonic flow problems • Swept wings at transonic speeds • Transonic aircraft **Two-dimensional, Supersonic Flows Around Thin Airfoils:** • Linear theory • Busemann's theory	Quiz/Test Final Examination	

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
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.	1.Define, investigate and analyse complex problems 2. Perform market research and industry structure analysis. 3. Conduct interviews and analyse data from primary sources. 4.To design the UAS platform suited for the mission and job requirements; 5. Articulate clearly a solution to an external and non-engineering audience. 6. Design solutions to complex problems – using appropriate design methodologies. 7. To prepare students for pursuing further graduate studies or advanced R&D in UAS. 8. To understand and use the current technology in guidance and navigation applicable to UAS; 9. To understand and apply fundamental engineering concepts related to UAS design and operation; 10. To understand and perform trajectory, mission and path planning, including multi-agent operations; 11. To understand the overall concept of small aircraft, unmanned aerial vehicle and related systems (UAS); 12. To design the holistic UAS system for specific applications in both aerospace and non-related industries; 13. *Understand and be able to launch a digital quantitative landing page for additional market research data. 14. Recognize complexity and assess alternatives in the light of competing requirements and incomplete knowledge. 15. To understand and apply the latest drone technology including AI-related technology to UAS and antidrone technology; 16. To gain awareness of the current law and regulations applicable to UAS in Singapore in order to practice safe flight operations 17. Function more effectively as an individual, and as a member or leader in diverse (engineering) teams and in multi-disciplinary settings. 18. To understand the working principles, scopes and limitations of sensors and communications sufficiently to choose the right equipment sets for missions;	Nil	Nil	Nil	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)	Class Participation/ Project/Lab Test/ Final Examination	
ME4233	Computational Methods in Fluid Mechanics	4	1	Computer simulation and modelling has become an important tool in advanced mechanical engineering, e.g. computational fluid dynamics (CFD) software which is used for fluid-related problems. This course introduces students to the principles and methodologies under the hood of typical CFD software. Major topics include numerical discretisation, stability and accuracy analysis, and methods for solving incompressible viscous fluid flow and convective heat transfer problems. Students will also experience writing a code/script to solve simple fluid problems. At the end of this course, students will have a working knowledge of the basic principles of fluid flow simulation and implementation of computational methods in solving complex problems.	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. Solve incompressible fluid flow through implementing a typical methodology in a 2D problem.	ME2134 Or ESP2106	Nil	Nil	• Basic theory of numerical discretisation • Finite difference discretisation • Stability and accuracy analysis • Solution methods for Poisson and elliptic type equations • Conservation laws and finite volume discretization • Formulation and solution methods for viscous incompressible fluid flows	Essays Final Examination	
ME4241	Aircraft Performance, Stability and Control	4	1	The course is concerned with the flying qualities of flight vehicle and the impact of aerodynamics, propulsion, structures and control systems on flight performance. The course is designed for aeronautical specialisation students who intend to work in the aerospace and defence industries. As such there is a strong emphasis on practical methods to estimate flight performance metrics required by industrial specifications e.g. Federal Air Regulations Part 23 and 25 and MIL-SPEC-8785. Industrial software e.g., MatLab (or open-source equivalent Octave, SciLab) will be used to compute flight performance metrics.	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. Estimate aircraft performance metrics for a given aerodynamic configuration. 4. 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	Part 1: Aircraft Performance • Straight and Level Flight • Climbing and Gliding • Power Requirement Curve • Take off and Landing Field Length • Range estimates, Breguet's equation • Endurance estimates, Turning Performance • Generation of flight envelopes Part 2: Aircraft Stability and Control • Static longitudinal stability • Static margin • Static directional stability • Longitudinal dynamic stability • Phugoid and short period modes • Lateral dynamic stability, roll, spiral and Dutch roll modes • Flying qualities assessment Matlab or equivalent software (Octave, SciLab) will be used to compute performance and stability metrics with reference to industry FAR and MIL-SPEC requirements.	Tests Final Examination	

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME4242	Soft Robotics	4	1	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. 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	Group Project/ Individual Assignment	**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 to appreciate and understand 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 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 typical to new-generation robots.	1. 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. Develop the kinematic models of the robotic manipulators 4. Derive the dynamic models of the robotic manipulators using Lagrangian and/or Newton-Euler formulations 5. Implement joint-based motion planning for robotic manipulators 6. Synthesize control algorithms for motion control of robotic manipulators	ME2142	ME2142	Nil	**1.Introduction, Spatial Descriptions and Transformations** • Robot definition • Robot classification • Robotics system components • Notations • Position definitions • Coordinate frames • Different orientation descriptions • Free vectors • Translations rotations and relative motion • Homogeneous transformations **2.Manipulator Forward and Inverse Kinematics** • Link coordinate frames • Denavit-Hartenberg convention • Joint and end-effector Cartesian space • Forward kinematics transformations of position • Inverse kinematics of position • Solvability • Trigonometric equations • Closed-Form Solutions • Workspace **3.Mechanics of Robot Motion** • Translational and rotational velocities • Velocity Transformations • The Manipulator Jacobian • Forward and inverse kinematics of velocity • Singularities of robot motion **4.Static Forces and Compliance** • Transformations of static forces and moments • Joint and End-Effector force/torque transformations **5.Robot Dynamics** • Newton-Euler formulation of manipulator dynamics • Closed-form dynamic equations • Physical interpretation of the manipulator dynamic equations • Lagrangian formulation • Transformations of generalised coordinates **6.Trajectory Planning** • Trajectory planning in joint space • Cubic polynomial for a path (with or without via-points) • Quintic polynomial path • Linear segment with parabolic blends (with or without via points) **7.Control of manipulators** • Independent joint control • Basics of linear control • Control-law partitioning • Modeling and control of a single joint • Control of nonlinear systems • Nonlinear control of manipulators (MIMO)	Project, Final Examination	**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.

Course Code	Course Title	Unit	Sem	Course Description	Learning Outcomes	Pre-requisites	Co-requisites	Preclusions	Syllabus	Assessment	Illustrative Reading List
ME4248	Simulation and Control of Manufacturing Systems	4	1	This course covers fundamental concepts and techniques related to the simulation and control of (discrete) manufacturing 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, discrete-event system models, state and state transitions, automata and formal language models of discrete-event manufacturing systems, specification of discrete-event system behavior, controllable and uncontrollable events, the basic supervisory control problem.	Upon successful completion of this model, students will be able to (1) Set up and conduct simulation of small-scale manufacturing systems in order to analyze their performance, and (2) Apply the concept of supervisory control of discrete-event systems modelled by automata and formal languages.	Nil	Nil	Nil	**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 processes. Selection 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 behavior; 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-distribution. **Part 2** • **System and control basics**: Input output modeling of manufacturing processes; state space; sample paths of dynamic systems; the concept of control; the concept of feedback. • **Discrete event systems**: Characteristic properties of discrete event systems; levels of abstraction; examples of discrete-event models of manufacturing systems. • **Formal languages and automata**: Language models of discrete-event systems; languages represented by automata; unary operations; composition operations; state space refinement. • **Finite-state automata**: Definition and properties of regular languages; regular expressions; state space minimisation; analysis of discrete-event systems; safety and blocking properties. • **Feedback control with supervisors**: Controlled discrete event systems; specifications on controlled system; modelling of specifications as automata; control with partial controllability; controllability theorem; realisation of supervisors.	Project Tests Final Exam	**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. Introduction to Discrete Event Systems, Christos G. Cassandras; Stéphane Lafortune Supervisory Control of Discrete-Event Systems. W. Murray Wonham; Kai Cai
ME4252	Nanomaterials for Energy Engineering	4	1	This course starts with basics of semiconductors relevant for p-n junction and solar cell devices. Introduces mixed conductors and ionic conductors which are relevant for fuel cells, batteries and supercapacitors. Transport measurements, with an emphasis on impedance studies, will be introduced. The importance of excess surface and interfacial contributions in nanostructured materials and their key roles in modifying thermodynamics and electrical properties will be discussed. Various energy conversion and storage devices (solar cells, fuel cells, batteries and supercapacitors) where the nanosized materials play key roles for improving their efficiencies will be taught. Course will end with remarks on the engineering aspects such as development of energy conversion and storage devices using nanomaterials.	1. Relate semiconductor properties to the underlying physical concepts relevant for various solar cells. 2. Compare energetics and working principles of solar cells, fuel cells and batteries. 3. Recognise role of surfaces/interfaces in nanomaterials for improving the energy conversion and storage processes. 4. Identify and critically evaluate current developments in energy conversion and storage devices. 5. Analyse environmental and economic benefits of nanomaterials for energy engineering.	Stage 3 or 4 Standing	Nil	Nil	1. Introduction to nanomaterials 2. Introduction to semiconductors 2.1 Carriers in semiconductors 2.2 Carrier concentration 2.3 Intrinsic and extrinsic semiconductors 2.4 Photon absorption and recombination 2.5 Carrier transport phenomena 2.6 Carrier separation 2.7 p-n junction 3. Transport measurements: DC and AC methods 4. Ionic conductors 5. Mixed conductors and defect chemistry. 6. Synthesis and characterisation of single crystals, polycrystalline materials and nanomaterials. 7. Size effects on transport and thermodynamics 7.1 Electrical conductivity 7.2 Thermodynamics 8. Solar energy conversion using nanostructured materials 8.1 Monocrystalline Si solar cells 8.2 Dye-sensitised solar cells 8.3 Perovskite solar cells 8.4 Quantum-dot solar cells. 9. Fuel cells 10. Rechargeable batteries and supercapacitors 11. Engineering aspects of nanomaterials 11.1 Designing miniaturised devices: fuel cells and batteries 11.2 Associated safety issues	Tests Final Exam	**Compulsory reading:** Martin A. Green, Solar Cells **Supplementary reading:** 1. J. Maier, *Physical Chemistry of Ionic Materials: Ions and Electrons in Solids*, John Wiley & Sons (2004)
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	Nil	Nil	Nil	• Overview of the needs and limitations of materials to repair/replace living tissues/organs • Major classes of biomaterials, their advantages and disadvantages when used as implant materials • Processing routes for the manufacturing of medical devices and how processing affects the materials' properties • Types of failure in implants and reasons for such failure • Performance of various clinical case studies requiring use of replacement devices	100% CA Essays Project	
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	ME2162	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, Optimisation of tool shape and design features of special single-point cutting tools • Conventional drills and milling cutters • Grinding wheels and dressing of grinding wheels	Project Final Examination	

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	ME2162	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. Computer-aided process planning 10. Automated operation planning for layered manufacturing processes.	Essays Final Examination	
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.	1. Define the characteristics and outline the general procedure of Finite Element Analysis (FEA), including scalar field problems. 2 Demonstrate clear understanding of using a FEA software (for example, SOLIDWORKS-Simulation) to conduct engineering analyses on FEA assignments. 3 Explain the different FE formulation approaches to derive the FE models for structural elements, such as 1D truss/bar, and beam elements, and 2D solid elements. 4 Understand and apply the Gauss quadrature rules to evaluate the FE integrals, implement them in basic codes, and solve simple engineering problems.	MA1505 (ME), MA1511 & MA1512- (ESP)	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).