Indian Institute of Technology Kanpur

COURSES OF STUDY

2025 Onward

Indian Institute of Technology Kanpur
KANPUR-208016

MECHANICAL ENGINEERING

Template for BT Program in Mechanical Engineering

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-1 (9) ELC111/ELC112/ ELC113 *	ETH111 (3) **	SCHEME-2 HSS-I (9-11)	SCHEME-3 EME (9-11)	SCHEME HSS-II (9)	--	SCHEME HSS-II (9)	SCHEME HSS-II (9)
MTH 111 (6)	MTH 113 (6)	ESC201 (14)	ME231 (8)	ME333 (3)	ME334 (4)	OE-1 (9)	OE-5 (9)
MTH 112 (6)	MTH 114 (6)	MSO202M (6)	ME222 (6)	ME301 (9)	ME302 (9)	OE-2 (9)	OE-6 (9)
PHY 113 (11)	PHY 112 (11)	MSO203M (6)	ME252 (9)	ME331 (9)	ME354 (9)	OE-3 (9)	DE-2 (9)
PHY 111 (3)	CHM 111 (3)	ESO201 (11)	ESO202 (11)	ME321 (9)	ME341 (9)	OE-4 (6)	DE-3/UGP-2 (9)
TA 111 (9)	ESC 111 (7)	ME209 (9)	ME261 (7)	ME361 (7)	ME371 (9)	DE-1/UGP-1 (9)	
CHM 112 (4)	ESC 112 (7)			ME381 (7)	ME351 (8)		
CHM 113 (4)	LIF111 (6)				MEXXX (9) -One course from Basket*		
PE111 (3)	PE112 (3)						
55	52	55-57	50-52	53	57	51	45

* DC Basket (MEXXX): 3 to 4 electives courses will be designated every even semester

Credit Table for BT Program in Mechanical Engineering		
Course type	Allowable Credit range	Credit in the department
Institute Core (IC)	112	112
E/SO	18-45	34
Department requirements	144-179	167 (140 DC + 27 DE)
Open electives (OE)	51-57	51
SCHEME	54-58	54-58
Total for 4-year BT/BS	391-420	418-422*

* Exceeds the credit range recommended by UGARC

Template for BTH Program in Mechanical Engineering

Template for 3rd to 8th semester for BTH Program in Mechanical Engineering					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 HSS-I (9-11)	SCHEME-3 EME (9-11)	SCHEME HSS-II (9)	--	SCHEME HSS-II (9)	SCHEME HSS-II (9)
ESC201 (14)	ME231 (8)	ME333 (3)	ME334 (4)	OE-1 (9)	OE-5 (9)
MSO202M (6)	ME222 (6)	ME301 (9)	ME302 (9)	OE-2 (9)	OE-6 (9)
MSO203M (6)	ME252 (9)	ME331 (9)	ME354 (9)	OE-3 (9)	DE-1 (9)
ESO201 (11)	ESO202 (11)	ME321 (9)	ME341 (9)	OE-4 (6)	UGP-2 (9)
ME209 (9)	ME261 (7)	ME361 (7)	ME371 (9)	UGP-1 (9)	DEH-2 (9)
		ME381 (7)	ME351 (8)	DEH-1 (9)	DEH-3 (9)
			MEXXX (9) - One course from Basket*		
55-57	50-52	53	57	60	63

- DEH: 27 credits of DEs at the level of 6 or 7 must be taken
- CPI criteria for BTH: 8.0
- UGP-1 and UGP-2 are mandatory for BTH

Template for BTM program in Mechanical Engineering

Template for 3rd to 8th semester for BTM Program in Mechanical Engineering					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 HSS-I (9-11)	SCHEME-3 EME (9-11)	SCHEME HSS-II (9)	--	SCHEME HSS-II (9)	SCHEME HSS-II (9)
ESC201 (14)	ME231 (8)	ME333 (3)	ME334 (4)	OE-1 (9)	OE-3 (9)
MSO202M (6)	ME222 (6)	ME301 (9)	ME302 (9)	OE-2 (6)	MTB-4 (9)
MSO203M (6)	ME252 (9)	ME331 (9)	ME354 (9)	MTB-1 (9)	MTB-5 (9)
ESO201 (11)	ESO202 (11)	ME321 (9)	ME341 (9)	MTB-2 (9)	MTB-6 (9)
ME209 (9)	ME261 (7)	ME361 (7)	ME371 (9)	MTB-3 (9)	
		ME381 (7)	ME351 (8)		
			MEXXX (9) - One course from Basket*		
55-57	50-52	53	57	51	45

- 54 credits of MTB courses should be taken from the Management Track Basket

Template for five-year dual degree program in Mechanical Engineering

Template for dual degree program in Mechanical Engineering (PG Part-Category A)			
7th	8th	9th	10th
DE PG-1 [09]	DE PG-4[09]	M.TECH. THESIS [36]	M.TECH. THESIS [36]
DE PG-2 [09]	DE PG-5[09]	-	-
DE PG-3 [09] OE PG-1 [09]	DE PG-6 [09]/ OE PG-1 [09]		

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION

- PG Component : 54 Credits
- Thesis Component : 72 Credits

36 OE credits may be waived off in the UG requirements

Template for dual degree program in Mechanical Engineering (PG Part-Category B)				
Sl. No.	Specialization	Compulsory Courses	Elective Credits	Thesis Credits
1.	SOLID MECHANICS AND DESIGN (SMD)	ME621 [9] ME625 [9] ME681 [9]	DE PG-1[09] DE PG-2[09] DE PG-3[09]	M.TECH THESIS [72]
2.	FLUID & THERMAL SCIENCES (FTS)	ME631 [9] ME641 [9] ME642 [9] ME681 [9]	DE PG-1[09] DE PG-2[09]	M.TECH THESIS [72
3.	MANUFACTURING SCIENCES (MFS)	ME661 [9] ME662 [9] ME663 [9] ME681 [9]	DE PG-1[09] DE PG-2[09]	M.TECH THESIS [72]

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION

- PG Component : 54 (27 Compulsory +27 Electives) Credits for SMD
- PG Component : 54 (36 Compulsory +18 Electives) Credits for FTS and
- Thesis : 72 MFS Credits

36 OE credits may be waived off in the UG requirements

Template for double major: second major in Mechanical Engineering

Template for double major	
Odd Semester	Even Semester
Pre-Requisites	
ESO201A [11] / ESO202A [11]	ESO201A [11] / ESO202A [11]
11	11
ME Mandatory Courses	
ME209 [09]&	ME231 [09]*
ME341 [09]&&	ME252 [09]
ME321 [09]&&&	ME261 [07]**
ME361 [07]	ME302 [09]
	ME354 [09]
	ME331 [09]***
	ME371 [09]
34	61

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN MECHANICAL ENGINEERING: 95

REMARKS:

1) * Equivalent courses for ME231 are ESO204 or CE261
2) ** Equivalent course for ME261 is MSE305
3) *** Equivalent courses for ME331 are CHE311 or (AE211+AE312)
4) & Equivalent course for ME209 is AE209
5) && Equivalent course for ME341 is CHE312
6) &&& Equivalent course for ME321 is (AE333+AE334)
7) Up to 36 OE credits may be waived from the parent department's BT/BS graduation requirements when they are used to fulfil requirements for the double major.

Minors in Mechanical Engineering

Minors	
MANUFACTUIRNG SCIENCES	COMPUTATIONAL TECHNIQUES IN MECHANICAL ENIGNEERING
Any THREE from the following	Any THREE from the following
ME661 [09] (Prerequisite TA212)	ME623 [09] (Prerequisite ESO202, MSO203M)
ME662 [09] (Prerequisite TA212)	ME630 [09] (Prerequisite ESO201, ESO204, SO203M)
ME663 [09] (Prerequisite ESO202, MSO203M)	ME685 [09] (Prerequisite- No backlog in core courses)
ME664 [09] (Prerequisite TA212, ESO204 or an equivalent course in Heat Transfer)	ME751 [09] (Prerequisite TA101)
ME665 [09] (Prerequisite TA212)	ME676 [09] (Nonlinear Finite Element Method in Solid Mechanics)
ME774 [09] (Prerequisite ESO202, MSO203B)	ME653 [09] (Atomistic Simulations in Engineering)
ME751 [09] (Prerequisite TA101)	-
ME761 [09] (Prerequisite TA212)	
27	27

DEPARTMENT OF MECHANICAL ENGINEERING			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
ME209	Dynamics	3-0-0-0-9	Coordinate systems, vectors and tensors; Dynamics of a system of particles; 3D rotations, Euler angles, and 3D angular velocity; Kinematics of rigid bodies; Constrained rigid body kinematics: types of joints, friction, rolling; Kinetics of rigid bodies; General 3D rigid body dynamics, including the gyroscope; Advanced examples including numerical solution of initial value problems; Steady mass flow and variable mass problems; Lagrange's equations for a finite-dimensional non-conservative mechanical system.
ME222	Nature and Properties of Materials	2-0-0-0-6	Introduction to Materials, Materials Testing and Properties, Mechanical Properties of Materials, Material Selection for Mechanical Design, Crystal Structures, Metals and Metallic Alloys, High strength and High temperature Superalloys, Engineering Ceramics, Polymers, Composite Materials: Polymeric, Ceramic and Metal Matrix Composites, Smart Materials
ME231	FLUID MECHANICS	2-1-0-0-8	Introduction, Fluid Statics, Kinematics of local fluid motion, Integral relations for fluid control volume, Differential relations for a fluid element, Viscous flow, Dimensional Analysis and similarity, Flow Past immersed bodies, Compressible flow
ME252	Theory of Mechanisms and Machines	3-0-0-0-9	Kinematics and dynamics of mechanisms and machines, analysis and synthesis through graphical and analytical methods.
ME261	Primary Manufacturing Processes	2-0-1-0-7	Introduction to primary manufacturing processes and properties of materials; Casting and solidification of alloys: Mechanism; Analysis of cooling curve; Runner and gating system design; Riser design; Joining processes: Fusion welding mechanism; Heat flow and material transfer mechanism; Microstructure formation; Welding defects and inspection; Bulk deformation processes: Brief review of plastic deformation and yield criteria; Mechanistic analysis of Forging, Rolling, Drawing and Forming processes including defects; Additive manufacturing processes: Mechanistic analysis of polymers, metals and ceramics based additive manufacturing processes
ME301	Energy Systems I		Thermodynamic analysis of various energy systems such as combustion engines, solar, thermal, and

		3-0-0-0-9	nuclear power plants, electrochemical energy conversion, refrigeration, and air-conditioning. The course also includes environmental impact of energy conversion and sustainable technologies for energy conversion
ME302	Energy Systems II	3-0-0-0-9	Introduction: General Theory and Classification of Turbomachines; Similarity and Dimensional Analysis; Two-dimensional Cascade Theory; Axial and Radial Flow Machines: Turbines, Compressors and Fans; Gas Turbine Cycles and Propulsion; Thermal Power plant: Flow through Nozzle and Steam Turbines; Hydraulic Machines: Pelton, Francis and Kaplan Turbines; Pump and Cavitation.
ME321	Introduction to Elasticity	3-0-0-0-9	Vector and tensor calculus; Concept of strain; Concept of stress; Equilibrium; stress-strain relationship; Boundary value problem of linear elasticity; Plane stress and plane strain problems; Axisymmetric problems; Torsion of non-circular sections; Contact problems; Wedge problems; Exposure of 3-D problems in elasticity; Energy methods; Special topics.
ME331	Advanced Fluid Mechanics	3-0-0-0-9	Introduction, Local approach, Navier-Stokes equations, Viscosity dominated flows, Inviscid flow, boundary layer, turbulent flow and surface tension dominated flows, design and analysis of energy systems
ME333	Experiments in Mechanical Engineering - I	0-0-3-0-3	Experiments on (a) Vibration and dynamics (b) Fluid Mechanics (c) Material testing
ME334	Experiments in Mechanical Engineering - II	0-0-4-0-4	Experiments on (a) Energy conversion (b) Mechanisms (c) Heat Transfer (d) Experimental stress analysis
ME341	Heat Transfer	3-0-0-0-9	Introduction. One- and Two-dimensional steady and transient conduction. Forced convection over a horizontal flat plate and inside tubes. Natural Convection over a vertical flat plate. Mass Transfer. Boiling and Condensation. Heat Exchangers. Thermal Radiation
ME351	Design of Machine Elements	2-1-0-8	Dimensions and assembly, deformations and compliance, unexpected deformations, material failure, fatigue, extremely long-serving components, unexpected failure modes, statistical aspects, and environmental aspects.

ME354	Vibration and Control	3-0-0-0-9	Vibrations of single and multi degree of freedom systems, with damping and forcing; approximation methods; introduction to control theory, Laplace domain, root locus, compensators, frequency domain analysis; introduction to modern control.
ME359	INTERNAL COMBUSTION ENGINES	3-0-0-0-9	Classification, Construction, Valve arrangements. Fuels, Fuel air cycle. Combustion, Effect of engine variables, Combustion chambers, Carburation and fuel injection, Knocking. Engine cooling, Friction and lubrication Super charging. Wankel engine testing and performance. Pollution.
ME361	Secondary Manufacturing Processes	2-0-1-0-7	Introduction to secondary manufacturing processes; Conventional machining processes: Orthogonal cutting mechanics; thermal aspects of machining; tool wear and life analysis; oblique cutting; milling; drilling; grinding; Non-traditional machining processes: AJM, USM, EDM, ECM, and LBM; Machines and their operations: Working of manual and CNC machines and their control; Metrology: Measurements and measurement equipment; measurement standards; limits, fits and tolerances; testing and calibration
ME371	Manufacturing Systems	3-0-0-0-9	Introduction to manufacturing systems and CIM; CAPP: CAD; Variant and generative processes; Feature recognition in CAPP; Concurrent Engineering: Concepts of sequential versus concurrent engineering; LCA; QFD; Quality Engineering: Cost of quality; SQC; Introduction to DOE; TQM; PPC: Forecasting; Inventory control; Aggregate planning; Master scheduling; MRP; Sequencing; Lean Manufacturing: Push vs pull system; JIT; Kanban system design; Cellular manufacturing and GT; Automated Material Handling Systems: ASRS design principles; AGV; robots in material handling; Recent trends in manufacturing systems.
ME381	Robotics	2-0-1-0-7	Introduction and Overview, Spatial Transformations, Forward and Inverse Position Kinematics, Velocity and Acceleration Kinematics, Robot Dynamics, Actuators and Sensors, Trajectory Planning, Robot Control
ME496, ME497	UNDER GRADUATE PROJECTS	0-0-0-0-9	CONTACT INDIVIDUAL FACULTY MEMBERS

ME888	AN INTRODUCTION TO PROFESSION AND COMMUNICATION	2-0-0-0-6	Background and introduction of mechanical engineering, the primary domain of activities and inter-disciplinary intersections, analytical, design and experimental tools, career choices and professional duties, contemporary research and development trends, start-up formation, introduction to communication, writing technical reports and project proposals, publishing and ethics, presentations, group discussions and interviews, innovation management.
ME613	THERMAL ENVIROMENTAL CONTROL	3-0-0-0-9	Introduction: Refrigeration and air-conditioning, definitions, Psychrometry, sensible/ latent cooling loads, apparatus, dew point, complete psychrometric analysis, building heat load calculation, infiltration and moisture transport, winter air conditioning, part load operations and control; Vapor Compression Refrigeration (VCR) cycles, multi-staging and cascading, design considerations of VCR components, aircraft refrigeration and air conditioning, design of cooling coil, heat pump, solar refrigeration system; Supporting material: Boiling heat transfer, forced convection boiling, film condensation, condensation on radial systems, Overall heat transfer coefficient, LMTD and NTU methods, cooling tower; Special topics/case studies: such as Solar thermal dynamics, energy efficient buildings, automobile air-conditioning, space thermal management, mini-microscale refrigeration systems, CO_2 based systems, VRF and VFD systems, etc.
ME617	ADVANCED THEORY OF TURBOMACHINERY	3-0-0-0-9	he equations of motion in a rotating coordinate system, effects of Coriolis and Centrifugal forces, energy equation; classification of turbomachines; two-dimensional cascade theory; fundamentals, two-dimensional analysis, angular momentum & energy transfer, *h-s* diagram, degree of reaction, the effect of Mach number, off-design performance and efficiency; three-dimensional flow in axial turbomachines, radial equilibrium, secondary flow, tip clearance and loss estimation; radial and mixed flow machines; multistage axial compressors and turbines; prediction of stage performance and effect of stacking; rotating stall and surge; turbine blade heat load and blade cooling; wind turbines; application of CFD in analysis and design of turbomachinery; discussion on experimental methods to measure flow and thermal fields in turbomachines.
ME621	INTRODUCTION TO SOLID MECHANICS		Review of strength of Materials and its limitations; Mathematical Preliminaries: Vector and tensors calculus; Indicial notation; The concept of strain: Finite deformation strain tensor; Linearized strain; Strain-Displacement relations; Physical

		3-0-0-0-9	interpretation of strain components; Principal Strains; Strain compatibility;The concept of stress: Cauchy’s principle and derivations of stress equilibrium equations; Stress components in 3D and their physical interpretations; Principal Stresses; Constitutive law for general linear elastic solid: Discussions on isotropic, orthotropic and transversely isotropic solid; thermoelasticity;Navier’s equations, stress and displacement based approaches; The isotropic linear elasticity boundary value problem; consequences of linearity (superposition, uniqueness, reciprocal relations);8. Plane Problems: plane stress, plane strain, anti-plane shear (also in axisymmetric coordinates) ;Solution methods for plane problems: Stress function approach/Series solutions Circular hole in a shear/tensile field;Curved beam problems: End loadings; Inhomogeneous problem; Near Singular problem; Wedge problems: Power-law traction fields; Williams’ asymptotic method ;Plane contact problems: The Flamant solution (distributed load over the half-plane); Frictionless contact problems (half punch, Hertz problem) ;Plane notch problems: Plane crack in a tensile field; Energy release rate ;Planar problems in thermoelasticity: Steady state problems ;Torsion of a prismatic bar: Prandtl’s stress function, Membrane analogy; Thin walled open sections; Rectangular bar; Multiply connected closed sections.
ME622	INTRODUCTION TO CONTINUUM MECHANICS	3-0-0-0-9	Introduction to the course ; Mathematical preliminaries (a) Vector and tensor algebra; b) Tensor analysis, derivatives of functions with respect to tensors; c) Fields, div, grad, curl; d) Divergence theorem, transport theorem ; Kinematics a) Configurations of a body, displacement, velocity, motion; b) Deformation gradient, rotation, stretch, strain, strain rate, spin tensor; c) Assumption of small deformation and small strain ;Balance laws a) Balances of mass, linear momentum and angular momentum; b) Contact forces and the concept of stress; c) Balance of energy and Clausius-Duhem inequality ; Constitutive relations a) Frame indifference; b) Material symmetry; c) Kinematic constraints (incompressibility, etc.); d) Thermodynamical restrictions; Viscous fluid: constitutive relations, non-Newtonian fluid, boundary value problem ; Finite elasticity: Hyperelasticity, isotropy, simple constitutive relations, boundary value problem
ME623	FINITE ELEMENT METHODS IN		Introduction to the course.; Variational Approach: fundamentals of variational calculus, Ritz method, Introduction of FEM as modified Ritz method, examples.

	ENGINEERING MECHANICS	3-0-0-0-9	; The method of weighted residuals, Galerkin's method to formulate finite element equations for 1D problems in solid mechanics and/or fluid mechanics and heat transfer: discretization, shape functions, element matrices and vectors, global assembly, boundary conditions; Solving finite element equations: different methods of solution, nodal numbering scheme, shape functions in natural coordinates, numerical integration, error analysis and convergence. ;4 th order PDEs in 1D: Euler-Bernoulli beam, interpolation functions with C 1 continuity,Timoshenko beam.; Boundary Value Problems in 2D: variational formulation and/or Galerkin's method,2D elements and shape functions, master elements, numerical integration, evaluation of boundary conditions, global assembly, symmetry of geometry and boundary conditions to reduce the size of the problem, modelling considerations, Examples from solid mechanics and/or heat transfer problems. Eigen value problems and time dependent problems: Finite element formulation for parabolic and hyperbolic PDEs in 1D, Time approximation, Finite Difference Schemes, mass lumping, examples of heat transfer problems, buckling, natural vibration etc. ; Special topics in FEM (instructor's discretion): 3D elements, plates and shells,special elements, introduction to non-linear FEM, XFEM, GFEM etc.
ME624	CALCULUS OF VARIATIONS	3-0-0-0-9	History of calculus of variations; function spaces; first variation, variational derivative; Necessary condition for an extremum, Euler equation, Null Lagrangian, natural boundary condition; Constraints and Lagrange multipliers; Noether theorem and conservation laws; Weierstrass-Erdmann condition; second variation, strong/weak minimizer; Necessary condition for a minimum, Legendre condition, Jacobi condition, conjugate points; Sufficient condition for a minimum, Weierstrass E-function. Field of extremals; convexity, strong ellipticity, minimizing sequences, lower semi-continuity, Singular minimisers.
ME625	APPLIED DYNAMICS AND VIBRATIONS	3-0-0-0-9	Review of single degree of freedom systems; Generalised coordinates, constraints, virtual work; Lagranges equation; Continuous systems; strings, beams; RaleighRitz and Galerkins methods; Dynamics of rigid bodies in three dimensions; Euler angles; Eulers equations of motion, Gyrodynamics.
ME626	VIBRATION OF CONTINUOUS SYSTEMS		Vibration of discrete systems with single and multi degree of freedom. Hamiltons principle, Langranges equations. Longitudinal vibration of bars, lateral vibration of straight and curved beams, vibration of membranes and plates, free and forced vibrations.

		3-0-0-0-9	Effect of damping. Wave motion in continuous systems.
ME627	NONLINEAR VIBRATION	3-0-0-0-9	Systems of ODEs, first order form, autonomous versus non-autonomous; Numerical solution; Phase space, singular points, stability, limit cycles; Analytical methods including harmonic balance, perturbation techniques (including Poincare-Lindstedt, averaging, multiple scales); Duffing's equation, multiple solutions and jump phenomenon; Van der Pol equation; resonances, modal interactions. Stability of periodic solutions, Floquet theory, Hill's and Mathieu's equations, Maps, Bifurcations and chaos.
ME630	COMPUTATIONAL FLUID DYNAMICS AND HEAT TRANSFER	3-0-0-0-9	Introduction: Governing equations for fluid flow and heat transfer, classifications of PDE, finite difference formulation, various aspects of finite difference equation, error and stability analysis, dissipation and dispersion errors, modified equations; Solutions of simultaneous equations: iterative and direct methods, TDMA, ADI; Elliptic PDE: One- and Two-dimensional steady heat conduction and their solutions, extension to three-dimensional; Parabolic PDE: Unsteady heat conduction, explicit and implicit methods, solution of boundary layer equation, unwinding; Solution of incompressible N-S equation: Stream function and vorticity formulation, primitive variable methods: MAC and SIMPLE.
ME631	VISCOUS FLOW THEORY	3-0-0-0-9	Introduction; Control volume analysis; Differential element analysis; Flow kinematics, Derivation of Navier-Stokes (NS) equations, initial and boundary conditions, calculation of forces, special forms of NS equations; Exact solutions of NS equations, fully developed flow, unsteady flow; Boundary-layer theory, inner and outer flows; flat plate, similarity variables, momentum-integral approach; flow over a circular cylinder; Linear stability theory and Orr-Sommerfeld equation; Turbulent boundary layers, Prandtl mixing theory, logarithmic law of the wall, effect of roughness, Moody's diagram
ME632	GEOPHYSICAL FLUID DYNAMICS	3-0-0-0-9	Equations of motion in rotating coordinate frames, Cartesian approximations, Density stratified flows and internal gravity waves, Taylor-Proudman theorem, Ekman layer, single and multiple layered shallow-water systems, Geostrophic adjustment and Thermal-wind balance, Potential vorticity, Poincare, Kelvin and Rossby waves, Kelvin-Helmholtz instability, Baroclinic instability, Wave-mean theory, 2D turbulence, chaotic advection in Stratosphere, Laplace tidal equations, Internal tides in deep oceans, tsunami waves
ME634	ADVANCED COMPUTATIONAL FLUID DYNAMICS		Finite difference (FDM) vs Finite volume (FVM) methods; Navier-Stokes (N-S) and energy equations; Hyperbolic system and time-dependent

		3-0-0-0-9	technique; explicit vs implicit method; central difference vs upwind scheme; Incompressible N-S equation: Steady and unsteady flow, artificial incompressibility; explicit methods: MAC and SMAC, implicit methods: SIMPLE and SIMPLER; Matrix and conjugate gradient methods; projection method; higher order discretisations. Compressible N-S equation: Finite volume formulations, geometric flexibility, Jameson's, MacCormack's, Steger and Warming schemes in FVM, flux splitting scheme and upwinding, different acceleration technique. Grid generation using algebraic and partial differential equations, transformation of N-S equation in curvilinear coordinate system, different solution techniques: explicit and implicit. Turbulence modeling.
ME639	LIQUID-VAPOUR PHASE CHANGE TECHNOLOGY	3-0-0-0-9	Introduction to two phase flow and heat transfer technology, Liquid vapor phase change phenomena, Interfacial tension, Wetting phenomenon, Contact angles, Transport effects, Dynamic behavior of interfaces, Phase stability and nucleation; Two phase flow fundamentals, Flow patterns and map representation, Development of homogeneous, separated flow and drift flux models, Flooding mechanisms; Boiling Fundamentals, Homogeneous and heterogeneous nucleation, Pool boiling and convective flow boiling, Heat transfer and CFH mechanisms, Enhancement techniques; Condensation fundamentals, External and internal condensation , Film condensation theory, Dropwise condensation theory, Enhancement techniques; Experimental techniques, Practical boundary conditions, Void fraction measurement techniques, Flow visualization techniques, Contact angle/Surface tension measurement, Conventional thermometry, Limitations, Data reduction, Application examples Application of two phase flow and heat transfer, Theory and operation of Boilers/Evaporators and condensers for Nuclear/Power/RAC industry, Electronics thermal management, Latent heat storage devices, Gravity assisted thermosyphons/ Vapor chambers, Conventional heat pipes, Micro heat pipes, Pulsating heat pipes, Capillary pumped loops/ Loop heat pipes, Micro two-phase heat exchangers Special related topics: for example, static and dynamic instabilities, microscale boiling and condensation , atomistic nucleation models, microgravity boiling, microfabrication/ integration techniques, contact resistance, surface roughness, Leidenfrost phenomena, etc.
ME641	CONDUCTION AND RADIATION		Conduction: Derivation of heat conduction equation. Summary of steady and unsteady equations of 1D-2D-3D conduction equation. Fins with variable

		3-0-0-0-9	cross-section. Multi-dimensional steady and unsteady problems in Cartesian and cylindrical coordinates. Semi-infinite solid. Duhamel's Superposition Integral. Solidification and Melting. Inverse heat conduction – method least squares and sensitivity analysis. Microscale heat transfer – phonon scattering. Radiation: Planck's law, Stefan-Boltzmann relationship, Radiative properties of surfaces. View factors for diffuse radiation. Radiation exchange in black and diffuse-gray enclosures. Enclosure theory for spatially distributed wall temperatures. Spectrally diffuse enclosure. Specularly reflecting surfaces. Participating media and radiative transfer equation. Radiative properties of molecular gases. The optically thin and optically thick approximations. Gas radiation. Combined Conduction and Radiation: Example of a spacecraft radiator. Solar radiation. Greenhouse effect
ME642	CONVECTIVE HEAT AND MASS TRANSFER	3-0-0-0-9	Introduction to convective heat transfer; conservation equations; boundary layers; free and forced convection; heat transfer in laminar and turbulent; internal as well as external flows; mixed convection; boiling and condensation; molecular diffusion in fluids; mass transfer coefficient; simultaneous heat and mass transfer; design of large- and small-scale motions in heat exchange devices; applications.
ME643	COMBUSTION	3-0-0-0-9	Introduction, review of thermodynamics, adiabatic flame temperature, chemical equilibrium, chemical kinetics, steady-state approximation, partial equilibrium, mass transfer, conservation equations and transport properties, laminar premixed flame, flame speed, ignition, quenching, flammability limits and stability, laminar non-premixed flame, conserved scalar concept, estimation of flame height, burning rate for a single droplet, turbulent premixed flames, Borghi diagram, flame height for turbulent non-premixed flames, liftoff and blowout phenomena, flame stabilization in turbulent flows, Soot and NO_x formation in premixed and non-premixed combustion
ME644	MACHINE LEARNING FOR ENGINEERS	3-0-0-0-9	Mathematical preliminaries, python programming, simple/multiple linear regression, nonlinear regression, logistic regression, k-nearest neighbours, perceptrons, random forest, naïve Bayes, support vector machines, artificial neural network, clustering, dimensionality reduction
ME645	SOLAR ENERGY TECHNOLOGY	3-0-0-0-9	Basic concepts, radiation spectrum, extraterrestrial radiation, sun earth relationship, Concept of time, terrestrial radiation, Diffuse and direct radiation, relationship between important angles, Angle of incidence on a tilted plane, shading, measurement

			of radiation, Radiation estimation on tilted plane, radiation augmentation, Flat plate collector, thermal analysis, Air heater, testing procedure, Single and double axes tracking, Parabolic trough collector, Compound parabolic concentrators, Basics of photovoltaic effect, Band bending, PN junction diode, bias, Light generated current, effect of temperature and intensity
ME647	AN INTRODUCTION TO TURBULENT FLOW	3-0-0-0-9	Origin of turbulence, instability and transition, irregularity, diffusivity, three-dimensional motions, dissipation, wide spectrum, length scales; Probability density, moments, correlations, integral micro scales, homogeneous and isotropic turbulence, Kolmogorov hypothesis, energy cascade, turbulence spectra; Reynolds decomposition, turbulent stresses, Reynolds equations, mixing-length model, dynamics of turbulence; Mixing layer, turbulent wakes and jets, grid turbulence; Channel and pipe flows, Reynolds stresses, turbulent boundary layer equations, logarithmic-law of wall; Introduction to turbulence modelling and experimental methods.
ME648	COMPUTER AIDED DESIGN OF THERMAL SYSTEMS	3-0-0-0-9	Introduction. Basic Considerations in Design. Modelling of Thermal Systems. Numerical Modelling and Simulation. Acceptable Design of a Thermal System: A Synthesis of Different Design Steps. Optimization.
ME649	EXPERIMENTAL METHODS IN THERMAL SCIENCES	3-0-0-0-9	Introduction, Details of an experimental setup, Static versus dynamic calibration, Design of experiments. Uncertainty analysis, Central limit theorem, Normal and Student's-t distribution, Data outlier detection, Error propagation. Temporal response of probes and transducers, Measurement system model, zeroth, first, and second order systems, Probes and transducers, Pressure transducers, Pitot static tube, 5-hole probe, Hotwire anemometer, Laser Doppler velocimetry, Particle image velocimetry, Thermocouples, RTD, Thermister, Infrared thermography, Heat flux measurement, Interferometry, Schlieren and shadowgraph techniques, Measurements based on light scattering, Absorption spectroscopy, Mie scattering, Rayleigh, Raman and other scattering methods, Data acquisition systems, Analog to digital converter, Resolution, Quantization error, Signal connections, Signal conditioning, Digital signal and image processing, Curve fitting (regression), Fourier analysis, FFT algorithm, Inverse FFT, Nyquist criterion, Numerical aspects of FFT, Probability density function, Auto- and cross-correlations
ME653	MOLECULAR SIMULATIONS IN	3-0-0-0-9	(a) Introduction and Motivation (b) Statistical Mechanics Foundation for Molecular Simulations; Common

	MECHANICAL ENGINEERING		Statistical Ensembles II. Simple Thermodynamic Averages and Fluctuations III. Structural Quantities, Time Correlation Functions and Transport Coefficients IV. Long-range and Quantum Corrections (c) Classical Molecular Dynamics Simulations I. Introduction II. Potentials III. Integration Algorithms and Boundary Conditions IV. MD simulations in various Ensembles (d) Monte Carlo Simulations I. Introduction II. Basic Monte Carlo Algorithm III. Trial Moves IV. MC simulations in various ensembles (e) Applications I. Computation of Elastic Constants of Solids, Elastic-plastic response of Materials II. Thermal Conductivity and other transport coefficients in Materials.
ME655	BUBBLES AND DROPLETS	3-0-0-0-9	The course starts with a brief review of the thermodynamics of phase change, the Navier-Stokes equations and its analytical solutions for cases relevant to the motion of droplets and bubbles. This is followed by discussion on processes involved in the formation of bubbles and droplets. Bubble dynamics under various conditions and the behavior of bubbles and droplets moving in a flow field are discussed elaborately. Subsequently the problem of droplet vaporization is taken up. The course is closed with discussion on one or more of special topics on experiments and simulations involving bubbles and droplets.
ME656	INSTABILITIES IN FLUID DYNAMICS	3-0-0-0-9	Phenomenology; The concept of stability; The rotating pendulum problem; Kelvin-Helmholtz instability; Instability of Taylor-Couette flow; Rayleigh-Bénard instability; Capillary instability of a jet; Weakly nonlinear analysis; Bifurcation theory; Instabilities in shear flows and non-modal stability analysis
ME659	TRIBOLOGY OF MACHINING PROCESSES	3-0-0-0-9	Fundamentals of machining, Mechanics of metal cutting, Thermomechanical analysis, Chip formation, Basic tribo-interaction in machining, Governing factors at machining interfaces, Methods for predicting friction, Frictional regimes, Friction models, Special tribometry, Cutting tool wear, Wear modes and characterization, Wear models, Wear monitoring and control, Modern lubri-coolant methods, Sustainability aspects in machining, Influence of lubri-coolant method of machined surface integrity, Surface engineering, Development of modern cutting tools, Laser processing and coatings, Coating degradation mechanisms, Experimental techniques in machining, Wear map generation, Split tool, Quick stop method, Ballistic machining, Chip geometry control, Surface and sub-surface characterization, Formation and detection of adiabatic shear banding

ME661	MACHINING SCIENCE I	3-0-0-0-9	Introduction to machining; Tool Geometry; Orthogonal cutting, friction, and temperature in metal cutting; Oblique cutting mechanics; Numerical modelling; Practical machining operations (turning, boring, drilling, milling); Measurement: Tool material, tool wear and tool life; Special topics; Laboratory topics.
ME662	MACHINING SCIENCE II	3-0-0-0-9	Introduction to advanced manufacturing processes, Mechanical Material Removal Processes (AJM, USM and WAJM), Electrochemical Machining Process (ECM, EDG, ESD), Thermal Material Removal Processes (EDM, EBM, LBM), Nanomanufacturing and self-assembly, PCB fabrication and vacuum forming.
ME663	METAL FORMING	3-0-0-0-9	Fundamentals of plasticity, yield and flow, anisotropy, instability, limit analysis. Applications to metal forming processes such as, forging, wire drawing, deep drawing, extrusion and rolling. Introduction to Finite Element Modelling of metal forming processes.
ME664	FUNDAMENTALS OF CASTING & SOLIDIFICATION	3-0-0-0-9	1. Introduction to casting problem: Principles of solidification, Introduction to fluid flow and microstructure in a casting process. 2. Solidification transport phenomena in casting: Solidification of pure metals and alloys, Nucleation and growth, Nature of solid-liquid interface, Constitutional undercooling, Dendritic growth, Directional solidification, Mathematical treatment of solidification transport phenomena involved in a casting process (mass and heat transfer, fluid dynamics, mushy zone), Mathematical analysis of distribution of solute during solidification, Micro and macro segregation. 3. Defects: Casting defects (compositional, microstructural, mould filling, shrinkage and other flow and heat transfer related defects), their causes and remedies, and Understanding the role of transport phenomena in the formation of these defects. 4. Some selected casting processes: Mold, die and investment casting, Direct chill casting, Ingot casting, Directional solidification, Micro casting, Manipulation and control of casting structure, properties and defects through advanced casting processes – inoculation practices, rheocasting, thixocasting, Multiphysics casting processes involving magnetic fields. 5. Casting design by controlling accompanied heat transfer, fluid flow and

			solidification: Mathematical treatment of solidification rates-exact and approximate methods, Mold-casting heat transfer, Riser design, Feeding distance, Mold filling and their relation with temperature distribution and dimensional design of the casting.
ME666	INVISCID FLOWS	3-0-0-0-9	Vorticity, vorticity equation, Kelvin’s theorem, Helmholtz laws, kinematic decomposition of velocity fields, uniqueness of solenoidal and irrotational velocity fields, superposition of irrotational flows, complex analysis, conformal transformations, finite wings, three-dimensional potential flows, unsteady potential flows, virtual mass, cavitation and bubble dynamics, waves in fluids
ME668	MACHINING DYNAMICS	3-0-0-0-9	Machining process modeling and analyses, Review of free and force vibration analysis, Experimental Modal analyses, Machining dynamics and regenerative chatter vibrations in turning, Process-machine interactions in milling
ME669	MODELING THERMAL TRANSPORT IN MANUFACTURING PROCESSES	3-0-0-0-9	1. Review of fundamentals of thermal transport in manufacturing: Introduction to the course – Importance of heat transfer in manufacturing and applications, Steady and transient heat conduction, Convection and Radiation, Fluid flow and Mass transfer. 2. Finite Difference and Finite Volume based modelling of heat transfer in manufacturing and numerical implementation: Basic introduction to FDM and FVM techniques, Mathematical formulation of thermal transport, Governing equations and general scalar transport equation, Steady and unsteady problems, Initial and Boundary conditions, Convection-diffusion problems, Mesh terminology, Accuracy, Consistency, Stability and Convergence, Phase change – Enthalpy based algorithm for melting/solidification, Two-phase mushy zone flows, Liquid-vapour phase change involved in manufacturing, Illustration using code. 3. Case studies on modelling and simulation of thermal transport in manufacturing processes: Solidification processing – Modelling of moving melting/solidification phase change interface, Alloy solidification, Segregation, Two-phase mushy zone flow, Modelling of casting, Marangoni convection driven flow, Modelling of welding, Heat assisted manufacturing process –Thermal modelling using enthalpy method for solid-liquid and liquid-vapour phase change interface, Melt pool formation and

			flow behaviour, Beam heat flux models, Thermal modelling in Laser Melting (LM), Electron Beam Melting (EBM), Machining: Electric Discharge Machining (EDM) and Heat assisted micro manufacturing process, Thermal deposition process – Modelling of free surface evolution, Modelling of droplet impact and deposition on substrates.
ME670	ADDITIVE MANUFACTURING	3-0-0-0-9	1. Introduction to Additive Manufacturing (AM): General overview, Introduction to reverse engineering, Traditional manufacturing v/s AM, Computer-aided design (CAD) and AM, Different AM processes and relevant process physics, AM process chain, Application level: Direct processes – Rapid prototyping, Rapid tooling, rapid manufacturing, Indirect processes – Indirect prototyping, Indirect tooling, Indirect manufacturing. 2. Materials science for AM: Discussion on different materials used for AM, Use of multiple materials, multi-functional and graded materials in AM, Role of solidification rate, Evolution of nonequilibrium structure, Structure-property relationship, Grain structure and microstructure. 3. AM technologies: Powder-based AM processes involving sintering and melting (selective laser sintering, laser engineered net shaping, electron beam melting, high energy beam involvement), Printing processes (droplet-based 3D printing), Solid-based AM processes, Extrusion based fused deposition modelling (FDM), Laminated object manufacturing (LOM), Stereolithography. Micro and nano additive manufacturing processes. 4. Mathematical models for AM: Transport phenomena models: temperature, fluid flow and composition, buoyancy-driven flow, surface tension driven free surface flow (study of molten pool), Case studies: Numerical modelling of fusion based AM process, Powder bed melting based process, Droplet-based printing process, Residual stress, Part fabrication time, Part fabrication cost, Optimal orientation and optimal layer thickness, Defect in AM and role of transport phenomena on its formation, Simulations (choice of parameter, experimental data and comparison between simulation and experiments), Model validation for different aspects. 5. Process selection, planning, monitoring and control for AM: Selection

			of AM technologies using decision methods, Additive manufacturing process plan: Building strategies and post-processing, Monitoring and control of defects, geometry, temperature, composition, and phase transformation.
ME671	EXPERIMENTAL STRESS ANALYSIS	3-0-0-0-9	Introduction to stress and strain and need for experiments. Localized measurement of deformation, electrical resistance strain gages including bridge configurations and strain amplifiers, LVDT and capacitance-based sensors, load cells. Measurement displacement: geometric Moiré,digital image correlation. Measurement of stress: photoelasticity in transmission and reflection.Techniques for evaluating material response at small volumes: nano-indentation, atomic force microscopy. Statistical analysis of experimental data. Measurement of displacement: Geometric Moiré, digital image correlation in 2D and 3D. Measurement of stress Photoelasticity: representing light using electric field, plane and circularly polarized light,interference, light propagation in optically an-isotropic media, stress optic law, analysis of plane and circular polariscope, fringe counting and calibration of optical constant, stress analysis using transmission and reflection photoelasticity, stress separation methods. Statistical analysis of experimental data Statistical distributions, confidence intervals for predictions, comparison of means, statistical conditioning of data, regression analysis, error propagation. Evaluating material behaviour at small volumes Nano-indentation: basic principles of instrumented indentation, data reduction methods for mapping properties such as hardness, modulus and fracture toughness. Atomic force microscopy: Basic principles and applications.
ME672	MICROMANUFACTURING PROCESSES	3-0-0-0-9	Introduction to micro and nano manufacturing; Traditional and micromachining processes; Nanomachining and nano finishing processes; Micro joining; Micro forming; Micro casting and micro molding; Miscellaneous topics in micro/nano manufacturing and measurement.
ME673	TRANSPORT IN POROUS MEDIA	3-0-0-0-9	Representative elementary volume (REV), Mass, momentum and energy transport, Darcy and Non-Darcy equations, equilibrium and nonequilibrium

			conditions, species transport, radioactive decay, equivalent thermal conductivity, viscosity, dispersion, Flow over a flat plate, flow past a cylinder, boundary-layers, reservoir problems, Field scale and stochastic modeling, Turbulent flow, compressible flow, multiphase flow, numerical techniques, hierarchical porous media, nanoscale porous media, multiscale modeling, Groundwater, waste disposal, oil and gas recovery, regenerators, energy storage systems, Flow visualization, quantitative methods, inverse parameter estimation
ME674	FLUID MECHANICS OF FLAPPING FOILS	3-0-0-0-9	Flapping foils in nature, airfoil and wing theory, vortex dynamics, governing equations and parameters, kinematics, vortex wakes, drag to thrust transition, thrust by forward moving foils, unsteady actuator disk theory, efficiency estimates, scaling laws, thrust generation in quiescent ambient, deflected wakes, unsteady mechanisms, flapping flexible foils, fluid-flexible-structure interaction, 3D foils, foils in tandem, biomimetic applications.
ME676	NON-LINEAR FINITE ELEMENT METHODS IN SOLID MECHANICS	3-0-0-0-9	Review of FE techniques for linear elasticity; Review of continuum mechanics —kinematics, balance laws, stress measures, Clausius Duhem inequality, frame indifference, stress rates and constitutive equations; Introduction to directional derivatives, formulation of variational principles for nonlinear problems and linearisation; Linearisation of variational principles for nonlinear problems; Generalised Newton Raphson scheme; Applications to hyperelasticity, metal plasticity and crystal plasticity; Issues of convergence rates, measures and patch tests; Techniques for dealing with locking issues;Using and incorporating UMAT and UEL subroutines in ABAQUS.
ME679	DAMAGE MECHANICS OF COMPOSITE MATERIALS	3-0-0-0-9	Introduction to composite materials Composite materials and their internal architecture, advantage as structural material, 3D orthotropic constitutive matrix, uni and multidirectional laminates, lamination theory ; Intra and Inter-laminar damage mechanisms Recapitulation of fracture mechanics, delamination, matrix cracking, fractographic observations, fibre compressive failure, fibre tensile failure, dynamic loading and impact damage, benchmark experiments to extract fracture parameters, laminate size effect on failure, effect of manufacturing induced defects on failure; Modelling delamination and matrix cracking Concept of quasi-brittle material and origin of cohesive zone model, adaptation to composites delaminaton and matrix cracking, different onset and propagation criteria, development of 3D mixed mode bilinear cohesive constitutive law, virtual crack closure technique (VCCT), analytical models for residual strength prediction; Fibre

			tensile and fibre compressive failure Onset strength and Weibull statistical theory for fibre tensile failure, fibre microbuckling and fibre kinking failure theories under compression, influence of shear nonlinearity;Essentials of continuum mechanics Deformation, strain and stress measures, large deformation and objective stressrates; Continuum damage mechanics Idea of continuum damage, strain equivalence principle, isotropic and anisotropic damage effect tensor, thermodynamic basis of continuum damage ; Finite element modelling framework for damage Governing equation for dynamic equilibrium, weak form for a body including cracks, finite element discretisation, formulation 3D isoparametric finite elements, dynamic explicit finite element method [5] Implementation of composite damage models Implementing damage models in commercial finite element programme via user defined material and user defined element packages, several aspects of damage modelling, demonstrative 3D simulation of benchmark failure cases [10]
ME681	MATHEMATICS FOR ENGINEERS	3-0-0-0-9	Linear Algebra: Vector space and its basis; Matrices as coordinate-dependent linear transformation; null and range spaces; Solution of linear algebraic equations: Gauss elimination and Gauss-Jordon methods, LU decomposition; Determinants; Eigenvalues and eigenvectors of matrices and their properties; Similarity transformation; Jordon canonical form and orthogonal diagonalization, symmetric matrices. Vector Calculus: Curves and surfaces; Gradient, divergence and curl, Line, surface and volume integrals; Gauss (divergence), Stokes and Green's theorems. Ordinary Differential Equations (ODEs): Techniques of the separation of variable and the integrating factor for 1st order ODEs; Solutions of linear, 2nd order ODEs with constant coefficients and Euler-Cauchy ODEs; System of 1st order ODEs, Homogeneous, linear, 2nd order ODEs with variable coefficients: power series and Frobenius methods; Sturm-Louville problem; Laplace transform method for non-homogeneous, linear, 2nd order ODEs. Partial Differential Equations (PDEs): Fourier series, integrals, and transforms; String vibration equation; heat equation; Laplace's equation.
ME682	DIFFERENCE EQUATIONS FOR ENGINEERS	3-0-0-0-9	Analogies between differential and difference equations, Elementary Difference Operations; Difference and shift operators, Difference Calculus, Summation, Interpolation, Extrapolation, Generating

			functions; Linear difference equations, First order and Higher Order Difference Equations; Linear difference equations with constant coefficients, Linear difference equations with variable coefficients, Method of undetermined coefficients and Method of variation of parameters, Limiting behavior of solutions; Systems of Linear difference equations; z-transform, Fourier analysis; Non-linear difference equations and boundary value problems; Asymptotic methods, Stability theory and simple dynamical systems; Partial Difference Equations; Lagrangian and Hamiltonian Formalism for Difference Equations; Differential-difference equations.
ME683	TECHNIQUES IN NON-DESTRUCTIVE EVALUATION	3-0-0-0-9	Need for NDE, overview of existing NDE methods, and some applications; Overview on measurements of displacement, stress, and strain; General solutions of hyperbolic and parabolic PDE; Basics of signal processing: Fourier transforms. Christoffel equation, boundary conditions. Sensors: Generation and reception. Near-field and far-field measurements; Time-of-flight method: Basics, imaging, and applications; Phased array: Theory and applications; EMAT: governing equations, construction of transducers, and applications; Guided waves: dispersion relations and applications; Synthetic aperture focused technique; Metamaterials in ultrasound imaging. Thermography: From black radiation to principles of thermal imaging; Fourier heat diffusion and boundary conditions; Contact and non-contact thermal techniques; Pulsed, pulsed-phase and vibrothermography: theory, experiments and processing data; Fabrication of sensors; Basics of instrumentation and optics; Digital image correlation; Discrete Fourier transforms and phase based amplification; Measurement of mechanical properties from digital images; Acoustic characterization; Resonant ultrasound spectroscopy; Hybrid techniques: eddy-current thermography, laser-ultrasonics; In-situ NDE: 3D printing, welding.
ME685	APPLIED NUMERICAL METHODS	3-0-0-0-9	Introduction to numerical techniques. Mathematical modeling; Taylor series approximation; root finding; linear algebraic equations; regression analysis and curve fitting; numerical differentiation, integration, ODEs, and PDEs; eigenvalue problems; computing on parallel architectures.
ME686	ENERGY STORAGE SYSTEMS	3-0-0-0-9	Multiobjective optimization, Robust design techniques (variation reduction techniques), Optimal control, stochastic programming. Role of Optimization inCAD: Why optimization? Optimization Geometric modelling Analysis. Implementation Issues: computational time versus accuracy, Interfacing with geometric modelling and

			analysis softwares, Graphics interfacing, Choice of Hardware platform. Application to engineering design problems, comparison with existing solutions.
ME687	MODELLING OF MULTIPHYSICS SYSTEMS	3-0-0-0-9	Introduction and dimensional analysis and review of numerical method: Review on vector calculus, scalar/vector fields, linear algebra, notation system, Taylor series, numerical methods for simultaneous linear equations, first/second order ODE and PDE, dimensional analysis; Review and modelling of simple systems: Conservation laws of mass, momentum and energy, thermal transport (Fourier's Law and Diffusion Equation), mass transport (Fick's Law, diffusive and convective mass balance), definitions of displacement gradient, strain (Euler/Lagrange), stress (nominal, PK-1/2), momentum conservation, Generalized Hooke's Law and Navier's equation, plane stress/strain, continuity and Navier Stokes equations, steady and transient flow models, electrodynamics, Maxwell's equations, electrochemical transport and kinetics, Butler Volmer and Tafel models, applied numerical problems for each physics; Modelling of coupled multiphysics systems: Thermal-elastic systems, gas-driven and thermal strain-driven actuating devices, Electrostatic-elastic systems, capacitive mass-spring and plate systems, stability analysis and bifurcation diagrams, Fluid-thermal systems, natural convection, Fluid-structural systems, Electrochemical-thermal-mechanical systems; Computational application of multiphysics problems: Numerical modelling of coupled systems, one-way and two-ways coupling, dimensional analysis and problem simplification; Multiscale modelling: Introduction to molecular dynamics.
ME688	COMPRESSIBILITY AND HIGH-SPEED FLOW	3-0-0-0-9	The fundamental of compressible flow, conservation laws, steady and unsteady inviscid subsonic and supersonic flows, method of characteristics, small-perturbation theories, linearized velocity potential flow, shock waves dynamics and wave structure, Prandtl-Meyer function, Reflected and intersecting shocks, self-similar compressible flows, compressible flows in ducts with area changes, friction and heat addition, compressible boundary layer, viscous and compressibility effects, shock wave-boundary layer interactions, turbulent flows, numerical techniques, transonic and hypersonic flows.
ME689	MICROSCALE TRANSPORT PHENOMENA	3-0-0-0-9	Introduction, Microfluidics, Microscale heat conduction, Microscale convection, Microscale mass transfer, Microscale radiation, Surface tension driven flows, Electro-kinetics, Magneto-fluidics

ME690	ALTERNATIVE FUELS & ADVANCE IN IC ENGINES	3-0-0-0-9	Combustion and Fuels: Combustion process in SI and CI engines, Petroleum based liquid fuels and refining; Liquid alternative fuels such as vegetable oils, biodiesel, and emulsified fuels, lubricating oils composition and effect of alternate fuels; Gaseous alternative fuels such as hydrogen, compressed natural gas, liquefied petroleum gas, di-methyl ether, and hythane; Modern developments in IC Engines such as EGR, MPFI, GDI, HCCI and Turbo-charging; Optical measurement techniques and tools: Particle image velocimetry, 3D and Holographic PIV, spray visualization, phase doppler interferometry for spray characterization, Optical engines and engine endoscopy; Pollution monitoring instruments and techniques, Control measures such as DOC, DPF, SCR and LNT.
ME691A	ENGINE MANAGEMENT	3-0-0-0-9	Diesel Engine Management: cylinder charge control systems, principles of diesel fuel injection, mixture distribution, diesel fuel injection systems, governors and control systems, discrete cylinder systems, single plunger fuel injection pumps, unit injector systems, unit pump systems, common rail systems, injection nozzles, minimizing emissions inside the engine, electronic diesel control (EDC), electronic control unit (ECU); Gasoline Engine Management: cylinder charge control systems, manifold fuel injection, gasoline direct injection, operation of gasoline engine on natural gas, ignition system, inductive ignition systems, different types of sensors such as temperature sensors, engine speed sensors, hall effect phase sensors, hot film air mass sensors, piezo-electric knock sensor, high-pressure sensor, lambda sensor, Electronic control unit, operating conditions, design and data processing.
ME692	WELDING TECHNOLOGY	3-0-0-0-9	Types of welding: Fusion welding process, Resistance welding, Chemical fusion welding, Beam welding process, Friction welding, Pressure welding. Thermal analysis of weldment: Modes of heat transfer during welding, Temperature profile in welding process. Fluid flow analysis of weldment: Forces contribution during welding, Convection. Microstructure evolution in welding: Thermodynamics of solidification, Driving force for solidification, Phase diagram of alloys, Constitutional undercooling, Microstructures in weld. Zones in a weldment: Peak temperature, cooling rates, zones in fusion welding, and effect of weld pool shape on microstructure. Stresses in welding: Residual stresses in welding, Distortion. Weld joint design: Type of weld joints, Weld design

			guidelines, Size of weld, and amount of welding. Other joining processes: Adhesive bonding and their mechanism, Welding of dissimilar materials, Welding polymers and other non-metallic materials, Defects in welding and weld testing: Welding defects, Weldability testing.
ME775	LASER AIDED MANUFACTURING	3-0-0-0-9	General overview, Fundamentals of lasers, laser-material interactions, laser plasma interactions, Brief review of materials, manufacturing processes and thermal modelling, Laser cutting and drilling, Laser micromachining, Laser-based joining, Laser forming, Laser additive manufacturing, Laser processing of metal surfaces, Laser safety, Laser automation and in-process sensing.
ME699	M TECH THESIS	0-0-0-0-9	M. Tech. Thesis
ME701	DESIGN FOR MANUFACTURE & ASSEMBLY	3-0-0-0-9	Introduction, Product design process, Selection of materials and shapes, Design for X, Modeling and simulation, Design for reliability
ME702	MECHANICAL ENGINEERING POSTGRADUATE SEMINAR	0-0-0-0-0	Seminars on state-of-the-art research themes and original research work
ME711	COMPUTATIONAL TURBULENCE	3-0-0-0-9	Introduction to turbulent flow and modelling, review of momentum and energy equations, statistical description of turbulence, energy cascade, RANS and URANS, Reynolds Stress (RS) equations and closure problems, turbulent kinetic energy equations, dynamics of turbulence, coherent and incoherent structures; review of computational method: SIMPLE and MAC; RANS-based turbulence modelling: (a) zero-equation model, (b) one- and (c) two-equation models (k-ε, k-ω models), closure models, application for free-shear and wall-bounded flows, direct numerical simulation: higher-order discretization and stability; large eddy simulation (LES): LES filtering, explicit and implicit filtering, LES equations, Smagorinsky model and its variants (DSM, SISM), dynamic model, grid independent LES, applications to free-shear and wall-bounded flows and hybrid LES.
ME720	THERMODYNAMICS OF CONTINUOUS MEDIA		Introduction to the Course and Some Applications of Difference Equations in Engineering, Preliminaries in linear algebra and analysis, Analogies between differential and difference equations, Elementary Difference Operations: the Difference and the Shift operators, The Difference and Summation Calculus, Linear difference equations, First order equations, Higher Order Difference Equations, Linear difference equations with constant coefficients, Linear difference equations with variable

		3-0-0-0-9	coefficients, Method of undetermined coefficients and variation of parameters, Generating functions, The z-transform and its applications, Systems of Linear difference equations and applications, The Sturmian theory and Fourier techniques, Asymptotic methods, Limiting behavior of solutions, Nonlinear difference equations and boundary value problems, Stability theory and relevance to dynamical systems, Partial Difference Equations, Differential-difference equations, Discrete Mechanics, Open problems.
ME724	MECHANICS OF THIN STRUCTURES	3-0-0-0-9	Three-dimensional nonlinear elasticity in curvilinear coordinates; Differential geometry of surfaces; Linear theories of plates and shells; Nonlinear membrane theory; Shell theory
ME721	THEORY OF PLASTICITY	3-0-0-0-9	Phenomenology of one dimensional elastoplasticity; Idealised plastic behaviour and the idea of tangent modulus;Hardening rule; Yield criteria; Haigh Westergaard stress space; Elasto-plastic stress strain relations;Drucker's postulates;Maximum plastic dissipation postulate;Stress-strain relations for perfectly plastic materials; Incremental stress strain relation for isotropic material; Dissipation in plasticity; Incremental relations for a material with internal variables; Deformation theory of plasticity; Problem Uniqueness and boundness theorem in plasticity; Principle of virtual power; Lower bound theorem; Upper bound theorem; Limit analysis of beams; Slip line fields; Numerical techniques in small strain plasticity
ME722	DYNAMIC FRACTURE MECHANICS		Overview and history, Discussion on inertial effects. Mathematical preliminaries. Basic linear elastodynamics, Waves in Periodic Structures, Causality Principle. One-dimensional Models. Static Cracks in a Linearly Elastic Body, Stress Intensity Factors and Crack Tip Singularity, Energy Release, General Crack System, Cohesive Zone Model. Elastodynamic solutions for a stationary crack, Scattering of a pulse and a time harmonic waves, Fracture initiation due to dynamic loading. Elastodynamic crack growth, the asymptotic crack tip field, Dynamic energy release rate. One-dimensional Discrete Models, Mode III fracture in square cell elastic lattice. Scattering of lattice waves. Instabilites in dynamic fracture. Modern topics and challenges in dynamic fracture.

ME723	WAVE PROPAGATION IN SOLIDS	3-0-0-0-9	Harmonic and non-harmonic motions, differences between waves, vibrations, and oscillations. Concepts on time period, wavelength, spatial and temporal frequencies; Derivation of one-dimensional wave equation in a string. The general form of wave displacement. Plane, cylindrical, and spherical waves with examples. Concepts of longitudinal and transverse waves, and particle, group, and phase velocities.; Review of elasticity - 4 conservation laws. Derivation of Naviers equation and Christoffel equation. Difference between elastodynamic and acoustic waves. Types of boundary conditions.; Derivation of D'Alembert's solution for one-dimensional wave and implications.; Dispersion analysis for string. Concepts of attenuation with imaginary parts of frequency and wavenumber.; Dispersive and non-dispersive waves in a viscoelastic medium. Longitudinal dispersive waves in rods, flexure waves in beams on a foundation.; Phase speeds for isotropic materials: Navier's equation and Helmholtz decomposition. Slowness diagrams; Phase speeds for anisotropic materials from Christoffel equation. Linear, elliptical, and circular polarizations of waves. Quasi-shear and quasi-longitudinal modes; Applications of Helmholtz decomposition. Waves in bulk medium. Waves in two dimensions – Rayleigh and Lamb waves. Guided waves. Basic governing acoustics in elastic fluids.; Reflection at a fluid-fluid interface. Derivation of Snell's law. Critical angles. evanescent waves, reflection characteristics at fluid-fluid, fluid-solid, solid-solid, and solid-fluid interfaces for P and SV/ SH waves. ; Energy flux, intensity, and Poynting vector. Velocity coefficients; Scattering - Absorption. Thermoelastic and Akhisier mechanisms. Derivation of absorption coefficient using Christoffel equation in terms of density and complex stiffness matrix. Choice of time dependence; Forward and backscattering, and applications. Scattering of shear horizontal waves by long cylindrical cracks.; Integral transform techniques. Application of Laplace and Fourier transform techniques for wave equations. Concepts of and problems using the Cagniard De Hoop method to identify Green's function; Theory for experimental characterization: Ultrasonic time-of-flight diffraction, guided waves, resonant ultrasound spectroscopy.; Advanced topics. One of the shock waves/nonlinear waves/thermal waves/waves in discrete media.
ME724	MECHANICS OF BIOLOGICAL MEMBRANES		Classical linear and nonlinear theories of plates and shells will be derived in a conceptually clear manner without various ad hoc assumptions made in the historical development of the subject. The course will be useful to anyone interested in the mechanical deformation of thin structures appearing commonly

		3-0-0-0-9	around us in both the man-made and the biological world.
ME726	HAMILTONIAN MECHANICS AND SYMPLECTIC ALGORITHMS	3-0-0-0-9	Vector fields and differential forms, exterior calculus, differential equations and associated flow, symplectic manifolds; Lagrange's Equations, Hamilton's Equations, Canonical Transformation, Legendre Transformation, Symplectic Transformations, Poincare-Cartan invariant, Hamilton-Jacobi equation, Simple example of Integrable systems; Symplectic Integrators, Application to N particle dynamics and other examples; Symplectic Runge-Kutta methods, Generating Functions, Variational Integrators.
ME727	COMPOSITE MATERIALS	3-0-0-0-9	Introduction : Need for composites, Types of composites, Metal matrix, Ceramic matrix and Carbon-Carbon composites; Polymer matrix composites;Constituent materials and fabrication methods :Characteristics of thermosetting and thermoplastic resins, Characteristics of Glass,Carbon and Kevlar Fibers, method of making and properties, types of fiber mats. Manufacturing of fiber composites: Hand layup, Pressure bag, Vacuum Bag and Autoclave processes, Pultrusion, Filament Winding, Bulk and Sheet moldingcompounds, Prepregs etc, including a video demonstration of a hand layup process.;Micromechanics of continuous unidirectional fiber composites :Prediction of elastic properties using strength of materials approach, Introduction to elasticity based approach for prediction of elastic constants (concentric cylinder model), Empirical relations (Halpin-Tsai) for elastic property prediction, Comparison of different approaches with examples, Prediction of strength and discussion on failure modes, Prediction of thermal and diffusion properties;Short fiber composites : Load transfer length, Prediction of elastic properties,Elastic property calculation for random fiber composites;.Analysis of orthotropic lamina : Generalized Hooke's law, Material symmetry, Orthotropic materials and transversely isotropic materials, Transformation of stress and strain,Stress-strain relations for transversely isotropic lamina under plane stress in material axis and off-axis, Failure theories (Maximum stress, strain, Tsai-Hill and Tsai-Wu);Analysis of laminated composites : Description of laminate sequence and type of laminates (UD, Symmetric and Asymmetric, Balanced, Quasi-Isotropic) etc., Classical laminate theory (CLT), Failure

			analysis of laminates using CLT: First ply failure, progressive failure analysis, Hygro-thermal stresses in laminates, Discussion on interlaminar stresses ;Additional topics : Characterization methods- Test methods for determining elastic constants and strength, Fracture oriented failure- Strength of notched composite laminates.
ME728	FRACTURE AND FATIGUE	3-0-0-0-9	Background; Griffith theory of fracture, energy release rate (ERR), conditions for stable and unstable crack growth, crack arrest; Linear elastic fracture mechanics : William’s analysis of stress field at the tip of a crack Solution of stress and displacement field for plane cracks using complex methods in plane elasticity (Westergaards or Kolosov-Muskhelishvili approach), Stress intensity factor (SIF) for plane and penny shaped cracks, Equivalence of SIF and ERR, fracture toughness ;Elasto-plastic fracture mechanics : First order estimate of crack tip plastic zone using Irwin’s and Dugdle’s approach, Plastic zone for plane stress and plane strain situation and effect on fracture toughness, Review of small strain plasticity, Crack tip fields in an elasto-plastic material (Discussion on HRR fields), J-integral as a fracture parameter and crack tip opening displacement; Mixed mode fracture : Prediction of crack path and critical condition for crack extension under mixed mode loading using Maximum tensile stress, Minimum strain energy density and Maximum energy release rate criteria;Experimental measurement of SIF and fracture toughness : SIF measurement using strain gages, optical techniques, Evaluation of fracture toughness ;Fatigue crack growth : Mechanism of crack nucleation and growth under cyclic loading, Determination of life of a cracked solid using Paris-Erdogan law and its variants; Advanced topics (one from the following) : Computational fracture mechanics, Dynamic fracture, Bi-material fracture.
ME729	MODELLING OF MECHANICAL PROPERTIES OF MATERIALS	3-0-0-0-9	Concepts of eigenstrains, representative volume element, averaging, Methods of obtaining average stiffness of materials with multiple elastic phases, voids and cracks, Bounds on overall properties, Computational homogenisation Module ; Viscoelastic phenomena, creep, relaxation, dynamic response Constitutive models for viscoelastic materials Modelling dynamic behaviour of viscoelastic solids Solving problems in viscoelasticity using the correspondence principle Viscoelastic response of materials with multiple phases Module ; Introduction to Finite Strain Stress Tensors Strain energy functions for isotropic materials Strain energy functions

			for anisotropic materials Micromechanical Theories for soft materials Mechanics of growing mass Hyperelastic solids with surface stresses Statistical Mechanics of rubber-like materials; Module; Phenomenological Theory of Plasticity Elastic Models of Dislocations Dislocation core Dislocation configurations and interactions Crystal Plasticity Polycrystal plasticity.
ME730	MODAL ANALYSIS: THEORY AND PRACTICE	3-0-0-0-9	Theoretical basis for modal analysis; FRF measurement considerations; Modal parameter extraction and derivation of mathematical models; Applications and advanced topics
ME741	INTERNAL COMBUSTION ENGINES, POLLUTION AND CONTROL	3-0-0-0-9	Fundamental Principles of Engine Design: Stages of Combustion, Combustion Equations, Heat of Combustion, Thermodynamic analysis of SI Engine combustion process: Thermo-Chemistry; Chemical Equilibrium, Equilibrium Combustion Products, Flame Propagation in Engines, Unburned and Burned Mixture States, In-cylinder Flow-Field Measurement: Fuel Injection, Measurement of In-cylinder Mixture Distribution, Fuel-Air-Mixing and Burning Rates in CI Engines, Engine Combustion and Flame Visualization. Data Acquisition System: Combustion and Heat Release Analysis in Engines. Major Pollutants & Formation Mechanisms, Measurement and Test Procedures. Control of Emissions from SI and CI Engines: Thermal Reactors, Catalytic Converters and Catalysts, and Fuel Modifications
ME742	BOILING & CONDENSATION	3-0-0-0-9	Applications of boiling and condensation; Difference between evaporation and boiling; Comparison of Nucleate and Flow boiling; Pool boiling: Nukiyama Experiment; Theory of vapour bubble formation: Homogeneous and Heterogeneous Nucleation; Bubble Growth Models; Mechanism of Critical Heat Flux (CHF); Various models and correlations; Pool Boiling of Binary Mixture; Flow Boiling: homogeneous and heterogeneous models; Flow Boiling in Microchannels; Flow Boiling of Binary Mixtures; Boiling enhancement techniques; Film and dropwise condensation; Nusselt's analysis of laminar film condensation on vertical plate, single horizontal tube, and vertical array of tubes; Laminar-wavy and turbulent film condensation; Film condensation inside horizontal tubes; Condensation enhancement techniques; Dropwise condensation on textured surfaces, droplet dynamics and coalescence, drop growth and dropwise condensation cycle, effect of subcooling, effect of non-condensables and moist air condensation; Special topics: Boiling and condensation in a microgravity environment, boiling and condensation

			on patterned surfaces, numerical modeling of boiling and condensation, atmospheric water generator.
ME743	FUEL CELLS	3-0-0-0-9	Review of classical thermodynamics; introductory electrochemistry; principles of chemical and electrochemical kinetics; transport phenomena in electrochemical system, Classical thermodynamic analyses of fuel cell systems; analyses of fuel cell kinetics; quantification of fuel cell performance, Conservation and rate equations; approximate analytical treatment of fuel cell systems; scope and limitations of one-dimensional analyses; introduction to computational fluid mechanics of fuel cell systems; measurement of fuel cell performance; lab visits; introduction to electrochemical impedance spectroscopy; Direct methanol fuel cell; microbial fuel cell; hydrogen generation and storage; limitations, recent advances and challenges in fuel cell research.
ME745	MODELING OF TURBULENT COMBUSTION	3-0-0-0-9	Introduction to turbulence, review of turbulence models: RANS, LES, DNS, simple closure of chemical source terms, turbulent premixed flames, mixture fraction-based modelling of turbulent non-premixed combustion: flamelet model and CMC method, PDF and Monte Carlo methods, scalar mixing models, droplet and spray combustion.
ME751	COMPUTER AIDED ENGINEERING DESIGN	3-0-0-0-9	Methodology of interactive, graphical, engineering design; Discretization, optimization, simulation in CAED. Design of curves and surfaces. Applications in conveyor systems, sheet metal working, tool design, pumps etc. Design of volumes. Intersection of surface and interference of volumes.
ME752	OPTIMIZATION METHODS IN ENGINEERING DESIGN	3-0-0-0-9	Classical optimization methods, unconstrained minimization; Univariate, conjugate direction, gradient and variable metric methods, constrained minimization, Feasible direction and projections. Integer and Geometric programming, genetic algorithms, simulated annealing techniques, design applications.
ME756	VIBRATION CONTROL	3-0-0-0-9	Factors affecting level of vibration, vibration reduction at the source, vibration control by structural design, selection of materials. Vibration control by additive damping; Dynamic vibration absorbers, vibration and shock isolators, Active control.
ME757	DYNAMICS OF ROTATING MACHINERY	3-0-0-0-9	Rotor bearing interaction. Flexural vibration, critical speeds of shafts, Effectsof anisotropic bearings, unbalanced response of an assymetric shaft. Gyroscopic effects. Aerodynamic effects. Equivalent discrete system. Geared and branched systems. Fluid film bearings: Steady state characteristics of bearings. Rigid and flexible rotor balancing. Measurement techniques.

ME761	COMPUTER AIDED MANUFACTURING	3-0-0-0-9	Introduction to Recent Manufacturing systems, Computer-aided design, geometric modelling, concurrent engineering, Computer aided process planning, computer control manufacturing systems, Automated Material Handling and storage system, Robotic systems, Quality engineering, statistical process control and automated inspection system, Manufacturing planning and control systems, Group technology and cellular manufacturing system.
ME762	INTRODUCTION TO ROBOTICS	3-0-0-0-9	Types of Robots. Spatial transformation and kinematics of open chain linkages. Mobile robots, Actuators, sensors, programming and control. Hands-on experiments. Applications: motion planning, grasping and industrial automation.
ME763	ROBOT MANIPULATORS: DYNAMICS AND CONTROL	3-0-0-0-9	Review of robot manipulators. Manipulator kinematics, dynamics and control. Singularity and workspace analysis. Introduction to manipulator design.
ME765	MANUFACTURING AUTOMATION	3-0-0-0-9	Introduction, Automated assembly lines, programmable automation, flexible automation, material handling, cellular manufacturing, component classification, NC programming, interpolation, trajectory generation, modeling of manufacturing machines, system identification, multi loop control, learning control, and industrial robots.
ME766	ROBOT MOTION PLANNING	3-0-0-0-9	Configuration spaces of mobile robots and manipulators, Geometric modelling and sensor-based map building. Methods of path planning and obstacle avoidance. Object manipulation and grasping.
ME769	ADVANCED TOPICS IN ROBOTICS	3-0-0-0-9	Advanced techniques of kinematics and dynamics of mechanical systems. Parallel actuated and closed loop manipulators. Redundant manipulators. Mobile robots and path planning. Complaint motion and grasping. Sensing and vision. Nonlinear control of robots. Any other relevant topic.
ME770	MATERIALS SELECTION IN MECHANICAL DESIGN	3-0-0-0-9	In this course, we will provide a brief introduction to the evolution of engineering materials: Steel, Aluminium,Copper, Titanium; Other metals; Alloys and composites; Ceramic and Polymeric materials; Mechanical and Thermal Properties of Materials. This will be followed by the discussions on Ashby Charts and Examples of Material Property Index evaluation. We will then briefly describe Material Processing; Materials and the design process and Functional requirements of engineering materials. Next we will focus on Materials selection based on properties alone and Materials selection based on properties & shape; Finally, we will take up a large number of case studies and show how to obtain the material property index in each case.

ME771	SMART MATERIALS AND STRUCTURE	3-0-0-0-9	In this course, we will begin with the Materials for both actuation and sensing encompassing: introduction to Piezoelectric and Magnetostrictive Materials which will be followed by: Materials for actuation: introduction to Shape Memory alloys, Magnetic shape memory material, Electro/Magneto rheological fluids. We will then discuss about the Constitutive Relations for Piezoelectric and Magnetostrictive Materials, Shape Memory Alloys and Electro/Magneto rheological fluids. Next we will take up Introduction to composite smart materials and micromodelling related issues;Energy based approach,Variational Formulations,Finite Element Modelling of Vibration of smart Laminates; Subsequently, we will discuss: State space based analysis & Design of smart controllers, Concepts of Controllability & observability; Intelligent system with integrated sensors & actuators; Self sensing actuators; Placement of Smart Actuators/Sensors for Shape and Vibration Control. Finally we will show applications of Smart Materials: Bio-inspired Design, Design of Soft Materials and Soft Robotics.
ME772	MECHATRONICS	3-0-0-0-9	Fundamentals of the integration of mechanical and electronic subsystems using computer-based control. Details of different types of sensors, actuators, DAC/ADC and micro controllers. Control systems design and modelling of computer controlled electro-mechanical systems. Industrial automation and robotics. Practical applications of mechatronics, design issues and industrial techniques currently in use.
ME773	GRANULAR MATERIALS	3-0-0-0-9	1. Introduction to granular materials: Illustrative examples; 2. Revision of continuum mechanics; 3. Materials with yield strength: I lohrCoulolllb and Drucker Prager materials; 4. Statics: Coulomb's, J ansseu's and Walker's method. Volume averaging; 5. Application: Hoppers, Dmns, Landslides Asteroids; 6. Micromechanical behavior: Particle particle interaction. Mean field theory; 7. Other features: Close packing, Crystallization, Force chains, Shear banding; 8. Slow dense flow: Plasticity theory; 9. Application: Flows in Hoppers and Buukers;10.Rapid granularflow:Smooth inelastic particles; 11. Examples: Plane Couette flow, Inclined cbntes; 12. Rapid granular flow: Rough inelastic particles; 13. Mixing and segregation:Brazil nut effect,Rotating drum and Avalanches; 14.Effect of air:Porous beds 15.Introduction to computational modeling.

ME774	BIOMEMS AND MICROSYSTEMS TECHNOLOGY	3-0-0-0-9	Introduction to BioMEMS and Microsystems technology, Biochips/ biosensors and introduction to device fabrication, Introduction to Cell biology, DNA & Protein chemistry, Microfluidics, Biochip Sensors & detection methods, potential of Microfluidics and introductory continuum mechanics at small scales, Microarrays and lab-on-chip devices, Introduction to MEMS Design. Microfluidics: Continuum mechanics at small scales, Basics of microfluidics, Gas flows, liquid flows, boundary conditions, low Reynold's no. flows, entrance effects, surface tension, electrokinetic techniques like electrophoresis, electroosmosis and dielectrophoresis, microfluids for internal flow control (micropumps and microvalves, device building and characterization)
ME778	ENGINEERING ACOUSTICS AND ITS CONTROL		Introduction to acoustics, wave propagation and attenuation in solids and fluids. One dimensional acoustic wave equations and Helmholtz equation, Types of boundary conditions and general solutions.; Introduction to Transfer functions and other concepts such as Acoustic pressure, acoustic particle velocity, Sound Pressure Level, Acoustic intensity and Acoustic Power, Decibel (dB) scale, Different types of acoustic impedances, Re-discussing Boundary Conditions, reciprocity, near-field and far-field, Spectrum and frequency bands, and Concepts of A-weighting, C-Weighting, and Z-Weighting, Adding and Subtracting SPL, coherent and incoherent sources.; Equivalent models: Admittance and impedance concepts for infinite and finite acoustic waveguides. Electro-acoustic analogies. Modeling of electro-magnetic-mechanical-acoustic systems. Transmission line equations ;Passive control: Normal Transmission and Reflection of plane waves - infinite cross-section two- and three-medium cases, and how they compare with Reactive noise control devices such as silencers. Measurement of radiated power, elementary radiators, sound radiation from bending waves. Passive attenuation of structure Borne sound: Damping models, effect of elastic inter layers, blocking masses, changes of material and cross-section.;Acoustic Wave Propagation in Waveguides such as rectangular and circular ducts, design of filters, mufflers (silencers), partitions and enclosures;Architectural and environmental acoustics, including human response To sound, Room acoustics - Sabine rooms, flat and long room, low and high frequency behavior, modal density, Room constant and reverberation time RT20, RT30 and RT60, how to measure the reverberation time, Auditoriumand classroom design; Fundamentals of measuring instruments (microphones, speakers, etc). Fundamentals of acoustic measurement techniques and

		3-0-0-0-9	signal processing.;Special topics: Active control of structure-borne sound: Wave absorbing controllers for rods, beams, and plates, metamaterials and their application in acoustics and acoustic black holes.
ME799	PHD THESIS	0-0-0-0-9	Ph. D. Thesis
ME850	BASIC CONTROL SYSTEM FOR MECHANICAL ENGINEERS	3-0-0-0-9	Elementary review of dynamic systems. Equations ofmotion. Numerical solution of ODEs. Linearization.Stability.; Laplace transforms and inverse Laplacetransforms. Block diagrams. Transfer functions. Feedback loops. poles and zeros. Transient responses. Stability. The Routh Hurwitz criterion. Nonminimum phase systems and their transient responses. Steady state responses.; Root locus plots. Nyquist plots. Bode plots. Implications for transient responses. Compensators. Lead and lag compensators. PID controllers. Tuning rules. ; Stabilization using a stable controller: motivation and sample problems.; Discrete time systems. Stability.; State space. Standard form for an LTI system. General solution. Controllability and observability. Pole placement. Connections with classical control.; Introduction to optimal control. The linear quadratic regulator. ;Introduction to time delayed control.; Simulations of nonlinear systems with linearization- based controllers. Case studies from the literature as time permits. In addition, the course will have a design-oriented project which requires a level of maturity appropriate for a postgraduate class.
ME851	COMPLIANT MECHANISMS	3-0-0-0-9	Genesis of compliant mechanisms; glimpse of applications of compliant mechanisms; mobility analysis; large deformation analysis: continuum and discrete perspectives: finite element analysis, pseudo rigid body analysis, and lumped analysis using spring lever and spring mass lever models; design of compliant mechanisms based on linkage synthesis methods, selection based methods, and structural optimization based methods; kineto-elastic maps and understanding limits of compliant mechanisms; static balancing of compliant mechanisms; applications in microsystems, precision engineering, biomedical, automotive, product design, etc.
ME899	MS - RESEARCH THESIS	0-0-0-0-9	MS (Research) Thesis
TA101	ENGINEERING GRAPHICS	2-0-1-0-7	Introduction to sketching; Principal views, principles of dimensioning; Introduction to computer aided graphics Missing view, sectional view and assembly drawings Overview of pictorial representation, and isometric drawing in detail Perspective drawing Lines, planes, auxiliary view Relationship between lines and planes intersection oflines and planes

			Intersections of solids and development of lateral surfaces
TA212	MANUFACTURING PROCESSES II	0-0-3-0-3	TA212: Manufacturing Processes – II course focuses on demonstration and practice of secondary manufacturing processes with an emphasis on machining. Main aspect of the lab course is realizing a project. This involves ideation, conceptualization, detailing in CAD, making engineering drawings, and manufacture and assembly of parts to make a working prototype.
ME646	Introduction to Space Materials and Manufacturing	3-0-0-0 [9]	Course Description: A) Objectives: This course aims to challenge the existing manufacturing processes from the perspective of space manufacturing. The course will enable students to learn about the availability of resources and their in-situ utilization for projected human needs in the Martian and Lunar ambience. With the increasing demand for crewed missions and India's ambitious participation in the space economy, the course will offer our students an opportunity to understand, contemplate and receive exposure to the future of manufacturing. Contents: 1. Introduction (4 lectures) Space race, industrialisation, colonies and stations, Exploration activities, Natural resources (Earth vs. Space), Space factories, Economy, Benefits and challenges, Future of space activities. 2. Space Environment (6 lectures) Lunar/Martian topography, Petrology, Solar cycle, Abundance/scarcity of energy, Impacts and volcanism, Asteroids/meteoroids, Extreme conditions, Identification and fulfilment of human needs, Space-food, Extreme condition habitats, Spacesuits, Physiological and psychological health, Utilization of local resources. 3. Challenging factors for space manufacturing (4 lectures) Vacuum conditions, Reduced/micro/quasi-absent/zero gravity, Gaseous environments, Radiation, Meteoritic impacts, Solar storms, Space objects, Physical/chemical/mineralogical properties of rocks, Simulating space environment on earth. 4. Material processing in space conditions (6 lectures) Material processing methods, Solar energy-based material processing, Lunar and Martian environments, Asteroidal ores, steels, composites, and Soil, Major/minor/incompatible/siderophile elements, Vapor-mobilized/solar-wind implanted

			elements, Location-specific rocks on Lunar and Martian environments, Methods and techniques of characterization, Rock disintegration, Soil refining, Lunarcrete, Solar furnace, Oxygen production, Metallic and rare elements processing. 5. In-space manufacturing using local resources (6 lectures) Basic manufacturing operations, Art of space manufacturing, Containerless processes, Ultrahigh vacuum processing, Qualification of manufacturing processes, Simulating space gravity, Plausibility of space manufacturing, Governing physics and anomalies, Metal printing and defects under extreme conditions, robotic operations for manufacturing. 6. Machining and assembly in space (4 lectures) Cutting and assembly processes, Vacuum and oxygen-free cutting, Maintenance of spacecraft/spaceships from outer space, Mining and He-3 production, Deep-drilling on Lunar/Martian surfaces, Cutting and drilling tool materials. 7. Miscellaneous space technologies and processes (5 lectures) Materials, design and manufacturing for launch pads/spaceships/lander/rover systems, Sample collectors, Engineered components, Functional performance requirements and processing methods. 8. Experiments on Space Manufacturing (5 lectures) Experiments on space materials at Space Manufacturing Cell @ IITK, Development and characterization of LUNES and MARTES regolith simulants, Space-simulated environments. Pre-requisites if any: NA Short summary for including in the Courses of Study Booklet: Introduction, Space environment and its description, Challenging factors in outer space and celestial bodies (Moon and Mars, specifically), Materials and resources available, Processing of space materials, Material processing in space for in-situ resource generation, Manufacturing for space conditions, In-space manufacturing, Challenges for conventional manufacturing on Moon/Mars, Miscellaneous processing, Experiments at Space Manufacturing Cell @ IITK.

<table>
<tr><td></td><td></td><td></td><td>Recommended books:
Reference book:
1. The cosmos economy, Jack Gregg, Springer Nature, ISBN 978-3-030-62568-9, Switzerland
2. Space mining and manufacturing, D. Sivolella, Springer Nature, ISBN 978-3-030-30881, Switzerland
3. Materials Processing in Space: Theory, Experiments, and Technology, L.L. Regel, Springer, ISBN 978-0306110269
4. Fundamentals of modern manufacturing, M.P.Groover, Wiley & Sons, ISBN 978-0470-467002

Remarks:
This course will be open to students in their final year, dual degree, PG, and MSc levels.</td></tr>
<tr><td>IDC611</td><td>Parallel Computation of Sparse Matrix Systems</td><td>3-0-1-0 [10]</td><td>Objectives:
Sparse Matrix systems in parallel environments are one of the widely used techniques in the scientific community and industry as well. This course aims to introduce students from interdisciplinary Engineering and science streams to the fundamentals of the sparse matrix systems. The students will learn about the basics of a sparse matrix, parallel programming, and solution techniques of the sparse matrix using a parallel environment. A sparse matrix is the outcome of discretized partial differential equations that represent the conservation laws to simulate fluid flow, heat transfer, and other related physical phenomena. Thereafter, the system of algebraic equations is solved to compute the values of the dependent variable for each of the elements to represent the physical processes. The course is targeted for all engineering and science disciplines to the emerging paradigm of quantum computing.

Contents: considering the duration of each lecture is 50 minutes (preferably in the form of 5 to 10 broad titles):

<table>
<tr><th>S No.</th><th>Broad Title</th><th>Topics</th><th>No. of lectures</th></tr>
<tr><td>1</td><td>Basics of Matrix Computations</td><td>1) Subspaces, Bases, Orthogonality, Matrices, | 6 Computations Projectors, Norms. Floating point arithmetic.</td><td>6</td></tr>
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					2) Systems of linear equations. Solution of Systems of Linear Equations: matrix LU factorization. Special matrices: symmetric positive definite, banded. 3) Error analysis, condition numbers, operation counts, estimating accuracy. 4) Orthogonality, the Gram-Schmidt process. Classical and modified Gram-Schmidt. Householder QR factorization. Least-squares systems. 5) Eigenvalues, singular values. The Singular Value Decomposition. Applications of the SVD. 6) Eigenvalue problems: Background, Schur decomposition, perturbation analysis, power and inverse power methods, subspace iteration; the QR algorithm. 7) The Symmetric Eigenvalue	

						Problem: special Properties and perturbation theory, Law of inertia, Min-Max theorem, symmetric QR algorithm, Jacobi method. Applications.	
				2	Sparse Matrices	1) Sparse matrices and their origin. Graph representation of sparse matrices, sparse graphs, Discretization of Partial Differential Equations. Electrical networks, Information retrieval. 2) Storage schemes for sparse matrices. Regular and irregular structures.	6
				3	Direct Solution methods of Sparse matrices	Direct solution methods; Variants of Gaussian Elimination; Permutations and orderings; Band and envelope methods; Cuthill-Mc Kee and reverse Cuthill-Mc Kee orderings; Graph representation. Elimination tree; The frontal and multifrontal approaches; Minimal degree and nested dissection	3

					orderings.	
			4	Iterative Solution Methods of Sparse matrices	Iterative methods; Projection methods; Onedimensional case: steepest descent, minimal residual methods; Krylov subspace methods; Conjugate gradient (CG) method; basic convergence theory; Connection to Lanczos tridiagonalization and orthogonal polynomials; The idea of preconditioning.	5
			5	Eigenvalue problems	Types of problems; Subspace iteration; Krylov methods; Arnoldi's method; The Lanczos algorithm; Nonsymmetric Lanczos.	3
			6	Basics of Parallel Programmin g	1) Introduction; Historical Perspective; Types of parallelism; Parallel algorithms and parallel computing. 2) Parallel computing platforms, Taxonomy, Pipelined-Vector-, superscalar. Examples of parallel platforms.	6

		3) Memory and cache performance issues, Hierarchical memories, Latency, bandwidth, Caches. 4) Parallel algorithms, design. Parallel performance metrics (Efficiency, load balancing, scalability, ...)	
7	Parallel Programming Using OpenMP, MPI, and Open ACC	1) Programming shared memory machines -Open MP. 2) Programming GPUs, CUDA, open ACC. 3) Basic communication operations. Programming with MPI. 4) Programming distributed systems - MPI	6
8	Parallel toolkit	1) Parallel Scientific Libraries: BLAS, LAPACK, SCALAPACK, ARPACK, LIS libraries (only two or three of them will be covered) 2) PETSC	5

Recommended pre-requisites, if any (examples: a- PS0201A,or b- P.50201A orequivalent): Undergraduate/Graduate Mathematics, Linear Algebra, and Programming

			Short summary for including in the Courses of StudyBooklet: This course introduces parallel computing to sparse matrix systems and their applications. It covers parallel architectures, parallel algorithms, and their analysis in the context of sparse linear systems and eigenvalue problems. The course will start with a general discussion of sparse matrices, their origins, and how they are stored and exploited. Then it will briefly cover direct solution methods and iterative methods for solving sparse linear systems of equations and sparse eigenvalue problems. Further, it will discuss other topics related to sparsity, e.g., graph-based algorithms in machine learning, and basic nonlinear techniques. Finally, it will also introduce programming on parallel platforms. Along with the programming medium; OpenMP, MPI, and CUDA for the NVIDIA Graphics Processing Units (CPUs), will also be covered, in conjunction with a quick overview of openACC. The course blends theory with practical issues such as parallel architectures and parallel programming. Recommended text/reference books: 1) Introduction to Parallel Computing, 2nd edition, by V. Kumar, A. Grama, A. Gupta, and G. Karypis (2003). 2) Introduction to Parallel Programming by Peter S. Patcheco, Elsevier (2011). 3) Programming Massively Parallel Processors, Third Edition: A Hands-on Approach by David B. Kirk and Wen-mei W. Hwu. (2017). 4) Using MPI, Portable Parallel Programming with the Message-Passing Interface by William Gropp, Ewing Lusk, and Anthony Skjellum, Second Edition, MIT Press, 1999. 5) Matrix Computations, 4th edition by G. Golub and C. Van Loan. John Hopkins, 2015. 6) Numerical linear algebra by Lloyd N. Trefethen and David Bau, III. SIAM, 1997. 7) Iterative methods for sparse linear systems (2nd edition) by Yousef Saad 8) Direct methods for sparse linear systems by T. A. Davis, SIAM publishing, 2006.
ME651	Advanced Engineering Thermodynamics	3-0-0-0[9]	Objective:The course is targeted to the PG students with background in mechanical engineering who are familiar with the basic UG thermodynamics course. In many cases, these students need familiarity with advanced topics in thermodynamics to apply in their inter-disciplinary research problems. The topics which are covered in material science, chemical engineering, physics or chemistry courses on thermodynamics often remain out of access for the students with mechanical engineering background.

			The proposed course attempts to bridge this specific gap