Mechanical Material Aerospace Engineering

S. No	New Course code	Name of Course	L-T-P-C	Proposed Level (UG/PG)
1	ME 111	Engineering Graphics Lab	1-0-3-5	UG
2	ME 113	Hands on Engineering Lab	0-0-3-3	UG
3	ME 201	Engineering Mechanics	2-1-0-6	UG
4	ME 202	Engineering Materials	2-1-0-6	UG
5	ME 203	Heat Transfer	3-0-0-6	UG
6	ME 204	Manufacturing Process I	3-0-0-6	UG
7	ME 205	Machine Drawing and 3D Modelling	1-0-2-3	UG
8	ME 206	Mechanics of Materials	3-1-0-8	UG
9	ME 207	Thermodynamics	2-1-0-6	UG
10	ME 208	Mechanical Measurements	3-0-0-6	UG
11	ME 210	Machine Drawing and 3D Modelling	1-0-2-3	UG
12	ME 212	Manufacturing processes and Metrology laboratory	0-0-3-3	UG
13	ME 219	Heat Transfer	3-1-0-8	UG
14	ME 220	Heat Transfer	3-0-0-6	UG
15	ME 222	Mechanics of Materials	2-1-0-6	UG
16	ME 223	Manufacturing Processes II	3-0-0-6	UG
17	ME 224	Fluid Mechanics Lab	0-0-3-3	UG
18	ME 302	Applied Thermodynamics	3-0-0-6 3-1-0-8	UG
19	ME 303	Kinematics and Dynamics of Machines	3-1-0-8	UG
20	ME 304	Machine Design	3-1-0-8	UG
21	ME 309	Theory of Machines	2-1-0-6	UG
22	ME 311	Mechanical Measurements Lab	0-0-3-3	UG
23	ME 312	Solid Mechanics Lab	0-0-3-3	UG
24	ME 313	Kinematics and Dynamics of Machinery lab	0-0-3-3	UG
25	ME 314	Heat Transfer lab	0-0-3-3	UG
26	ME 315	Manufacturing processes laboratory	0-0-3-3	UG
27	ME 323	Introduction to Aerospace Engineering	3-0-0-6	UG
28	ME 324	Design of Machine Elements	2-1-0-6	UG
29	ME 325	Process of certification of composite aircraft structures	1-0-0-2	

30	ME 328	Applied Thermodynamics Laboratory	0-0-3-3	UG
31	ME 329	Research and Development Project	6 credits	
32	ME 330	Mechanical Measurements Lab	1-0-3-5	UG
33	ME 331	Basic Operation Research	3-0-0-3	UG
34	ME 401	Finite Element Analysis	3-0-0-6	UG
35	ME 402	Synthesis of Mechanisms	3-0-0-6	UG
36	ME 403	Vibrations of Linear Systems	3-0-0-6	UG
37	ME 404	Introduction to Combustion	3-0-0-6	PG
38	ME 405	B.Tech. Project-ME	6 credits	
39	ME 407	I.C. Engines	3-0-0-6	UG
40	ME 408	Geometric Modeling and Computer Graphics	2-0-2-6	UG
41	ME 409	Composite Materials: Manufacturing, Properties & Applications'	3-0-0-6	UG
42	ME 410	Computer Integrated Manufacturing	3-0-0-6	UG
43	ME 412	Energy and Environment Lab	0-0-3-3	UG
44	ME 420	Dynamics and Modelling of Weather and Climate	3-0-0-6	UG
45	ME 421	Energy and Environment Lab	3-0-0-6	UG
46	ME 422	Reverse Engineering Laboratory	0-0-3-3	UG
47	ME 424	B.Tech Project ME - II	6 credits	UG
48	ME 425	Additive Manufacturing	3-0-0-6	UG
49	ME 426	Introduction to Computational Fluid Dynamics	3-0-0-6	UG
50	ME 427	Fluid Flow and Heat Transfer in Porous Media	3-0-0-6	UG
51	ME 428	Refrigeration and Air-conditioning	3-0-0-6	UG
52	ME 429	Solar Energy Collector Systems	3-0-0-6	UG
53	ME 431	Impact Mechanics and Modelling	3-0-0-6	UG
54	ME 432	Power Plant Engineering	3-0-0-6	UG
55	ME 433	Vehicle Mechanisms and Dynamics	3-0-0-6	UG
56	ME 434	Wind Turbine Design and Operation	3-0-0-6	UG
57	ME 437	Energy Sources and Sustainability	3-0-0-6	UG
58	ME 439	Theory of Elasticity	3-0-0-6	UG

59	ME 440	Rocket Propulsion	3-0-0-6	UG
60	ME 441	Systems and Energy Efficiency in Buildings	3-0-0-6	UG
61	ME 442	Atmosphere and Ocean Dynamics	3-0-0-6	UG
62	ME 443	Smart Manufacturing	3-0-0-6	UG
63	ME 444	Aerodynamics	3-0-0-6	UG
64	ME 445	Introduction to Aerospace Materials	3-0-0-6	UG
65		Fundamentals of Tribology	3-0-0-6	PG
66	ME 601	Advanced Heat Transfer	3-0-0-6	PG
67	ME 602	Introduction to Turbulence and its Modelling	3-0-0-6	PG
68	ME 603	Advanced Finite Element Methods	3-0-0-6	PG
69	ME 604	Multiphase Flow	3-0-0-6	PG
70	ME 605	Additive and Forming Manufacturing Processes	3-0-0-6	PG
71	ME 606	Nonlinear Solid Mechanics for Finite Element Method	3-0-0-6	PG
72	ME 607	Advanced Solid Mechanics	3-0-0-6	PG
73	ME 608	Advanced Mechanisms and Dynamics ofMechanical Systems	3-0-0-6	PG
74	ME 609	Advanced Fluid Mechanics and Heat Transfer	3-0-0-6	PG
75	ME 610	Compressible Flow and Gas Dynamics	3-0-0-6	PG
76	ME 611	Experimental Theory & Laboratory	1-0-3-5	PG
77	ME 620	Design of Heat Exchangers	3-0-0-6	PG
78	ME 621	Introduction to Programming and Modeling Laboratory	1-0-3-5	PG
79	ME 622	Kinematics, Dynamics and Control of Mechanical System	4-0-2-10	PG
80	ME 623	Tribology	3-0-0-6	PG
81	ME 624	CNC & Part Programming	3-0-0-6	PG
82	ME 625	Linear Viscoelasticity	3-0-0-6	PG
83	ME 626	Experimental Methods in Thermal and Fluid Engineering	3-0-0-6	PG
84	ME 627	Mechanics of Composite Materials	3-0-0-6	PG
85	ME 628	Mechanical Vibrations	3-0-0-6	PG
86	ME 629	Fundamentals of Acoustics	3-0-0-6	PG
87	ME 630	Turbomachinery Aerodynamics	3-0-0-6	PG
88	ME 631	Metal Forming and Plasticity	3-0-0-6	PG
89	ME 632	Mechanical Engineering Experimental Laboratory	1-0-3-5	PG
90	ME 633	Sustainable Energy for Transportation	3-0-0-6	PG

91	ME 634	Practicum	0-0-3-3	PG
92	ME 635	Introduction to Statics and Dynamics	3-0-0-6	PG
93	ME 636	Smart manufacturing and material selection	3-0-0-6	PG
94	ME 637	Design of Mechatronic Systems	3-0-0-6	PG
95	ME 638	Foundations of Dynamics	3-0-0-3	PG
96	ME 639	Vehicle Dynamics	3-0-0-3	PG
97	ME 640	Battery Chemistry and Thermal Management	3-0-0-3	PG
98	ME 641	Alternative Energy Sources for Transportation	3-0-0-3	PG
99	ME 642	Boundary-layer and Aerodynamics	3-0-0-3	PG
100	ME 643	Finite Element Analysis	3-0-0-3	PG
101	ME 644	Additive Manufacturing and Material selection	3-0-0-3	PG
102	ME 645	Modeling of Metal Plasticity: Discrete and Continuum approaches	3-0-0-6	PG
103	ME 647	Advanced CAM	2-0-2-6	PG
104	ME 648	Design and Manufacturing of Composites	3-0-0-6	PG
105	ME 649	Energy for Transportation	3-0-0-3	PG
106	ME 646	Fracture Mechanics	3-0-0-6	PG
107	ME 701	Functional Materials Manufacturing for Energy and Biomedical Applications	1-0-0-2	PG
108	ME 702	Engineering Mathematics for Advanced Studies	3/4-0-0-6/8	PG
109	ME 703	Fatigue and Fracture Mechanics	3-0-0-6	PG
110	ME 704	Combustion and Fire Dynamics	3-0-0-6	PG
111	ME 705	Convective Heat Transfer	3-0-0-6	PG
112	ME 706	Satellite Attitude Dynamics and Control	3-0-0-6	PG
113	ME 802	Applied Elasticity	2-1-0-6	PG
114		Seminar	4 credits	PG
115	ME 447	Automobile Engineering Fundamentals	3-0-0-6	UG
116	ME 905	Nonlinear Oscillation	3-0-0-6	PG
117	ME 449	BIO ENERGY CONVERSION	3-0-0-6	UG
118		Introduction to High Performance Computing	6 credits	PG
119		Heat Exchangers	3-0-0-6	PG
120		Fluid Dynamics		PG
121		Advanced Thermodynamics	3-0-0-6	PG
122		Fundamentals of Casting and Welding	3-0-0-6	PG

123		Physical and Mechanical Metallurgy	3-0-0-6	PG
124		CNC (Computer Numerical Controlled) and Additive/Subtractive Manufacturing	3-0-0-6	PG
125		Mechanics of Machining and Forming	3-0-0-6	PG
126		Modeling and Simulation in Materials and Manufacturing	3-0-0-6	PG
127		Mechatronics and Robotics	2-0-2-6	PG
128		Design of Mechanical Transmission Systems	3-0-0-6	PG
129		Dynamics and Control	3-0-0-0	PG
130		Research Methodology	1-0-0-2	PG
131		Production Planning and Control	3-0-0-6	PG
132		Advanced Materials and Processing	3-0-0-6	PG
133		Operations Research	3-0-0-6	PG
134		Industrial Engineering and Technology Management	3-0-0-6	PG
135		Hybrid Manufacturing Processes	3-0-0-6	PG
136		Product Design and Manufacturing	3-0-0-6	PG
137		Advanced Material characterization Techniques	3-0-0-6	PG
138		Polymer Science and Engineering	3-0-0-6	PG

1	**Title of the course** (L-T-P-C)	**Engineering Graphics Lab (1-0-3-5)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Engineering Graphics with mini-drafter: Around half a semester and bit more with following topics to be covered. • Introduction to Engineering Graphics • Curves • Projections of Points • Projection of Lines • Projection of Planes • Projections on Auxiliary Planes • Projections of Solids • Sections of Solids • Intersections of Solids Engineering Graphics with 2D Drafting Software: 5 weekly computer laboratory sessions covering above using AutoCAD® as a drafting software, 5th session on Isometric Projections.
4	**Texts/References**	1. N. D. Bhatt, revised and enlarged by V. M. Panchal and P. R. Ingle, Engineering Drawing, 53rd Edition, 2014, Charotar Publishers, Anand. 2. Warren J. Luzadder and Jon M. Duff, Fundamentals of Engineering Drawing, Prentice-Hall of India. 3. Gopalakrishna K. R., Engineering Drawing Vol. I & II Combined., Subhas Stores, 25th Edition, 2017. 4. Narayana. K. L., and Kannaiah, P. E., Text Book on Engineering Drawing, 2nd Edition, 2013, Scitech Publications, Chennai. 5. Venugopal K. and Prabhu Raja V., Engineering Drawing + AutoCAD, New Age International Publishers, 5th Edition, 2011.

1	**Title of the course** (L-T-P-C)	**Hands on Engineering Lab** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**List of Experiments (Mechanical Workshop)** • To make a Square-fit from the given mid steel pieces (Fitting) • To make a V-fit from the given mid steel pieces (Fitting) • To make a rectangular tray as per required dimensions (Sheet Metal) • To build a transition piece (Sheet Metal) • To make a Butt joint using the given two M.S pieces (Arc welding) • To make a lap joint using the given two M.S pieces (Arc welding) • To build a pipe-line using fittings for given flow circuit (Plumbing) **List of Experiments (Electrical Workshop)** • To control one lamp by a one switch with provision for plug socket with switch control (Electrical wiring) • To do stair case wiring (i.e. control of one lamp by two switches fixed at two different places) (Electrical wiring) • Measurement of hot and cold resistance of filament • Improvement of Power Factor • Calibration of Energy meter • Measurement of Power using three ammeter/voltmeter method **List of Experiments (Electronics)** • Understanding breadboard, One-way traffic • Introduction to Arduino and Buzzer • Using Arduino speed measurement of motor/ glowing of LED • Control of water level using Arduino • Line follower using Arduino
4	**Texts/References**	Elements of Workshop Technology Vol. 1 (2015), S. K. Hajra Choudhary, A. K. Hajra Choudhary and Nirjhar Roy, Media Promoters and Publishers Pvt. Ltd. W. A. J. Chapman, Workshop Technology, Vol. 1 (2006), Vol 2 (2007), and (1995), CBS Publishers.

1	**Title of the course** (L-T-P-C)	**Engineering Mechanics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module 1:** Introduction to Engineering Mechanics covering, Force Systems Basic concepts, Particle equilibrium in 2-D & 3-D; Rigid Body equilibrium; System of Forces, Coplanar Concurrent Forces, Components in Space – Resultant- Moment of Forces and its Application; Couples and Resultant of Force System, Equilibrium of System of Forces, Free body diagrams, Equations of Equilibrium of Coplanar Systems and Spatial Systems; Static Indeterminacy **Module 2:** Friction covering, Types of friction, Limiting friction, Laws of Friction, Static and Dynamic Friction; Motion of Bodies, wedge friction, screw jack & differential screw jack; **Module 3:** Basic Structural Analysis covering, Equilibrium in three dimensions; Method of Sections; Method of Joints; How to determine if a member is in tension or compression; Simple Trusses; Zero force members; Beams & types of beams; Frames & Machines; **Module 4:** Centroid and Centre of Gravity covering, Centroid of simple figures from first principle, centroid of composite sections; Centre of Gravity and its implications; Area moment of inertia- Definition, Moment of inertia of plane sections from first principles, Theorems of moment of inertia, Moment of inertia of standard sections and composite sections; Mass moment inertia of circular plate, Cylinder, Cone, Sphere, Hook; **Module 5:** Virtual Work and Energy Method- Virtual displacements, principle of virtual work for particle and ideal system of rigid bodies, degrees of freedom. Active force diagram, systems with friction, mechanical efficiency. Conservative forces and potential energy (elastic and gravitational), energy equation for equilibrium. Applications of energy method for equilibrium. Stability of equilibrium. **Module 6**: Particles dynamics- Kinematics of Particles: Rectilinear motion, Plane curvilinear motion - rectangular coordinates, normal and tangential coordinates, polar coordinates, Space curvilinear - cylindrical, spherical (coordinates), Relative and Constrained motion. Kinetics of Particles: Force, mass and acceleration – rectilinear and curvilinear motion, work and energy, impulse and momentum – linear and angular; Impact – Direct and Oblique. Kinetics of System of Particles: Generalized Newton’s Second Law, Work-Energy, Impulse-Momentum, Conservation of Energy and Momentum **Module 7:** Introduction to Rigid body dynamics Kinematics of Planar Rigid Bodies: Equations for rotation of a rigid body about a fixed axis, General plane motion, Instantaneous Center of Rotation in Plane Motion Plane Motion of a Particle Relative to a Rotating Frame. Coriolis Acceleration Kinetics of Planar Rigid Bodies: Equations of Motion for a Rigid Body, Angular Momentum of a Rigid Body in Plane Motion, Plane Motion of a Rigid Body and D’Alembert’s Principle, Systems of Rigid Bodies, Constrained Plane Motion; Energy and Work of Forces Acting on a Rigid Body, Kinetic Energy of a Rigid Body in Plane Motion, Systems of Rigid Bodies, Conservation of Energy, Plane Motion of a Rigid Body - Impulse and Momentum, Systems of Rigid Bodies, Conservation of Angular Momentum. **Module 8**: Mechanical Vibrations covering, Basic terminology, free and forced vibrations, resonance and its effects; Degree of freedom; Derivation for frequency and amplitude of free vibrations without damping and single degree of freedom

		system, simple problems, types of pendulum, use of simple, compound and torsion pendulums
4	**Texts/References**	**Textbooks:** 1. J. L. Meriam and L. G. Kraige, Engineering Mechanics, Vol I – Statics, Vol II – Dynamics, 6th Ed, John Wiley, 2008. 2. F. P. Beer and E. R. Johnston, Vector Mechanics for Engineers, Vol I - Statics, Vol II – Dynamics, 9th Ed, Tata McGraw Hill, 2011. 3. R. C. Hibbler, Engineering Mechanics: Principles of Statics and Dynamics, Pearson Press, 2006. **References:** 1. S. P. Timoshenko and D. H. Young, Engineering Mechanics. Fourth Edition. McGraw-Hill, New York, 1956. 2. I. H. Shames, Engineering Mechanics: Statics and dynamics, 4th Ed, PHI, 2002. 3. Robert W. Soutas-Little; Daniel J. Inman; Daniel Balint, Engineering Mechanics: Dynamics – Computational Edition, 1st Ed., Cengage Learning, 2007 4. Robert W. Soutas-Little; Daniel J. Inman; Daniel Balint, Engineering Mechanics: Statics-Computational Edition, 1st Ed., ,Cengage Learning, 2007

1	**Title of the course** (L-T-P-C)	**Engineering Materials** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	• Economic, Environmental and Societal Issues in • Materials Science & Engineering • Basic Materials Science: Crystallography, phase diagrams, • grain boundaries, dislocation movements and their effects on • Properties • Material properties: Stress-strain relationships, Tensile • strength, Toughness, Impact Strength, Ductility, Malleability, • Stress intensity, Fatigue • Failure: by Oxidation, Corrosion (Types, impact on material • Strengthening mechanisms: Solute Hardening, chemical hardening, dispersion hardening, Aluminium alloys: Properties, phase diagrams and uses • Copper alloys: Properties phase diagrams and uses • Ferrous Alloys (Steels): Types, properties, iron-carbon • phase diagrams • Material Selection: Ashby Charts • Ceramics: Structure and Properties, Mechanical Properties • of Ceramics, Types and Application of Ceramics, Fabrication • and Processing of Ceramics • Polymers: Molecules, Structures and Shapes, Thermosetting • & Thermoplastic, Polymer Crystals, Polymer Characteristics • and Applications, Synthesis, Processing and Degradation. • Composites: Processing Fiber Reinforced Composites, • Structural Composites, Application of Compositescold working, strain Hardening
4	**Texts/References**	**TEXTBOOKS** 1. W.D. Callister, Jr. & D.G. Rethwisch: 'Materials science and Engineering: An Introduction', 9th Ed., John Wiley (2014) 2. W.F.Smith and J.Hashemi: 'Foundations of Materials Science and Engineering', 5th Ed., McGraw-Hill(2009). **REFERENCE** 1. D.R.Askeland, P.P.Phule& W.J. Wright: 'The Science and Engineering of Materials' 7th Ed., Cengage Learning(2014). 2. V.Raghavan: Materials Science and Engineering: A First Course' 6th Ed. PHI(2015). 3. J.F. Shackeford: 'An Introduction to Materials Science for engineers' 8th Ed., Pearson (2016). 4. R.A.Higgins: 'Properties of Engineering Materials' 2nd Ed., Industrial Press (1994). 5. T.Fishcher: 'Materials Science for Engineering Students', Academics Press (2009). 6. V.Raghavan: 'Physical Metallurgy: Principles and Practice' 3rd Ed., PHI (2015)

1	**Title of the course** (L-T-P-C)	**Fluid Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction :Scope, definition of fluid as continuum, fluid properties.(2hr) Fluid Statics: Pressure at a point, basic equation for pressure field, pressure variation(fluid at rest):standard atmosphere, Measurement of pressure manometer,Hydrostatics force on a plane and curve surface, Buoyancy, flotation and stability, pressure variation in a fluid with rigid body motion linear motion, rigid body rotation(4hr) Elementary Fluid Dynamics: Statics, stagnation pressure, Bernoulli Equation assumptions(4hr) Fluid Kinematics The velocity filed : Eulerian and Largrangian flow descriptions, steady and deformation, Acceleration field: material derivative, unsteady and convective effects. Control volume and system representation : Reynolds' Transport Theorem, physical interpretation, steady, unsteady effects, moving control volume, potential function(6Hr) Integral approach Conservation of mass derivation of continuity, fixed, non-deforming control volume, moving non-deforming control volume, deforming control volume. Conservation of momentum: linear momentum and moment of momentum equation and their application., comparison of energy equation with Bernoulli's equation(6hr) Differential approach : linear motion and angular motion with deformation, Conservation of mass: differential form of continuity equation, stream function, Conservation of linear momentum, Inviscid flows, Irrotational flow(6hr) Viscous flow : Stress relationships,NS Equations, Simple solutions for viscous flows(4hr) Dimensional analysis Buckingham's II-theorem,Dimensionless groups & their importance (3hr) Viscous Flow in Pipes : General characteristics of pipe flow, fully developed laminar and turbulent flow, turbulent shear stress, turbulent velocity profile, Pipe Flow rate measurement.(4hr) Boundary layer: Boundary layer characteristics boundary layer structure and thickness on a plate, Blasius boundary layer, momentum integral boundary layer equation for a flat plate(4hr)
4	**Texts/References**	1. Yunus A. Cengel, John M. Cimbala, Fluid Mechanics, Tata McGraw Hill Education,2011 2. F.M.White Fluid Mechanics, Seventh Edition, Tata McGraw Hill Education,2011, 3. Kundu,Pijush K., and Ira M.Cohen.Fluid Mechanic, Elsevier,2001

1	**Title of the course** (L-T-P-C)	**Manufacturing Process I** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Mechanical Measurements
3	**Course content**	**Casting processes**: dispensable and permanent mould processes; analysis of melting, pouring and solidification phenomena; design of pattern, core, feeder and gating system; casting defects and inspection. **Joining processes**: fusion and solid-state welding; brazing and soldering; weld joint design, cooling rate, and joint properties; welding defects and inspection. **Bulk and Sheet Forming processes**: rolling, forging, extrusion and drawing; sheet metal working; forming limit diagram; loads, friction and lubrication; forming defects and inspection. **Powder processing**: Powder manufacture, characterization, compaction and sintering; metal injection moulding; hot and cold iso-static pressing. Polymers and Composites: Thermoplastics, thermosets, elastomers and composites; related processes; injection mould design; moulding defects and inspection. Advanced processes: Free form fabrication (rapid prototyping), and net shape manufacturing processes.
4	**Texts/References**	1. Ghosh A. and Mallick A.K., Manufacturing Science, Affiliated East West Press, 2001. 2. Rao P.N., Manufacturing Technology- Foundry, Forming and Welding, TMG Hill, 1987. Schey J., Introduction to Manufacturing Processes, Tata McGraw Hill, 2000. 3. DeGarmo E.P., Black J.T., Kohser R.A., Materials and Processes in Manufacturing, PHI, 1997. 4. Pye R.G.W., Injection Mold Design, Longman Scientific & Technical, Essex, 1989.

1	**Title of the course** (L-T-P-C)	**Machine Drawing and 3D Modelling** **(1-0-2-3)**
2	**Pre-requisite courses(s)**	Exposure to Engineering Graphics Laboratory (ME 111)
3	**Course content**	**Introduction**: Engineering design process and drawings. Drawing standards. Computer aided drafting and use of software packages for engineering drawings **Detachable Fasteners**: Screw threads: conventional representations and specifications; Threaded fasteners:Types, forms, standard, and specifications; Drawing of connections; Foundation bolts; Locking Devices: Classification, principles of operation, standard types andtheir proportions; Shaft Couplings: Common types, standard proportions for some couplings; Pipe Joints, common pipe connections **Permanent Fastenings**: Rivets: Standard forms andproportions; Riveted Joints: Common types of joints,terminology, proportions and representation; Welds:Types of welds and welded joints, edge preparation, specifications, and representation of welds on drawings **Assembly Drawings**: with sectioning and bill of materials. Assemblies involving machine elements like shafts, couplings, bearing, pulleys, gears, belts, brackets. Engine mechanisms-assembly. Detailed part drawings from assembly drawings **Tool Drawings**: Jigs and fixtures **Production Drawings**: Limits, fits, and tolerances of size and form; Types and grade, use of tolerance tables and specification of tolerances, form and cumulative tolerances, tolerance dimensioning; Surface quality symbols, terminology and representation on drawings, correlation of tolerances and surface quality with manufacturing techniques 3D Modelling exercise: use of Reverse Engineering to disassemble and measure components
4	**Texts/References**	**1.** D K Cheng, “Fundamentals of Electromagnetics”, Addison Wesley, MA 1993. **2.** R K Shevgaonkar, “Electromagnetic Waves”, McGraw- Hill Education (India) Pvt Limited, 2005 **3.** Hayt, William H., Jr., and John A. Buck, “Engineering Electromagnetics", 7th ed. McGraw-Hill, 2006.

1	**Title of the course** (L-T-P-C)	**Mechanics of Materials** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Module 1:** Basics: Fundamentals of mechanics of deformable solids. Concepts of stress and strain and their relationships. Axially loaded members - Normal stress and strain, Simple (direct) shear stress and strain, Hooke's law, Stresses on inclined planes under axial loading, thermal stresses and strains, statically indeterminate problems. Elastic strain energy under axial loads. **Module 2:** Torsion: torsion of circular cross-section shafts (Solid and hollow sections): Deformation field, Torsion formulae for stresses and angular deflection, Elastic strain energy under torsion, Closely-wound helical springs – stresses and deflections. **Module 3**: Bending: Euler – Bernoulli model: normal and shear stresses, deflections for symmetric bending. Statically indeterminate problems, Elastic strain energy under flexure. **Module 4:** Combined stresses: State of stress and strain at a point , transformation laws , Mohr's circle diagram for stress and principal stresses, thin walled structures : thin cylinders and spheres. Theories of failure: Maximum Normal-Stress theory, Maximum shear-stress theory and Maximum Distortional-energy theory. **Module 5:** Energy methods – Castigliano's theorem and its applications, fictitious-load method. Stability of structures – Buckling of idealized and elastic columns
4	**Texts/References**	**TEXTBOOKS:** 2. S.H Crandall, N.C Dahl and S.J Lardner, An Introduction to Mechanics of Solids, Tata McGraw Hill, Third Edition, 2012. 3. E.P. Popov, Engineering Mechanics of Solids, Prentice Hall of India, 2nd edition, 2012. **REFERENCES:** 1. J. M. Gere and Goodno, Mechanics of Materials, 7th ed, Cengage Learning India, 2012. 2. J.P Den Hartog, Strength of Materials, Dover, 1949. 3. J.M Gere and S.P Timoshenko, Mechanics of Materials, CBS Publishers, 1986 4. R. C. Hibbeler, Mechanics of Materials, Pearson, 10th edition, 2016 . 5. S.P Timoshenko and D.H Young, Elements of strength of Materials, 5th ed, Affiliated East West Press, 1976. 6. F. P. Beer, E. R. Johnston Jr., John T. DeWolf , D. F. Mazurek, Mechanics of Materials, McGraw- Hill Education; 7th edition, 2014 7. M. Salvadori and R. Heller, Structure in Architecture, Prentice Hall Inc, 1963. 8. S.P Timoshenko, History of Strength of Materials, Dover, 1983. 9. M. H. Sadd, Elasticity: Theory, Applications, and Numerics, 1st ed, Elsevier India, 2006.

1	**Title of the course** (L-T-P-C)	**Thermodynamics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Thermodynamic Systems, properties & state, process &cycle **Heat & Work**: Definition of work and its identification, work done at the moving boundary, Zeroth law, **Properties of pure substance**: Phase equilibrium, independent properties, and equations of state, compressibility factor, Tables of thermodynamic properties & their use, Mollier Diagram **First law**: First law for control mass & control volume for a cycle as well as for a change of state, internal energy & enthalpy, Specific heats; internal energy, enthalpy & specific heat of ideal gases. SS process, Transient processes. **Second Law of Thermodynamics**: Reversible process; heat engine, heat pump, refrigerator; Kelvin- Planck & Clausius statements ,Carnot cycle for pure substance & ideal gas, Concept of entropy; the Need of entropy definition of entropy; entropy of a pure substance; entropy change of a reversible & irreversible processes; principle of increase of entropy, thermodynamic property relation, corollaries of second law, Second law for control volume; SS & Transient processes; Reversible SSSF process; principle of increase of entropy, Understanding efficiency. **Irreversibility and availability**: Available energy, reversible work & irreversibility for control mass and control volume processes; second law efficiency. **Thermodynamic relations**: Clapeyron equation, Maxwell relations, Thermodynamic relation for enthalpy, internal energy, and entropy, expansively and compressibility factor, equation of state, generalized chart for enthalpy. **Thermodynamic Cycles**: Otto, Diesel, Duel and Joule Third Law of Thermodynamics
4	**Texts/References**	**1.** Sonntag R., Claus B. & V. Wylen G, Fundamentals of Thermodynamics, John Wiley, 2000. **2.** G Rogers, YR Mayhew, Engineering Thermodynamics Work and Heat Transfer, Pearson 2003 **3.** J.P Howell, P.O. Bulkins, Fundamentals of Engineering Thermodynamics, McGraw Hill,1987 **4.** Y Cengal, M A Boles, Thermodynamics: An Engineering Approach, Tata McGraw Hill, 2003. **5.** Michael J. & H.N. Shapiro, Fundaments of Engineering Thermodynamics, John Wiley, 2004.

1	**Title of the course** (L-T-P-C)	**Mechanical Measurements** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Introduction**: generalized measurement system, static calibration, calibration, random errors, uncertainty analysis, dynamic characteristics. Zero, first and second order measurement systems. **Temperature measurement**: Introduction to temperature measurement. Thermocouples: laws governing their use; Static and Dynamic characteristics. Other measurement techniques. **Pressure measurement**: Manometers, elastic transducers, static and dynamic characteristics. Other devices for measurement. **Flow measurement**: obstruction meters, variable area meters, velocity measurement. **Strain measurement:** electrical type strain gauges, metallic resistance strain gauge, selection and installation of strain gages, circuitry for strain measurement, temperature compensation, calibration, semi-conductor strain gauges, stress analysis methods **Force and torque measurement:** standards, elastic transducers, strain gage load cells, hydraulic and pneumatic systems, torque measurement, combined force and moment measurement. **Measurement of motion**: LVDT, general theory of seismic instruments, vibrometers and accelerometers, piezoelectric accelerometers and vibrometers-circuitry and calibration, exciter systems, vibration test methods. **Signal conditioning:** Operational amplifiers, filters. **Sampling, and data acquisition:** Sampling concepts, Bits and words, number systems, Analog to digital conversion and digital to analog conversion, data acquisition systems and components, analog input/output communication, Digital input/output communication.
4	**Texts/References**	**1.** Measurement systems: Application and Design, "E.O. Doebelin, Fourth Ed., 1990, McGrawHill. **2.** Richard S. Figliola and Donald E. Beasley, Theory and Design for Mechanical Measurements, John Wiley and Sons.

1	**Title of the course** (L-T-P-C)	**Machine Drawing and 3D Modelling** **(1-0-2-3)**
2	**Pre-requisite courses(s)**	Exposure to Engineering Graphics Lab (ME 111)
3	**Course content**	**Introduction**: Engineering design process and drawings. Drawing standards. Computer aided drafting and use of software packages for engineering drawings **Detachable Fasteners**: Screw threads: conventional representations and specifications; Threaded fasteners: Types, forms, standard, and specifications; Drawing of connections; Foundation bolts; Locking Devices: Classification, principles of operation, standard types and their proportions; Shaft Couplings: Common types, standard proportions for some couplings; Pipe Joints, common pipe connections **Permanent Fastenings**: Rivets: Standard forms and proportions; Riveted Joints: Common types of joints, terminology, proportions and representation; Welds: Types of welds and welded joints, edge preparation, specifications, and representation of welds on drawings **Assembly Drawings**: withsectioning and bill of materials. Assemblies involving machine elements like shafts, couplings, bearing, pulleys, gears, belts, brackets. Engine mechanisms-assembly. Detailed part drawings from assembly drawings **Tool Drawings**: Jigs and fixtures **Production Drawings**: Limits, fits, and tolerances of size and form; Types and grade, use of tolerance tables and specification of tolerances, form and cumulative tolerances, tolerance dimensioning; Surface quality symbols, terminology and representation on drawings, correlation of tolerances and surface quality with manufacturing techniques **Modelling exercise:** use of Reverse Engineering to disassemble and measure components
4	**Texts/References**	**1.** K. L Narayana, P. Kannaiah, K. Venkata Reddy. Machine Drawing, 3rd Ed., New age International Publishers, 2006. **2.** K.C. Johan. Text Book of Machine Drawing, PHI Learning, 2009.

1	**Title of the course** (L-T-P-C)	**Manufacturing processes and Metrology laboratory (0-0-3-3)**
2	**Pre-requisite courses(s)**	Introduction to Communication Systems
3	**Course content**	**List of experiments:** Angle measurement using Sine bar Chip Thickness measurement using microscope Calibration of measuring instruments Three Wire Method Of Measuring Pitch Diameter Surface Roughness testing Manual Milling Manual Turning Welding of AI, etc. Shaping Green Sand molding.
4	**Texts/References**	• Jerzy A. Slade Coordinate Metrology: Accuracy of Systems and Measurements ISSN2195-9862, Springer publisher • Val Marinov Manufacturing Process Design Laboratory Manual, Kendall/Hunt PublishingCompany, ISBN 1465275312, 9781465275318 • R. K. Rajput A Textbook of Manufacturing Technology: Manufacturing Processes • Ghosh and A. K. Mallik, Manufacturing Science, Affiliated East West Press, 1985. HMT,Production Technology, Tata McGraw Hill, 1980. • J. Mcgeough, Advanced Methods of Machining, Chapman and Hall, 1988.

1	**Title of the course** (L-T-P-C)	**Fluid Mechanics** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Introduction: Scope, definition of fluid, fluid as continuum, fluid properties: density, specific weight, specific gravity, viscosity, kinematic viscosity, classification of fluid motion Fluid Statics: Pressure at a point, basic equation for pressure field, pressure variation (fluid at rest): incompressible and compressible fluid, standard atmosphere, Measurement of pressure: manometry, Hydrostatic Force on a plane and curve surface, pressure prism, Buoyancy, flotation and stability, pressure variation in a fluid with rigid body motion – linear motion, rigid body rotation. Elementary Fluid Dynamics: Newton's second law along and normal to a streamline, physical interpretation, static, stagnation pressure, Use of Bernoulli Eq.: free jets, confined flows, restrictions on the use of Bernoulli Eq.: compressibility effects, unsteady effects, rotational effects and others. Fluid Kinematics: The velocity field: Eulerian and Lagrangian flow descriptions, 1D, 2D and 3D flows, steady and unsteady flows, streamlines, streaklines and pathlines. Acceleration field: material derivative, unsteady and convective effects. Control volume and system representation: Reynolds Transport Theorem, physical interpretation, steady, unsteady effects, moving control volume. Integral approach: Conservation of mass: derivation of continuity, fixed, non-deforming control volume, moving non-deforming control volume, deforming control volume. Conservation of momentum: linear momentum and moment of momentum equation and their application. First law of thermodynamics: derivation & application of energy Eq., comparison of energy equation with Bernoulli's equation, application of energy equation to non-uniform flows, combination of energy equation and moment of momentum equation. Differential approach: linear motion and deformation, angular motion and deformation, Conservation of mass: differential form of continuity equation, stream function, Conservation of linear momentum: description of forces acting on the differential element, equations of motion, Inviscid Flow: Euler's equation of motion, the Bernoulli's equation, Irrotational flow, Bernoulli equation for irrotational flow, the velocity potential, flow net. Viscous flow: Stress deformation relationships, Navier-Stokes Eqs., Simple solutions for viscous compressible fluids: parallel flow through straight channel, Couette, plane Poiseuille, Hagen- Poiseuille, flow betn. two co-axial cylinders. Dimensional analysis and modelling: Importance of dimensional analysis, Buckingham's Pi Theorem, Dimensionless groups, Dimensional analysis through governing differential equations Viscous Flow in Pipes: General characteristics of pipe flow – laminar or turbulent flow, entrance region and fully developed flow, pressure and shear stress. Fully Developed Turbulent Flow – transition from laminar to turbulent flow, turbulent shear stress, turbulent velocity profile. Moody chart, minor losses, non- circular conduits, single pipes and multiple pipe systems, Pipe Flow rate measurement. Flow Over Immersed Bodies: Boundary layer characteristics: boundary layer structure and thickness on a flat plate, Blasius boundary layer, momentum integral boundary layer equation for a flat plate, transition from laminar to turbulent, momentum integral boundary layer equation for a flat plate, turbulent boundary layer flow.

4	**Texts/References**	**1.** Yunus A. Cengel, John M. Cimbala, Fluid Mechanics, Tata McGraw Hill Education, 2011. **2.** F.M.White, Fluid Mechanics, Seventh Edition, Tata McGraw Hill Education, 2011. **3.** Philip J.Pritchard, Alan T.Mcdonald,RobertW.Fox, Introduction to Fluid Mechanics, Wiley, 2009. **4.** John F. Douglas, J. M. Gasoriek, Lynne Jack and John Swaffield, Fluid Mechanics, Pearson, 2008.

1	**Title of the course** (L-T-P-C)	**Heat Transfer** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	● Introduction: Typical heat transfer situations, Modes of heat transfer, Introduction to laws, some heat transfer parameters ● Conduction: Fourier's law and thermal conductivity, Differential equation of heat conduction, boundary conditions and initial conditions, Simple one dimensional steady state situations – plane wall, cylinder, sphere (simple and complex situations), concept of thermal resistance, concept of U, critical radius. variable thermal conductivity (exercise), Special one dimensional steady state situations: heat generation, pin fins, Other fin configurations (exercise), Two dimensional steady state situations, Transient conduction, Lumped capacitance model, One dimensional transient problems: analytical solutions, 1D Heisler charts, Product solutions, Numerical methods in conduction, Steady state 1D and 2D problems, 1D transient problems: Explicit and implicit ● Radiation: Basic ideas, spectrum, basic definitions, Laws of radiation, black body radiation, Planck's law, Stefan Boltzman law, Wien's Displacement law, Lambert cosine law, Radiation exchange between black surfaces, shape factor, Radiation exchange between gray surfaces – Radiosity-Irradiation method, Parallel plates, Enclosures (non-participating gas), Gas radiation Forced Convection: Concepts of fluid mechanics, Differential equation of heat convection, Laminar flow heat transfer in circular pipe: constant heat flux and constant wall temperature, thermal entrance region, Turbulent flow heat transfer in circular pipe, pipes of other cross sections, Heat transfer in laminar flow and turbulent flow over a flat plate, Reynolds analogy, Flow across a cylinder and sphere, flow across banks of tubes, impinging jets ● Natural Convection: Introduction, governing equations, Vertical plate – Pohlhausen solution, horizontal cylinder, horizontal plate, enclosed spaces Heat Exchangers: Types of heat exchangers, LMTD approach – parallel, counter-flow, multi-pass and cross flow heat exchanger, NTU approach: parallel, counter- flow, shell and tube, cross flow heat exchanger Condensation and Boiling: Dimensionless parameters, boiling modes, correlations, forced convection boiling, laminar film condensation on a vertical plate, turbulent film condensation ● Mass Transfer: Analogy between heat and mass transfer, mass diffusion, Fick's law of diffusion, boundary conditions, steady mass diffusion through a wall, transient mass diffusion, mass convection, limitations of heat and mass transfer analogy.
4	**Texts/References**	**1.** Incropera FP and Dewitt DP, Fundamentals of Heat and Mass Transfer, 5th e, John Wiley & Sons, 2010. **2.** Cengel YA, Heat and Mass Transfer - A Practical Approach, Third edition, McGraw-Hill, 2010. **3.** Holman JP, Heat Transfer, McGraw-Hill, 1997.

1	**Title of the course** (L-T-P-C)	**Mechanics of Materials** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Module 1:** Basics: Fundamentals of mechanics of deformable solids. Concepts of stress and strain and their relationships. Axially loaded members - Normal stress and strain, Simple (direct) shear stress and strain, Hooke's law, Stresses on inclined planes under axial loading, thermal stresses and strains, statically indeterminate problems. Elastic strain energy under axial loads. **Module 2:** Torsion: torsion of circular cross-section shafts (Solid and hollow sections): Deformation field, Torsion formulae for stresses and angular deflection, Elastic strain energy under torsion, Closely-wound helical springs – stresses and deflections. **Module 3**: Bending: Euler – Bernoulli model: normal and shear stresses, deflections for symmetric bending. Statically indeterminate problems, Elastic strain energy under flexure. **Module 4:** Combined stresses: State of stress and strain at a point , transformation laws , Mohr's circle diagram for stress and principal stresses, thin walled structures : thin cylinders and spheres. Theories of failure: Maximum Normal-Stress theory, Maximum shear-stress theory and Maximum Distortional-energy theory. **Module 5:** Energy methods – Castigliano's theorem and its applications, fictitious-load method. Stability of structures – Buckling of idealized and elastic columns
4	**Texts/References**	**TEXTBOOKS:** **1.** S.H Crandall, N.C Dahl and S.J Lardner, An Introduction to Mechanics of Solids, Tata McGraw Hill, Third Edition, 2012. **2.** E.P. Popov, Engineering Mechanics of Solids, Prentice Hall of India, 2nd edition, 2012. **REFERENCES:** **1.** J. M. Gere and Goodno, Mechanics of Materials, 7th ed, Cengage Learning India, 2012. **2.** J.P Den Hartog, Strength of Materials, Dover, 1949. **3.** J.M Gere and S.P Timoshenko, Mechanics of Materials, CBS Publishers, 1986 **4.** R. C. Hibbeler, Mechanics of Materials, Pearson, 10th edition, 2016 . **5.** S.P Timoshenko and D.H Young, Elements of strength of Materials, 5th ed, Affiliated East West Press, 1976. **6.** F. P. Beer, E. R. Johnston Jr., John T. DeWolf , D. F. Mazurek, Mechanics of Materials, McGraw- Hill Education; 7th edition, 2014 **7.** M. Salvadori and R. Heller, Structure in Architecture, Prentice Hall Inc, 1963. **8.** S.P Timoshenko, History of Strength of Materials, Dover, 1983. **9.** M. H. Sadd, Elasticity: Theory, Applications, and Numerics, 1st ed, Elsevier India, 2006.

1	**Title of the course** (L-T-P-C)	**Manufacturing Processes II** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Material Removal Processes: Mechanics of Machining, tool geometry and materials, chip formation, tool temperature, tool wear, tool life, surface finish, machinability. Optimization of machining processes. Machine Tools: Generation of surfaces by machining, basic operations on shaping, slotting and planning machines, lathe, drilling and boring machines and grinding machines. Process Parameters and setups. Production Machines: Capstan and turret lathes, automats, broaching machines, centreless grinding machines. Special purpose machines for thread cutting and gear cutting (hobbing and shaping). Finishing processes honing, laping burnishing and deburring. Introduction to modern machining processes: EDM, ECM, LASER, Jigs and fixtures, principles of location and clamping, synthesis of simple jigs and fixtures. Principles of assembly engineering, theory of dimensional chains, fully interchangeable and selective assembly. Introduction to Numerical Control.
4	**Texts/References**	**1.** G. Boothroyd and W. A. Knight, Fundamentals of Machining and Machine Tools, Marcel Dekker, 1989. **2.** A. Ghosh and A. K. Mallik, Manufacturing Science, Affiliated East West Press, 1985. HMT, Production Technology, Tata McGraw Hill, 1980. **3.** J. Mcgeough, Advanced Methods of Machining, Chapman and Hall, 1988. **4.** M. F. Spotts, Dimensioning and Tolerancing for Quality Productions, Prentice Hall, 1983.

1	**Title of the course** (L-T-P-C)	**Fluid Mechanics Lab** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	Exposure to Fluid Mechanics
3	**Course content**	List of Experiments: ● Stability of floating bodies for determining the metacentre and buoyancy ● Reynolds experiment for laminar/turbulent flow visualisation ● Measurement of discharge coefficient for different shaped orifices with varying head ● Demonstration of Bernoulli's principle ● Visualisation of Free and Forced vortices ● Demonstration of linear momentum and impact forces of Jet for different deflection angles ● Pressure loss in pipe friction for laminar/turbulent flow ● Minor losses in Pipe system (fittings: bend, elbow, contraction/expansion) ● Major losses in Pipe system: Effect of pipe material, dimensions ● Fluidized Granular Bed ● Submerged Jet ● Flow Measurement by Venturi-meter, Orifice-meter & Rota-meter ● Heleshaw Apparatus ● Hydraulic Jump ● Course project set-up
4	**Texts/References**	**1.** Yunus A. Cengel, John M. Cimbala, Fluid Mechanics, Tata McGraw Hill Education, 2011. **2.** F.M.White, Fluid Mechanics, Seventh Edition, Tata McGraw Hill Education, 2011. **3.** Philip J.Pritchard, Alan T.Mcdonald,RobertW.Fox, Introduction to Fluid Mechanics, Wiley, 2009. **4.** John F. Douglas, J. M. Gasoriek, Lynne Jack and John Swaffield, Fluid Mechanics, Pearson, 2008.

1	**Title of the course** (L-T-P-C)	**Applied Thermodynamics (3-1-0-8)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction to the Course, General Scheme of things, Energy Resources, Heat Engines. Recap of I law for Closed and Open Systems. Classification of cycles as Open/Closed, Refrigeration/Power, Multi-component/ Single- component, Internal combustion/ external combustion, etc. Performance parameters: Network, thermal efficiency, heat rate, specific fuel consumption, work ratio, specific output, mean effective pressure, volumetric efficiency, COP, refrigeration effect. Carnot vs. other cycles. General stoichiometry and definition of terms (rich mixture, lean mixtures). Heat of formation, Heat of reaction, Calorific Value of fuel, Estimation methods for Calorific values, Exhaust Gas Analysis, Orsat Apparatus. Otto Cycles, Diesel Cycles, Air-standard cycles and Actual cycles, Dual cycle, p-theta diagram. Combustion and knocking in SI engine. Combustion and knocking in CI engine. Carburetion. Brayton cycle with explanation of various terms Modifications of Brayton cycle. Rankine cycle. Modifications to Rankine cycle. Feed Water Heaters and analysis. Moisture separators/ application of Rankine to Nuclear power plants. Vapour Compression and Reverse Brayton Cycles Vapour Absorption Cycles. Psychrometry. Reciprocating, rotary and centrifugal Compressors. Gas Power Cycles: Simple gas turbine cycle - single and twin shaft arrangements, intercooling, reheating, regeneration, closed cycles, optimal performance of various cycles, Ideal vs Real cycles; Jet Propulsion: turbojet, turboprop, turbofan, ramjet, thrust and propulsive efficiency; Rocket Propulsion. Direct Energy Conversion: thermionic and thermoelectric converters, photovoltaic generators, MHD generators, fuel cells.
4	**Texts/References**	**1.** Moran M. J. and H. N. Shapiro., Fundamentals of Engineering Thermodynamics, Third Edition, Wiley, New York, 1995. **2.** Cengel Y. A. and Boles M. A., Thermodynamics: An Engineering Approach, McGraw Hill, 3rd Ed., 1998 **3.** Dossat R. J. and Horan T. J., Principles of Refrigeration, Pearson Education, 4th Indian Reprint, 2004. **4.** Arora C. P., Refrigeration and Air-conditioning, Tata McGraw Hill, 2nd Ed., 2003. **5.** H I H Saravana muttoo, G F C Rogers and H. Cohen, Gas Turbine Theory 4e, Pearson, 2003

1	**Title of the course** (L-T-P-C)	**Kinematics and Dynamics of Machines (3-1-0-8)**
2	**Pre-requisite courses(s)**	Exposure to Engineering Mechanics (ME 201)
3	**Course content**	Introduction to Mechanisms. Position, velocity and acceleration analysis. Design of Cam Follower Mechanisms. Gear tooth profiles, spur gears and helical gears. Epicyclic Gear Trains. Dynamic Analysis of Mechanisms. Balancing. Analysis and Applications of Discrete and Continuous System Vibration.
4	**Texts/References**	**1.** B. Paul, Kinematics and Dynamics of Planar Mechanisms, Prentice Hall, 1979. **2.** J.J. Uicker, G.R. Pennock, and J.E. Shigley, Theory of Machines and Mechanisms (3rdedition), Oxford University Press, New York, 2005. **3.** S.S. Rattan, Theory of Machines (2nd edition), Tata McGraw Hill, New Delhi, 2005. **4.** R.L. Norton, Design of Machinery (3rd edition), Tata McGraw Hill, New Delhi, 2005. **5.** F.S. Tse, I.E. Morse, and R.T. Hinkle, Mechanical Vibrations, CBS Publishers and Distributors, 1983. **6.** J.S. Rao, and K. Gupta, Introductory Course on Vibrations, Wiley Eastern, 1984. **7.** J.P. Den Hartog, Mechanical Vibrations, McGraw Hill, 1956.

1	**Title of the course** (L-T-P-C)	**Machine Design** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Exposure to Mechanics of Materials
3	**Course content**	1. **Introduction to Design Review of Failure theories (Static and Fatigue)** –: Failures Resulting from Static Loading, Fatigue Failure Resulting from Variable Loading 2. **Shafts and couplings:** - Design of Shafts, keys and keyways, Couplings, Analysis of clutches and brakes 3. **Bearings:** Theories of lubrication to motivate design of rolling element bearings and hydrodynamic bearings, Design of hydrodynamic bearings for various types of shaft loadings and end conditions, Choice of rolling element bearings from charts 4. **Gears:** Gear force analysis, Basic of gear nomenclature of spur, helical, bevel and worm and worm gears; Design of gears (Spur gears): - Stresses induced in gears, Lewis bending equations, AGMA based calculation of pitting and bending stresses and strengths, Calculation of appropriate safety factors and power rating, Design of spur gears for simple power transmission; Overview of procedures involved in design of helical, bevel and worm gears. Special requirements in these types of gears are to be emphasized without going into the details. 5. **Design of Springs:** Basic spring nomenclature: - Forces deflection and stiffness, Various spring configurations, Materials for Spring; Designing of helical compression springs for static and fatigue loads 6. **Design of Belts:** Nomenclature, types of drives, derivation of belting equation, Design of flat belt and 'V' belt for simple power transmission between shafts. Choices of pulleys appropriate for the drives 7. **Design of fasteners, rivets and dowel pins:** Nomenclature for bolts and screws, Concept of friction between threads. Analysis and applications of power screws, Choice of appropriate bolts, screws for joining simple mechanical members which are then subjected to tensile, compressive and torsional loading, Preloading of bolted assembly, Design of bolts for static and dynamic loads. Concept of joint stiffness factor; 8. **Design of joints**: Choices of rivets and dowel pins for taking shear loads, Determining shear loads, for various types of eccentric loading conditions welded joints
4	**Texts/References**	**<u>TEXTBOOKS</u>** 1. Robert L. Norton, Machine Design, An Integrated Approach, Second Edition, Pearson 2. Richard Budynas, Keith Nisbett, Shigley's Mechanical Engineering Design, McGraw-Hill **<u>REFERENCE</u>** 1. Deutschman, D., Michels, W.J. and Wilson, C.E., Machine Design Theory and Practice, Macmillan, 1992. 2. Juvinal, R.C., Fundamentals of Machine Component Design, John Wiley, 1994. 3. Spottes, M.F., Design of Machine elements, Prentice-Hall India, 1994.

1	**Title of the course** (L-T-P-C)	**Theory of Machines** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Introduction**: Definitions Link or element, kinematic pairs, Degrees of freedom, Grubler's criterion (without derivation), Kinematic chain, Mechanism, Structure, Mobility of mechanism, Machine. Kinematic Chains and Inversions: Inversions of Four bar chain; Single slider crank chain and Double slider crank chain **Velocity and Acceleration Analysis of Mechanisms (Graphical & Analytical Methods)**: Velocity and acceleration analysis of Four Bar mechanism, slider crank mechanism and Simple Mechanisms **Gears:** Gear terminology, law of gearing, Characteristics of involute action, Path of contact. Arc of contact, Contact ratio Interference in involute gears. Methods of avoiding interference, Back lash. Gear Trains: Simple gear trains, Compound gear trains for large speed. reduction, Epicyclic gear trains, Algebraic and tabular methods of finding velocity ratio of epicyclic gear trains **Cams:** Types of cams, Types of followers. Displacement, Velocity and, Acceleration time curves for cam profiles. Disc cam with reciprocating follower having knife-edge, roller and flat-face follower, Disc cam with oscillating roller follower. Follower motions including SHM, Uniform velocity, uniform acceleration and retardation and Cycloidal motion **Static & Dynamic Force Analysis**: Introduction: Static equilibrium. Equilibrium of two and three force members. Members with two forces and torque. Free body diagrams. Static force analysis of four bar mechanism and slider-crank mechanism without friction. D'Alembert's principle, Inertia force, inertia torque. Dynamic force analysis of four-bar mechanism and slider crank mechanism. Dynamically equivalent systems **Balancing of Rotating Masses**: Static and dynamic balancing. Balancing of single rotating mass by balancing masses in same plane and in different planes. Balancing several rotating masses by balancing masses in same plane and in different planes **Balancing of Reciprocating Masses**: Inertia effect of crank and connecting rod, single cylinder engine, balancing in multi cylinder-inline engine (primary & secondary forces), V-type engine; Radial engine – Direct and reverse crank method **Introduction to Vibrations**
4	**Texts/References**	**1.** B. Paul, Kinematics and Dynamics of Planar Mechanisms, Prentice Hall, 1979. **2.** J.J. Uicker, G.R. Pennock, and J.E. Shigley, Theory of Machines and Mechanisms (3rd edition), Oxford University Press, New York, 2005. **3.** S.S. Rattan, Theory of Machines (2nd edition), Tata McGraw Hill, New Delhi, 2005. **4.** R.L. Norton, Design of Machinery (3rd edition), Tata McGraw Hill, New Delhi, 2005.

1	**Title of the course** (L-T-P-C)	**Mechanical Measurements Lab (0-0-3-3)**
2	**Pre-requisite courses(s)**	Exposure to Mechanical Measurements
3	**Course content**	**List of experiments:** • Study of the output characteristics of RC circuit for various inputs (Sine wave, square wave and step input) • Study of the output characteristics of LRC circuit for various inputs (Sine wave, square wave and step input) • Study of the working of orificemeter, venturimenter and rotameter • Steady state and transient calibration of temperature sensors (thermocouple and RTD) • Steady state and transient calibration of pressure sensors • Measurement of rotational speed by encoder, infrared sensor and stroboscope • Measurement of stress/strain through strain gage rosettes • Utility of operational amplifiers for generation of square wave, differentiator and integrator • Study of Analog to digital converter and digital to analog converter
4	**Texts/References**	1. E.O. Doebelin, Measurement systems: Application and Design, Fourth Ed., 1990, McGrawHill. 2. Richard S. Figliola, Donald E. Beasley, Theory and Design for Mechanical Measurements, John Wiley and Sons.

1	**Title of the course** (L-T-P-C)	**Solid Mechanics Lab** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**List of Experiments:** • Calibration of photoelastic material using a disk under diametral compression, a beamunder four-point bending and an uni-axial tensile specimen; and SCF evaluation in a circular ring, acrane hook and a plate with hole. • Stresses in thin pressure vessels using strain gauges; • Deflection of curved beams – a ring, a semi-circular ring, a quadrant and an angular davit • Stability of columns – To evaluate the buckling load for different materials (Steel, Copper,Aluminium and Brass) under different end conditions (Hinge-Hinge and Hinge-fixed condition) • Hardness test – Rockwell, Vickers and Brinell Hardness test • Impact testing machine: Izod and Charpy test • Torsion testing machine Tests of UTM: Tension (Ductile and Brittle), compression (brittle and ductile), bending ofbeam, leaf spring characteristics
4	**Texts/References**	S. Crandall, N. Dahl, S. Lardner, An Introduction to Mechanics of Solids, Tata MG Hill, 2012. E.P. Popov, Engineering Mechanics of Solids, Prentice Hall, 2012. Gere abd Goodno, Mechanics of Materials, 7th ed., Cengage Learning India, 2012.Gere and Timoshenko, Mechanical of Materials, CBS Publishers,1986.

1	**Title of the course** (L-T-P-C)	**Kinematics and Dynamics of Machinery lab** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Fabrication or model demonstration of ● Lower and Upper joins ● Multi-degree of freedom linkages with verification of Kutzback's Equation ● Inversions of 4R, 3R-P and 2R-2P four-link linkages ● Grashof Criterion ● Approximate and Exact Straight line generating mechanisms ● Pantograph Linkages ● Ackerman's steering linkage ● Geneva Mechanism ● Simple, Compound and Planetary Gear trains – Verification of velocity analysis, velocity ratio, instantaneous centers – Demonstration of inversion in synthesis of Cam profiles – Examination of geometry of involute gears in mesh – Passive Vibration Analysis; Damped response – Active Vibration Analysis; Frequency Response; Resonance – Vibration of two degree of freedom systems – Balancing of rotating masses – Balancing of reciprocating masses – Critical speed of shafts
4	**Texts/References**	1. Kinematics, Dynamics, and Design of Machinery: Edition 3 2. Kenneth J. Waldron, Gary L. Kinzel, Sunil K. Agrawal, 10 May 2016 John Wiley & Sons

1	**Title of the course** (L-T-P-C)	**Heat Transfer lab** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**1.** Measurement of thermal conductivity of a composite material **2.** Measurement of convective heat transfer coefficient **3.** Transient heat conduction **4.** Heat transfer through fins **5.** Jet impinging **6.** Boiling and Condensation **7.** Critical heat flux measurement **8.** Emissivity measurement **9.** Heat flux meter calibration **10.** Heat transfer in the tubular heat exchanger **11.** Heat transfer by radiation
4	**Texts/References**	**1.** Incropera F. P. and Dewitt D. P., Fundamentals of Heat and Mass Transfer, 5th Ed., Wiley and Sons, New York, 2002. **2.** Gayler J. F. W. and C. R Shotbolt, Metrology for Engineers, ELBS, 1990.

1	**Title of the course** (L-T-P-C)	**Manufacturing processes laboratory** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	Manufacturing processes
3	**Course content**	**List of experiments:** 1. CNC milling programming 2. CNC turning programming 3. Surface Roughness testing 4. Eccentric Turning 5. Angle measurement using Sine bar 6. Chip Thickness measurement using microscope 7. Different type of drilling 8. Shaping 9. Green Sand moulding Casting process Solidification Study Digital Fabrication (3D printing)
4	**Texts/References**	• Val Marinov Manufacturing Process Design Laboratory Manual, Kendall/Hunt Publishing Company, ISBN 1465275312, 9781465275318 • R. K. Rajput A Textbook of Manufacturing Technology: Manufacturing Processes • Ghosh and A. K. Mallik, Manufacturing Science, Affiliated East West Press, 1985. HMT, Production Technology, Tata McGraw Hill, 1980. • J. Mcgeough, Advanced Methods of Machining, Chapman and Hall, 1988.

1	**Title of the course** (L-T-P-C)	**Introduction to Aerospace Engineering (3-0-0-6)**
2	**Pre-requisite courses(s)**	Thermodynamics, Fluid Mechanics during UG
3	**Course content**	**Historical Developments** in Aviation, Aviation milestones, Components of an aircraft, Types of aerial vehicles. **Basic Aerodynamics:** Fluid dynamic equations & their basis, Ideal fluid, viscous flows, Flow past a body, Flow Separation, Generation of Lift, Drag & Moment, Non-dimensional coefficients, Airfoils & Wings, Airfoil families, Supersonic flight, Wave Drag, Aircraft Drag Polar, **Properties of atmosphere:** ISA, IRA, Pressure altitude, Altimeter; Aircraft speeds TAS, EAS, CAS, IAS. **Aircraft Performance:** Steady level flight, Altitude effects, Absolute ceiling, steady climbing flight, Energy methods, V-n diagram, Range and Endurance, Sustained level turn, pullup, Take-off and Landing **Longitudinal Static Stability, Control systems and Neutral Point** **Propulsion:** Introduction to various aircraft propulsive devices: Piston-prop, Turbo-prop, Turbojet, Turbofan, Turboshaft, Vectored- thrust, Lift engines. Gas Turbine Cycles and cycle based performance analysis; Introduction to gas turbine components - Intake, Compressors, Turbines, Combustion Chamber, Afterburner, and Nozzle. Single spool and Multi- spool engines. Power-plant performance with varying speed and altitude. **Aircraft structures:** Introduction to Flight Vehicle Structures and Materials**,** Forces Acting on an aircraft.
4	**Texts/References**	**1.** Anderson, J. D., The Aeroplane, a History of its Technology, AIAA Education Series, 2002. **2.** Anderson, J. D., Introduction to Flight, McGraw-Hill Professional, 2005. **3.** Hill, P., and Peterson, C., Mechanics and Thermodynamics of Propulsion, ISBN 978-0132465489, Pearson Education, 2009. **4.** Sun, C.T., Mechanics of Aircraft Structures, John Wiley and Sons, New York, 2006. **5.** Megson, T.H.G., Aircraft Structures for Engineering Students, Butterworth-Heinemann, Oxford, 2013. Lecture notes.

1	**Title of the course** (L-T-P-C)	**Design of Machine Elements** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Fundamentals of Mechanical Engineering Design**: Mechanical engineering design, Phases of design process, Design considerations, Engineering Materials and their Mechanical properties, Standards and Codes, Factor of safety, Material selection, Static Stresses: Static loads. Normal, Bending, Shear and Combined stresses, Stress concentration factor **Design for Impact and Fatigue Loads**: Impact stress, Fatigue failure: Endurance limit, S-N Diagram, Stress concentration effects, Notch sensitivity, fluctuating stresses, Goodman & Soderberg relationship, cumulative fatigue damage.Curved Beams: Stresses in curved beams of standard cross sections used in crane hook, punching presses & clamps, closed rings and links **Threaded Fasteners & Power Screws:** Stresses in threaded fasteners, effect of initial tension, design of threaded fasteners under static loads, eccentrically loaded bolted joints, types of power screws, efficiency & self-locking, design of power screw, screw jack: (complete design) **Riveted Joints & Weld Joints:** Rivet types, rivet materials, failures of riveted joints, efficiency, boiler joints, Lozanze joints, riveted brackets, eccentrically loaded joints, types of welded joints, strength of butt, fillet welds, Welded brackets with transverse & parallel fillet welds, eccentrically loaded welded joints **Design of Shafts, Joints, Couplings and Keys:** Torsion of shafts, design for strength and rigidity with steady loading, ASME codes for power transmission shafting, shafts under combined loads. Rigid and flexible couplings, Flange coupling, Bush and Pin type coupling and Oldham's coupling, Design of Cotter and Knuckle joints, Design of keys- square, saddle, flat and feather **Mechanical Springs & Flexible mechanical Elements:** Types of springs, spring materials, stresses in helical coil springs of circular & non-circular cross sections. Tension & compression springs, concentric springs; springs under fluctuating loads Belts: Materials of construction of flat & V belts, power rating of belts,concept of slip and creep, initial tension, effect of centrifugal tension, maximum power condition, Selection of flat & V belts, length & cross section from manufacturers' catalogues. Construction & application of timing belts, Wire ropes: Construction of wire ropes, stresses, selection of wire ropes. Chain drive: Types of power transmission chains, modes of failure for chain, & lubrication of chains **Gear drives, Clutches & Brakes:** Classification of gears, materials for gears, standard systems of gear tooth, gear tooth failure modes and lubrication of gears, Spur Gears, Design of Clutches, Design of Brakes **Bearing Design:** Lubricants, their properties, bearing materials, properties; mechanisms of lubrication, hydrodynamic lubrication, Numerical examples on hydrodynamic journal & thrust bearing design, static, dynamic load carrying capacities, equivalent bearing load, load life relationship; probability of survival.
4	**Texts/References**	**TEXTBOOKS:** 1. **Mechanical Engineering Design**, Joseph E Shigley and Charles R. Mischke. McGraw Hill International edition, 6th Edition, 2009. **REFERENCES:** 1. **Machine Design, Robert L. Norton, Pearson Education Asia, 2001.** **DATA HANDBOOK: Design Data Hand Book**, K. Lingaiah, McGraw Hill, 2nd Ed.

1	**Title of the course**	**Process of certification of composite aircraft structures**
	(L-T-P-C)	**(1-0-0-2)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	• Introduction to composite materials and structures • Airworthiness regulations • Certification requirements • Process of certification • Building block approach • Analysis philosophy • Testing philosophy – allowables, elements, subcomponents, and components tests • Conclusions
4	**Texts/References**	**1.** Garg and Andrew Sheppard, Certification Approach For Wing Moveable Trailing Edge Components For Commercial Transport Aircraft, SAMPE 2013 - Long Beach CA - June 6-9 / 2013 **2.** A. Fawcett, J. Trostle, S. Ward, 777 EMPENNAGE CERTIFICATION APPROACH ICCM11 (1997) **3.** William G. Roeseler, Branko Sarh, Max U. Kismarton, COMPOSITE STRUCTURES: THE FIRST 100 YEARS, ICCM16 (2007) **4.** MIL Handbook 17-1, 17-2, 17-3, 17-4, 17-5 **5.** Michael C. Niu, Composite airframe structures **6.** R. M. Jones, Mechanics of Composite materials **7.** J E McCarry and W. G. Roeseler, NASA CR 3767, Durability and damage tolerance of large cpmposite primary aircraft structure (LCPAS), 1984 **8.** 14CFR-part 23- AIRWORTHINESS STANDARDS: NORMAL CATEGORY AIRPLANES (EASA 23- for European) **9.** 14CFR-part 25- AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES (EASA 25- European) **10.** 14CFR-part 21- Certification Procedures for Products and Parts **11.** 14CFR-part 26- Continued airworthiness and safety improvements for transport category airplanes. **12.** The FAA and industry guide to Product certification, May 2017 **13.** Advisory circular- FAA AC 20-107B, Composite Aircraft Structure **14.** Advisory circular –FAA AC25.571 d, Damage Tolerance and Fatigue Evaluation of Structure **15.** JSSG-2006, 30 October 1998 DEPARTMENT OF DEFENSE JOINT SERVICE SPECIFICATION GUI **16.** EN-SB-08-001, 18 March 2011, Revision ADE Revised Damage Tolerance Requirements and Determination of Fail-Safety Life Limits for Fail-Safe Metallic Structures **17.** MIL-HDBK-516C, 12 December 2014, AIRWORTHINESS CERTIFICATION CRITERIA **18.** Military airworthiness, European defence agency

1	**Title of the course** (L-T-P-C)	**Mechanics and Measurement Lab** **(1-0-3-5)**
2	**Pre-requisite courses(s)**	No
3	**Course content**	**We are looking for 10 to 12 experiments for engineering physics programme from the set of experiments listed below, taken out of the existing list of Mechanical engineering experiments.:** **1.** Measurement of convective heat transfer coefficient **2.** Boiling and Condensation **3.** Critical heat flux measurement **4.** Heat transfer in the tubular heat exchanger **5.** Reynolds experiment for laminar/turbulent flow visualization **6.** Demonstration of Bernoulli's principle **7.** Demonstration of linear momentum and impact forces of Jet for different deflection angles **8.** Major losses in Pipe system: Effect of pipe material, dimensions **9.** Study of the working of orificemeter, venturimenter and rotameter **10.** Steady state and transient calibration of temperature sensors (thermocouple and RTD) **11.** Steady state and transient calibration of pressure sensors **12.** Measurement of stress/strain through strain gage rosettes **13.** Tensile and Compression Test 14.Deflection of springs and beams 15.Polariscope SCF Determination 16.Rockwell, Vickers and Brinell
4	**Texts/References**	**1.** Yunus A. Cengel, John M. Cimbala, Fluid Mechanics, Tata McGraw Hill Education, 2011. **2.** F.M.White, Fluid Mechanics, Seventh Edition, Tata McGraw Hill Education, 2011. **3.** Philip J.Pritchard, Alan T.Mcdonald, Robert W.Fox, Introduction to Fluid Mechanics, Wiley, 2009. **4.** John F. Douglas, J. M. Gasoriek, Lynne Jack and John Swaffield, Fluid Mechanics, Pearson, 2008. **5.** E.O. Doebelin, Measurement systems: Application and Design, Fourth Ed., 1990, McGrawHill. **6.** Richard S. Figliola, Donald E. Beasley, Theory and Design for Mechanical Measurements, John Wiley and Sons. **7.** Incropera F. P. and Dewitt D. P., Fundamentals of Heat and Mass Transfer, 5th Ed., Wiley and Sons, New York, 2002. **8.** Gayler J. F. W. and C. R Shotbolt, Metrology for Engineers, ELBS, 1990.

1	**Title of the course** (L-T-P-C)	**Basic Operation Research (3-0-0-3)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction to operation research, Linear Programming (LP): Terminology and formulations, Graphical and Algebraic solutions to LP, Simplex Algorithm: Algebraic form, Tabular form, Types of LPs, Matrix method, Duality: Writing the dual of an LP, Primal-Dual relationships, Dual: Basic understanding, significance, interpretation, Dual Simplex algorithm, Transportation Problem, Assignment Problem, Solving LPs using Solver, Sensitivity analysis.
4	**Texts/References**	Operations Research: Applications and Algorithms Author: Wayne L Winston Publisher: Indian University, 4th edition, 2004. Operations Research Theory & Applications, Author : J K Sharma, Publisher : Macmillan India Ltd. Introduction To Operations Research, Author: – Hiller & Liberman , Publisher: Tata McGraw Hill.

1	**Title of the course** (L-T-P-C)	**Finite Element Analysis** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	Approximate solution of differential equations - - Weighted residual techniques. Collocation, Least Squares and Galerkin methods. Piecewise approximations. Basis of Finite Element Method. Formulation of the matrix method -- "stiffness matrix"; transformation and assembly concepts. Example problems in one dimensional structural analysis, heat transfer and fluid flow. Elements of Variational calculus. Minimisation of a functional. Principle of minimum total potential. Piecewise Rayleigh - Ritz method and FEM. Comparison with weighted residual method. Two dimensional finite element formulation. Isoparametry and numerical integration. Algorithms for solution of equations. Convergence criteria, patch test and errors in finite element analysis. Finite element formulation of dynamics. Applications to free vibration problems. Lumped
4	**Texts/References**	**1.** Bathe, K. J., Finite element procedures in Engineering Analysis, Prentice Hall of India, 1990. **2.** Cook, R.D., D. S. Malkus and M. E. Plesha, Concepts and Applications ofFinite element analysis, John Wiley, 1989. **3.** Reddy, J. N., An Introduction to the Finite Element Method, 2nd ed., McGraw Hill, 1993. **4.** Seshu, P. Finite Element Method, Prentice Hall of India, New Delhi, 2003. **5.** Zienkiewicz, O. C., and K. Morgan, Finite elements and approximation, John Wiley, 1983. **6.** Zienkiewicz, O. C., and R. L. Taylor, The

1	**Title of the course** (L-T-P-C)	**Synthesis of Mechanisms** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	• **Planar mechanisms and geometry of motion:** Definition, Basic concepts, classification of links and pairs, Mechanisms, Machine and Inversions, Grashof's Law, Transmission of torque and force in mechanisms, Mobility, Degree of freedom (DOF), Grübler criterion, DOF permitted by turning and sliding, Equivalent mechanisms, Unique mechanisms. • **Number synthesis:** DOF and effect of odd and even number of links, Minimum number of binary links in a mechanism Possibility of minimum number of turning pairs in a mechanism, Enumeration of kinematic chain, DOF of spatial mechanisms. • **Synthesis of linkages:** Type, number and dimensional synthesis, Precision points, structural error, Chebyshev spacing. Poles and relative poles. • **Graphical method for synthesis –** Motion generation, Path generation, Function generation, Overlay method. • **Analytical method for synthesis –** Freudenstein's equation, Loop closure technique, Bloch's method of synthesis, Order synthesis. • **Coupler curves:** Equation of coupler curves, Synthesis for path generation, Robert-Chebyshev theorem (cognate linkages).
4	**Texts/References**	**TEXTBOOKS** 1. Ghosh and Mallik, *Theory of Mechanisms and Machines*, East West Press Pvt. Ltd. **REFERENCES** 1. George N. Sandor and Arthur G. Erdman, Mechanism Design: Analysis and Synthesis Volume I, Third Edition, Prentice Hall, 1996. 2. George N. Sandor and Arthur G. Erdman, Advanced Mechanism Design: Analysis and Synthesis Volume II, First Edition, Pearson, 1984.

1	**Title of the course** (L-T-P-C)	**Vibrations of Linear Systems** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Concepts of Vibrations:** Harmonic motion and definitions and terminology, Harmonic analysis, Fourier series expansion, Importance of vibration, Basic concepts of vibration, Classification of Vibration, Vibration analysis procedure. Characteristics of Discrete System Components, Equivalent Springs, Dampers and Masses, Modeling of Mechanical Systems, System Differential Equations of Motion, Nature of Excitations, System and Response Characteristics – Superposition Principle, Vibration about Equilibrium Point. **One DOF systems:** Free Vibrations – Undamped and damped vibrations, Harmonic Oscillator, Types of damping, Viscously Damped Single DOF Systems, Measurement of Damping, Coulomb Damping – Dry Friction. Forced Vibrations – Response of Single DOF System to Harmonic Excitations, Frequency Response Plots, Systems with Rotating Unbalanced Masses, Whirling of Rotating Shafts, Harmonic Motion of the Base, Vibration Isolation, Vibration Measuring Instruments – Accelerometers, Seismometers, Energy Dissipation, Structural Damping, Response to Periodic Excitations, Fourier Series. Response of Single DOF systems to Nonperiodic Excitations, The Unit Impulse - Impulse Response, The Unit Step Function - Step Response, The Unit Ramp Function - Ramp Response, Response to Arbitrary Excitations - The Convolution Integral, Shock Spectrum, System Response by the Laplace Transformation Method -Transfer Function, General System Response. **Two DOF Systems:** System Configuration, Equations of Motion-2 DOF Systems, Free Vibration of Undamped Systems, Natural Modes, Response to Initial Excitations, Coordinate Transformations – Coupling, Orthogonality of 3 Modes - Natural Coordinates, Beat Phenomenon, Response of Two-Degree-of-Freedom Systems to Harmonic Excitations, Undamped Vibration Vibrations of Continuous Systems: Vibrating String, Longitudinal vibrations of Bar, Torsional vibrations of Rod. Lateral vibrations of Beam.
4	**Texts/References**	**TEXTBOOKS** **1**. S S Rao, Mechanical Vibrations, Pearson Education, 5th Edition, 2004. **REFERENCES** **1.** W T Thomson, M D Dahleh and C Padmanabha, Theory of Vibration with applications, Pearson Education, 2008. **2.** Leonard Meirovitch, Fundamentals of Vibrations, **3.** McGraw-Hill, 2000. **4.** Den Hartog, Mechanical Vibrations, Dover Publications.

1	**Title of the course** (L-T-P-C)	**Introduction to Combustion** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Fluid Mechanics, Thermodynamics, Heat transfer
3	**Course content**	Combustion thermodynamics: Stoichiometry, Enthalpy of reaction, Adiabatic flame temperature, Chemical equilibria thermodynamics. Chemical Kinetics: Arrhenius theory of chemical reaction, Theories of reaction rate, Equilibrium with kinetic approach, Molecularity and order, Analysis of simple reactions. Transport processes in Combustion: Momentum transport, heat transport, Mass diffusion, conservation equations. Premixed combustion: Explosion, detonation, deflagration, Wave propagation modes in premixed, reactive medium- Rankine Hugoniot relation, Laminar premixed flames, Simple theories of premixed flame propagation, Spalding's analysis of 1D premixed flame Non-premixed flame: Diffusion flame analysis, Shvab-Zeldovich reaction, Burke- Schumann analysis
4	**Texts/References**	**1.** Stephen R Turns, An Introduction to Combustion: Concepts and Applications, 2nd Ed, Mc Graw Hill Publication **2.** Law, C. K, Combustion physics, 2006, Cambridge University press **3.** Warren C Strahle, An Introduction to Combustion, Combustion Science and Technology Book Series, Gordon and Breach Science Publishers **4.** Williams F. A, Combustion theory, 2nd Ed, CRC Press **5.** Kuo, Kenneth K, Principles of Combustion, 2nd Ed, Wiley Publication

1	**Title of the course** (L-T-P-C)	**I.C. Engines** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Principles/Fundamentals of Communications
3	**Course content**	**General concepts**: Fundamental Operating Procedures - Open circuit, Closed circuit, Internal combustion, External combustion, Spark ignition, Compression ignition (2 hr) **Reciprocating engine technology**: 2-stroke, 4-stroke, Pistons, connecting rods and crankshaft, Valve train, camshaft and timing gear, Engine block, cylinder and head geometry, Manifold, surface finish, track length, Fuel systems, carburettors, fuel injection, Turbo- and super-charger, Ignition, timing and spark advance (4 hr) **Recall of thermodynamics** - Definition and comparison of common internal combustion cycles, Otto cycle, Diesel cycle, Dual cycle, Atkinson cycle (6 hr) **Fuel-air systems**: Fuel Delivery Systems - Fuel delivery, The problem of part throttle operation, Air intake systems, Intake manifold design and tuning, Turbo-charging, Super-charging, Fuel management and control theory, Fuel injection, ECU operation, Sensors and instrumentation (6 hr) **Valve train and timing**: Operation, Arrangement -- Push-rod; Single overhead cam shaft (SOHC) design; Dual-overhead cam shaft (DOHC) design, Camshaft function and design considerations, Valve timing, Valve-train design considerations; Component and Event Timing - Valve actuation timing, Valve timing diagram, Spark ignition event and timing, Compression ignition injection event and timing (6 hr) **Fuels & Combustion** - Definition of hydrocarbon based fuels, Stoichiometric Burn Efficiency, Air / Fuel Ratio, Gasoline, Diesel, Octane rating, Cetane rating, Hydrocarbon emission, Flame types, Thermodynamic efficiencies, Ignition requirements, Combustion chamber and head design (6 hr) **Ignition** - Common ignition sources, Combustion abnormalities, Spark plug design considerations, Ignition timing; (6 hr) **Emissions & Controls** - Introduction to emissions, Chemistry of emissions, Emission controls, Catalytic converter operation, Exhaust gas recirculation (EGR), Valve overlap control, Introduction to variable camshaft timing (VCT) (4 hr)
4	**Texts/References**	1. Internal Combustion Engines – V Ganesan 2. Fundamentals of Internal Combustion Engines -- Gill P W., J H. Smith, E J. Ziury 3. Internal Combustion Engine Fundamentals – John B Heywood 4. IC Engines: Combustion and Emissions – B. P. Pundir

1	**Title of the course** (L-T-P-C)	**Geometric Modeling and Computer Graphics** **(2-0-2-6)**
2	**Pre-requisite courses(s)**	Knowledge of basic mathematics concepts, Exposure to hands-on Programming in C++
3	**Course content**	Section I: 3D Geometric Curves, Surfaces and Volume (10 hr) - Implicit/explicit/parametric representation - Geometric continuity - de Castelau algorithm and Bezier curve - B-Splines and Bezier surface patch, NURBS - Interpolation techniques - Lagrangian, Cubic, Hermite, Bilinear - Principal curvature and Gaussian curvature - Constructive Solid Geometry, Sweeping, Revolutions Section II: 3D Surfaces for Complex Geometries (10 hr) - Boundary Representation (B-Reps) - Tessellation primitives - Medial axis - Voronoi diagram and Delaunay triangulation - Level Sets, Isosurfaces, and Marching Cube algorithm - Surface area and Volume estimation for 3D tessellation - Polygonal mesh processing - decimation, subdivision, smoothing - Catmull Clark subdivision Section III: Computer Graphics and Visualization (10 hr) - Wireframe, Surface, and Solid modeling - Affine and rigid transformations - Ray tracing - Visualization examples of scalar, vector and tensor data - Programming Considerations: Object Orientated, Geometric Datastructures, Parallel processing and GPU.
4	**Texts/References**	**1.** Mathematics for 3D Game Programming and Computer Graphics by Eric Lengyel, 3rd Edition, Course Technology PTR Cengage Learning. (Textbook) **2.** Curves and Surfaces For CAGD by G. Farin, 5th Edition, Morgan Kauffman Publishers. **3.** Polygon Mesh Processing BY Botsch, Kobbelt, Pauly, Alliez & Levy, 1st Ed., AK Peters Ltd. **4.** Geometric Modeling and Mesh Generation from Scanned Images by Jessica Zhang, 1st Edition, Taylor and Francis Group.

1	**Title of the course** (L-T-P-C)	**Composite Materials: Manufacturing, Properties & Applications'** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	• Introduction: Definition and classification, Importance of composites over other materials. Revision of some mechanical properties. • Reinforcements: Functions of reinforcements and their forms, Glass fibers: Production, composition and properties, Production and properties of carbon and aramid fibers, Ceramic particulate and whisker reinforcements. • Micromechanics: Estimation of modulus and tensile strength. Prediction of thermal and electrical properties • Role of matrix and characteristics of different matrix materials. • Reinforcement-matrix Interfaces: wettability, interactions at the interfaces. Mechanical, physical and chemical bonding. • Polymer matrix composites (PMC): Important polymeric matrices, Manufacturing methods: Unit operations, hand lay-up, spray-up, pressure bag molding, vacuum bagging, prepags, compression molding, autoclaving, RTM, filament winding and pultrusion. • Metal matrix composites (MMC): Property advantages, comparison between MMCs & PMCs. Manufacturing of MMCs: Solid state processes: Diffusion bonding and P/M routes, Liquid state processes: Melt-infiltration, stir casting, in-situ processing, spray deposition and electrodeposition. • Properties and applications of selected PMCs and MMCs in industry. Ceramic matrix composites (CMC): Types of CMCs, main processing methods, and important applications. • Introduction to Nanocomposites.
4	**Texts/References**	**1. Text Books:** (1) K.K. Chawla, 'Composite Materials: Science and Engineering', 3rd Ed. Springer- Verlag, N.Y. (2012). (2) F.L. Matthews and R.D. Rawlings, 'Composite Materials: Engineering and Science', CRC, Woodhead Pub. Ltd., Cambridge, England (2008). **2. References**: (1) N. Chawla and K. K. Chawla, 'Metal Metrix Composites' 2nd Ed, Springer, N.Y. (2013). (2) ASM Handbook Vol.21: Composites, Eds. **3.** D.B. Miracle and S. L. Donaldson , ASM International, Ohio (USA) (2001).

1	**Title of the course** (L-T-P-C)	**Computer Integrated Manufacturing** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	1. **Computer aided design**: Drafting and drawing models, Surface, Wireframe, Solid models, coordinate transformations, parametric models, Bézier curve, B-spline curves, Data exchange: DXF, IGES, STEP 2. **Computer aided manufacturing**: fundamentals of part programming, path generation, post processing and verification. 3. **Computer aided process planning**: Process planning, domain, process planning steps, manual process planning, computer aided process planning: variant, generative and automatic process planning 4. **Computer integrated manufacturing**: Fundamental manufacturing processes, manufacturing trend, mass customization, engineering process for product realization, activities in a production cycle, information flow, design for manufacturing, industry 4.0 5. **Numerical control systems**: manufacturing process selection, process information maps, process engineering, design for manufacturability and assembly **6. Relevant Course Project component**
4	**Texts/References**	1. G Boothroyd, P Dewhurts W A Knight, Product Design for Manufacture and Assembly, CRC press, Taylor and Francis 2. M F Ashby, 2011, Materials selection in Mechanical Design, Butterworth-Heinemann; 4th edition. 3. K G Swift, J D Booker, 2003, Process Selection : from Design and Manufacture, Butterworth 4. TS Chang. Computer integrated manufacturing, Pearson Prentice Hall

1	**Title of the course** (L-T-P-C)	**Energy and Environment Lab (0-0-3-3)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Fuel cells** • Determine characteristics of a fuel cell • Determine performance of fuel cell with AC and DC loads **Thermal energy storage using phase change materials (PCM)** • Evaluation of heat transfer, system thermal efficiency during charging and discharging of PCM • Evaluation of two PCM systems in cascade **Wind turbine** • Determine the wind turbine coefficient of performance, and characteristics of a wind turbine • Determine the charge controller efficiency, power curve and conduct power analysis for different loads **Solar thermal energy** • Evaluation of performance in thermosyphonic mode of flow • Evaluation of performance in forced mode of flow **Solar concentrator system** • Evaluation of performance in thermosyphonic mode of flow Evaluation of performance in forced mode of flow
4	**Texts/References**	Lab manuals

1	**Title of the course** (L-T-P-C)	**Dynamics and Modelling of Weather and Climate (3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	• **Concepts of Weather and Climate:** World climate system; climate of the hemispheres, solar radiation; heating and cooling rates of the atmosphere; latitudinal distribution of the radiation balances of the earth's surface, atmosphere and earth's atmosphere system • **Climate System Description and Its Components**: Atmosphere, ocean, cryosphere, land Surface and the terrestrial biosphere • **Energy Balance, Hydrological and Carbon Cycles**: Earth's energy budget, the hydrological cycle, the carbon cycle • **Brief History of Climate:** Forced and internal variability, time scales of climate variations, reconstructing past climates, climate since the earth's formation, glacial-interglacial cycles, recent and future climate changes • **Numerical Weather and Climate Prediction:** Governing systems of equations, Reynolds' equations, Approximations, components of a climate model, physical-process parameterizations, considerations of modeling surface processes, lateral and upper boundary conditions, model setup and initialization, predictability, sources of error • **Climate System Response to Perturbations**: Radiative forcing, equilibrium and transient response of the climate system, water vapour feedback, other direct physical and bio-geo-chemical feedbacks
4	**Texts/References**	• H. Goosse, Climate System Dynamics and Modelling, CUP, Reprint, 2015. • T.T. Warner, Numerical Weather and Climate Prediction, CUP, Illustrated, 2010. • R.V. Rohli, and A.J. Vega, Climatology, Jones & Bartlett Publishers, 3rd edition, 2013.

1	**Title of the course** (L-T-P-C)	**Turbomachines** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Fluid Mechanics; Thermodynamics
3	**Course content**	**Introduction**: (2) Classifications of Turbomachines, Advantages of Rotary over Reciprocating, Applications **Basic Fluid Mechanics, Thermodynamics**: (3) Conservation of Mass, Momentum and Energy, Work and Energy Equations in a Rotating Frame with Constant Angular Velocity, Static and Stagnation Properties, Compressible gas flow relations, Mechanical Efficiency and Internal Efficiency, Internal Energy & Entropy **Dynamic Similitude**: (4) Definition, Dimensionless Parameter Groups with a Constant Density Fluids, Buckingham PI Theorem and its Significance, Characteristic Numbers of Turbomachines, Specific Speed and Specific Diameter, Power Specific Speed, Imperfect Similitude, **Hydraulic Pumps**: (6) Components, Priming of Pumps, Head Developed by pump, NPSHA and NPSHR, Cavitation, Characteristics of pumps, Types of vanes, Specific speed, Special Pumps e.g. Borehole Pumps, Slurry Pumps, Vertical Submerged Pumps. **Hydraulic Turbines**: (6) Hydraulic Energy, Types, Pelton Turbines: Impulse Turbines: Performance Characteristics, Velocity triangles, Specific Speed, Francis and Kaplan Turbines: Reaction Turbines: Velocity Triangles, Degree of Reaction and Speed Ratio, Cavitation, Draft Tubes, Conditions for maximum efficiency **Steam Turbines**: (6) Types of Turbines: Impulse and Reaction, Velocity triangles, Efficiencies, Condition for maximum efficiencies, Compounding of turbines - Velocity and Pressure, Degree of reaction, Reaction Turbines **CD Nozzles**: (6) Relation between area and velocity, Mach Number and Mach Cone, 1D steady isentropic flow, Choking in isentropic flow, Nozzle efficiency, CD Nozzle and characteristics. **Gas Turbines:** (6) Turbine and compressor cascade, Elementary cascade theory, Cascade nomenclature, Lift and drag, Turbine cascade correlation, Optimum space-chord ratio of turbine blades (Zweifel), Axial flow turbines: Two-dimensional Theory, Stage losses and efficiency **Compressors:** (4) Axial Flow Compressors, Principle of operation, Work done, power input factor, efficiency, Passage Vortex and Trailing Vortices, Loss Assessment, Diffuser, Losses in centrifugal compressors, Axial velocity distribution along blade height, Degree of Reaction, performance characteristics, Radial compressors
4	**Texts/References**	**1.** Fluid Mechanics and Thermodynamics of Turbomachinery – SL Dixon, Elsevier; 7th edition, BH **2.** Gas Turbine Theory, Cohen, Rogers and Saravanamuttoo, Pearson India **3.** Turbines, compressors and Fans, SM Yahya, McGraw Hill Education, 2017. **4.** Hydraulic Machines, VP Vasandani, Khanna Publishers **5.** An Introduction to Energy Conversion: Turbomachinery - Vol. III, Kadambi & Prasad, NAIP, 2011.

1	**Title of the course** (L-T-P-C)	**Reverse Engineering Laboratory** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	**Laboratory Hands-on Practice:** The students focus on hardware reverse engineering (RE). In the process of RE students understand existing technologies, functions, features, objects, components and systems. By carefully disassembling, observing, testing, analyzing and reporting, students would understand how something works and suggest ways it might be improved. The RE process requires careful observation, disassembly, documentation, analysis and reporting. The reverse engineering process may be non-destructive. This means that the object or component can be reassembled and still function just as it did before it was taken apart. Throughout the reverse engineering project, the students are able to think of ways these objects could be improved. Is there some way it could function better? or manufactured less expensively? The students will use observations to make suggestions for improvement of the product. **Learning Topics:** Forward Engineering Design, Design Thought and Process, Design Steps, System RE, RE Methodology, RE Steps, System level Design, and Examples, Product Development Cycle, Product Functions, Engineering Specifications, Product Architecture, Mechanical RE, Computer-Aided RE, Electronic RE, Identify electronic components, PCB RE, Schematic Drawings and Analysis
4	**Texts/References**	• Product Design: Techniques in Reverse Engineering and New Product Development, K. Otto and K. Wood Prentice Hall, 2001. • Reverse Engineering: An Industrial Perspective, Raja and Fernandes. Springer-Verlag, 2008 • Reversing: Secrets of Reverse Engineering, Eldad Eilam Publisher: Wiley, 2005

1	**Title of the course** (L-T-P-C)	**Additive Manufacturing** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Manufacturing processes
3	**Course content**	**Module: 1.** General overview, Introduction to reverse engineering, Traditional manufacturing, Rapid Tooling, Rapid Manufacturing; Indirect Processes - Indirect Prototyping. Indirect Tooling, Indirect Manufacturing. Introduction to Additive Manufacturing (AM): Overview of Additive Manufacturing (AM) (5 hr) **Module: 2.** Software & Methods, Solid moduling**,** Designing for Additive Manufacturing (DfAM), Software Tools vs. Requirements, Pre- & Post-processing 3D Scanning & the Scanning Process, Sculpting & Repairing Data, AM File Formats, STEP File Format, More Detail on NURBS Model Validation, Working with DICOM Files for 3D Printing Medical Imagery, Data formats, conversion, checking, repairing and transmission. Synergic integration technologies Part slicing and Build Orientation, Area-filling strategies, applications and limitations of AM. (7 hr) **Module: 3.** AM technologies, classification of AM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion, Binder Jetting, and Direct Energy Deposition, Popular AM processes. Additive manufacturing of different materials (7 hr). **Module: 4.** Materials science for AM, discussion on different materials used in AM, use of multiple materials, multifunctional and graded materials in AM, role of solidification rate, Biomaterials, Heirarchical Materials & Biomimetics, Ceramics & Bio-ceramics, Shape-Memory Materials, 4D Printing & Bio-active materials (7 hr). **Module: 5.** Key Related Processes, Process selection, decision methods planning, control for AM, Monitoring and control of defects, and selection of Additive Manufacturing processes, tooling and manufacturing systems based on product requirements (7 hr). **Module: 6.** Applications of AM, Direct Digital Manufacturing, Distributed Manufacturing, Mass Customization Biomedical Applications, Aerospace & Automotive Applications, Architectural Engineering Food & Consumer Applications, Personalized Surgery Art, Fashion, Jewelry, Toys & Other Applications (7 hr)
4	**Texts/References**	**1.** Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing. Evener, 2014 **2.** C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing. World Scientific, 2003. **3.** Lu, L., Fuh, J., Wong, YS., 2001, Laser Induced Materials and Processes for Rapid Prototyping, Kluwer. **4.** Pique, A., Chrisey, DB., 2002, Direct Write Technologies for Rapid Prototyping Applications: Sensors, Electronics and Integrated Power Sources, Academic Press. **5.** Venuvinod, PK., Ma, W., 2004, Rapid Prototyping - Laser Based and Other Technologies, Kluwer.

1	**Title of the course** (L-T-P-C)	**Introduction to Computational Fluid Dynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	ME 203 Fluid Mechanics; Numerical Analysis; Computer Programming
3	**Course content**	**1.** Review of Governing Equations: General conservation equation; specific mass, momentum, energy conservation equations **2.** Fundamentals of Numerical Methods: Direct and iterative solvers for linear equations; PDE, Classification, Basics of finite-difference, finite- volume finite-volume methods; Notion of accuracy, consistency, stability, convergence; Verification and validation. **3.** Diffusion Equation: 1-D steady conduction; Source terms and non-linearity; 2-D steady conduction; Unsteady conduction; Non-trivial boundary conditions. **4.** Advection-Diffusion Equation: Steady 1-D advection- diffusion equation; Upwinding, numerical diffusion, higher-order schemes; 2-D advection-diffusion equation **5.** Incompressible Navier-Stokes equations, Incompressibility and pressure-velocity coupling; Staggered vs collocated grids; SIMPLE and PISO algorithms. **6.** Special Topics: Non-Cartesian coordinate systems; Curvilinear grids; Unstructured grids; Advancedlinear solution methods such as multigrid methods, preconditioning; Use of numerical libraries; Introduction to parallel programming for CFD. **7.** Mesoscopic approaches to discrete simulation of fluid dynamics **8.** Tutorial on a commercial CFD code & an open-source code (e.g. OpenFOAM).
4	**Texts/References**	**1.** "An Introduction to Computational Fluid Dynamics", by H. W. Versteeg and W. Malalasekera; 2nd edition, Pearson Education Ltd., 2007. (ISBN: 9780131274983) **2.** "Introduction to Computational Fluid Dynamics: Development, Application and Analysis", by Atul Sharma; Wiley, 2016. (ISBN: 9781119002994)

1	**Title of the course** (L-T-P-C)	**Fluid Flow and Heat Transfer in Porous Media (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to fluid mechanics and heat transfer
3	**Course content**	**Module 1:** Mechanics of Fluid flow through Porous Medium: porosity, volume averaging procedure, Equation of continuity, momentum equation (Darcy's Law, Forchheimer equation, Brinkman equation), Turbulence in porous media. (10 hr) **Module 2:** Heat Conduction in Porous Medium: Local thermal equilibrium, effective stagnant thermal conductivity, thermal dispersion, local thermal non-equilibrium, interfacial heat transfer coefficient (8 hr) **Module 3:** Forced Convection through Porous Medium: external flow, internal flows and jet impinging flows (9 hr) **Module 4:** Natural Convection through Porous Medium: external flows (9 hr) **Module 5:** Radiation heat transfer through Porous Medium: Radiation transport equation, energy equation with radiation (6 hr)
4	**Texts/References**	**1.** Donald A Nield and Adrian Bejan, Convection in Porous Medium, Springer publications, Newyork, 2017, Fifth Edition. **2.** M. Kaviany, Principles of Heat Transfer in Porous Media, Springer publications, Newyork, 1999, Second Edition **3.** Arunn Narasimhan, Essentials of Heat and Fluid Flow in Porous Media, Ane Books Private Limited, New Delhi, 2016, First Edition. 4.Faruk Civan, Porous Media Transport Phenomena, John Wiley and Sons, Singapore, 2011, First Edition. **5.** F.A. L. Dullien, Porous Media: Fluid Transport and Pore Structure, Academic Press, London, 1992, Second Edition **6.** Kambiz Vafai, Handbook of Porous Media, Taylor and Francis, Florida, 2005, Second Edition

1	**Title of the course** (L-T-P-C)	**Refrigeration and Air-conditioning** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Introduction:** Review of the laws and concepts of thermodynamics, coefficient of performance, heat transfer, history of refrigeration, evolution of various refrigeration systems and working fluids, broad classification of refrigeration systems and motivation for high efficiency cooling systems **Refrigeration cycles and techniques:** Reversed-Carnot cycle, reversed-Brayton cycle, simple and actual vapour compression cycles, aircraft refrigeration cycle, effect of design and operating parameters, multi-pressure systems, vapour absorption cycles and other methods such as evaporative and thermoelectric cooling, vortex tube. **Refrigeration subsystems:** Refrigerants, environmental impact of refrigerants, brines, sorbents and dessicants, Compressors, condensors, evaporators, expansion devices, capillary tubes, component selection and balancing, lubrication, solubity of refrigerants, operating and safety controls, sensing and actuating elements **Refrigeration systems:** Vapour compression and vapour absorption systems **Prelude for air-conditioning systems:** Properties of moist air and psychrometric processes, comfort conditions, factors affecting comfort, humidifiers and dehumidifiers, duct and air- handling systems **Air-conditioning principles and systems:** Basic equipments in air-conditioning and classification of air-conditioning systems, winter and summer air conditioning systems, domestic split and window air-conditioners, central air-conditioning systems, room sensible heat factor Estimation of cooling load: sensible and latent heat gains, heat gains from various sources **Applications of refrigeration and air-conditioning:** Description of thermodynamic principles and components of specific systems such as domestic refrigerator, industrial refrigerator, ice manufacturing plant **Enviromental impact and future of cooling systems:** Environmental impact of refrigeration, renewable energy-based refrigeration, solar cooling
4	**Texts/References**	**<u>Textbook</u>:** C.P. Arora, Refrigeration and Air Conditioning, McGraw Hill Edu.; 3rd Ed., 2017. **<u>References</u>:** **1.** G.F. Hundy, A.R. Trott, T.C. Welch, Refrigeration, Air conditioning and Heat pumps, 5th ed., Elsevier, 2016, **2.** RJ. Dossat, Principles of Refrigeration, John Wiley & Sons, Inc., 5th ed., 2001, **3.** P.N. Ananthanarayana, Basic Refrigeration and Airconditioning, McGraw- Hill Edu, 3rd ed., 2005. **4.** ASHRAE Handbook - Fundamentals (SI), 2017, **5.** ASHRAE Handbook- Heating, Ventilating, and Air-Conditioning APPLICATIONS (SI), 2015, **6.** A.A.M. Sayigh J.C. McVeigh (eds.), Solar Air Conditioning and Refrigeration, Pergamon, 1992. **7.** R.S. Khurmi, J.K. Gupta, A Textbook of Refrigeration and Air-conditioning, S Chand, 5th Ed., 2018.

1	**Title of the course** (L-T-P-C)	**Solar Energy Collector Systems** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Recap of solar energy:** Solar angles, Declination of Sun, Solar Tracking, Sun path diagram, Solar radition (4 hrs) **Solar thermal-energy collectors:** Basic construction and design aspects of flat-plate collector, stationary compound parabolic collector, evacuated tube collector, Sun-tracking concentrating collectors: Parabolic trough collector, Linear Fresnel reflector, Parabolic dish reflector, Heliostat field collector: Solar thermal-electric power. (6 hrs) **Thermal analysis of solar collectors:** Thermal analysis of flat-plate collectors including air- collectors, Thermal analysis of compound parabolic collectors, Thermal analysis of parabolic trough collectors, Collector thermal efficiency, Collector incidence angle modifier, acceptance angle of concentrating collectors, Uncertainty quantification in solar collector testing. (8 hrs) **Solar water-heating (SWH) systems:** Passive systems as thermosiphon, integrated collector storage, Active systems as direct circulation, indirect water-heating, air- water-heating, and Pool heating, Heat storage as sensible or latent hear, Solar ponds, Applications of SWHs, Module and array design of SWH systems. (8 hrs) **Solar air-heating (SAH) systems:** Active, hybrid or passive, With or without storage, With or without fins, Single/double pass, performance enhancement techniques for SAHs, intergartion of thermal-storage unit with SAHs, Applications of SAHs, Solar sterling engine. (8 hrs) **Photovoltaic (PV) systems:** Photovoltaic effect, PV cell characteristics, Module and array design of PV systems, PV technology and materials, PV module equipment, Applications of PVs, Design and sizing of PVs, Hybrid PV/T systems. (8 hrs)
4	**Texts/References**	**Textbooks:** **1.** S.A. Kalogirou, Solar Energy Engineering: Processes and Systems, Elsevier; 2nd Ed., 2014. **2.** S.P. Sukhatme, J.K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill Education, 3rd Ed.,1996. **References:** **1.** V. Sivaram, Taming the Sun – Innovations to Harness Solar Energy and Power the Planet, 1st Ed., MIT Press, 2018. **2.** JA. Duffie, WA. Beckman, Solar Engineering of Thermal Processes, Wiley, 4th Edition, 2013.

1	**Title of the course** (L-T-P-C)	**Impact Mechanics and Modelling** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to statics and dynamics; instructor consent is required
3	**Course content**	**Introduction and appreciation** of Impact in engineering; **Impact Mechanics of Rigid Body** - Impulse – Momentum Equations and limitations of rigid body impact mechanics; **Impact Mechanics of Deformable Bodies** - 1-D wave propagation in solids induced by impact; multi-dimensional impact mechanics of deformable bodies – waves in semi-infinite media; **Experimental Impact Mechanics** - quasi-static material tests and high strain rate testing of materials, **Modeling Deformation and Failure Under Impact** - Constitutive Models for Material Deformation and Plasticity, Failure/Damage Models and temperature rise **Computational Impact Mechanics** - Principles of Numerical Formulations, Numerical Simulation Using Finite Element Methods, Numerical Integration Methods, Computational Aspects in Numerical Simulation; **Vehicle Collision -** Mechanics of Vehicle Collision, Crash Impact Tests for Safety Regulations, Concepts in Analysis of Vehicle/Occupant Systems, Crashworthiness and Crash Energy Management, Crashworthiness of electric vehicles
4	**Texts/References**	**TEXTBOOKS** **1.** Rao, C. Lakshmana; Narayanamurthy, V.; Simha, K. R. Y. - Applied Impact Mechanics, 1st Edition, Wiley, 2017 **2.** W. J. Stronge, Impact mechanics, 2nd Edition, Cambridge University Press, 2018 **REFERENCE** **1.** Norman Jones, Structural Impact, 2nd Edition, Cambridge University Press, 1990

1	**Title of the course** (L-T-P-C)	**Power Plant Engineering** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Thermodynamics, Heat transfer
3	**Course content**	**Review** of the laws and principles of thermodynamics and fluid mechanics **Introduction to power generation** and various cycles, review of resources locally and globally. **Coal based thermal power plants**: Steam cycles, parameters affecting efficiency, reheating and regeneration, supercritical cycles, cogeneration, combined and coupled cycles, pressurized fluidized bed combustor, integrated gasification combined cycles, gas turbine and steam turbine combined cycle **Subsystems for power plants**: fuels, combustion and firing methods, fuel handling systems, steam generator, feedwater heater, furnace, steam turbine, condenser, cooling tower **Gas turbine power plants**: Ideal and real Brayton cycle, effect of operating variables on efficiency and specific work, modifications of Brayton cycle, combined steam and gas turbine plants, aircraft and marine powerplants, turbojet, turbofan, turboprop and turboshaft configurations **Hydroelectric power plant**: hydrological cycle, elements of a hydroelectric plant, hydraulic turbines and their selection. **Nuclear power plant**: nuclear fission and fusion, classification of nuclear reactors, boiling water reactor, pressurized water reactor, heavy water reactor, fusion power reactor. **Non-conventional and renewable power generation**: magnetohydrodynamic power, thermoelectric power, fuel cells, geothermal, ocean, solar and wind power **Environmental degradation:** Effluents from power plants, methods of pollution control
4	**Texts/References**	**1.** P. K. Nag, “Power plant Engineering,” McGraw Hill, 2017. **2.** Black and Veatch (ed), “Power plant engineering,” Springer, 1996. **3.** A. B. Gill, “Power Plant Performance,” Elsevier, 2016. **4.** M. M. El-Wakil, “Powerplant Technology,” McGraw Hill, 2017. **5.** F. T. Morse, “Power Plant Engineering,” D. Van Nostran, 1953 **6.** R. W. Haywood, “Analysis of Engineering Cycles,” 4th Edition, Pergamon Press, 1991.

1	**Title of the course** (L-T-P-C)	**Vehicle Mechanisms and Dynamics (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to statics and dynamics; instructor consent is required
3	**Course content**	• **Anatomy of a vehicle (including mechanisms)**: tire, braking, suspension, chassis, car body, gear box, clutch system, steering. • **Basic Mechanics Review** : Review of kinematics and dynamics of particles and planar rigid bodies. • **Linearized Dynamics**: Simple linearized rigid models of different components. Dynamic stability and the vehicle performance under different operating conditions such as understeering, neutral steering, oversteering, and factors associated with the vehicle- terrain interaction. • **Suspension and comfort and safety**: Concept of vehicle ride comfort. Introduction to random excitation and electronics stability controls. Performance characteristics of a comfort vehicle ride. • **Software Modelling**: Introduction to the development of one-dimensional vehicle driveline using different softwares such as MATLAB Simulink/MAPLESIM/System Modeller
4	**Texts/References**	**TEXTBOOKS** **1.** "Road Vehicle Dynamics - Fundamentals and Modelling with Matlab" by George Rill and Abel Arrieta Castro, CRC Press, 2020 **2.** Automotive Engineering: Powertrain, Chassis System and Vehicle Body, Butterworth- Heinemann; 2009 **REFERENCE** **1.** "Fundamentals of Vehicle Dynamics", by Thomas D. Gillespie, **(**Premiere Series Books) **2.** Performance Vehicle Dynamics, by James Balkwill, Butterworth Heinemann, 2018

1	**Title of the course** (L-T-P-C)	**Wind Turbine Design and Operation** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Introduction** to wind energy, its characteristics and resource estimation, Wind turbine components, wind turbine topology **Aerodynamics** of Wind Turbines, one-dimensional momentum theory, airfoils, blade design, momentum and blade element theories, tip loss, performance prediction, off-design performance, rotor design procedure, aerodynamic issues in wind turbines, aerodynamics of vertical axis wind turbines **Structural dynamics of wind turbines**, loads in a wind turbine, rotor dynamics, Flapping Blade Model, Linearized Aerodynamics Model, wind turbine materials **Electrical aspects** of wind turbine, electrical machines, power converters, ancillary electrical equipment **Wind turbine control**, aerodynamic and generator torque controls, stall-regulated and active-pitch regulated controls, operating states of a wind turbine, dynamic control of wind turbines, control issues in wind turbines **Applications:** hybrid power, offshore wind energy, other applications **Environmental impact:** avian interaction, noise, Electromagnetic interference **New concepts** of wind turbines
4	**Texts/References**	1. J.F. Manwell, .G. McGowan, and A.L. Rogers, "Wind energy explained, Theory, design and application," 2nd edition, Wiley, 2009. 2. T. Corke, R. Nelson, "Wind Energy Design", CRC Press, 2018.

1	**Title of the course** (L-T-P-C)	**Energy Sources and Sustainability** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Classification of energy sources** **Non-renewable and renewable sources:** a general comparative assessment in terms of current usage, environmental impact, past and future trends, sustainable sources, global and local outlook. **Non-renewable sources:** characteristics, properties and applications of coal, oil, natural gas, and nuclear fuels **Renewable sources:** characteristics, properties and applications of biomass, hydrogen and biofuels, solar and photovoltaics, wind, geothermal, tidal and wave, hydroelectric sources, fuel cells, catalysis for fuel cells and sustainable chemical processes, batteries
4	**Texts/References**	

1	**Title of the course** (L-T-P-C)	**Theory of Elasticity** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	**Module-1:** Analysis of Stress: Stress tensors. Cauchy's stress principle, direction cosines, stress components on an arbitrary plane with stress transformation. Principal stresses in three dimensions, stress invariants, Equilibrium equations, Octahedral stresses, Mohr's stress circle, construction of Mohr Circle for two and three dimensional stress systems, equilibrium equations in polar coordinates for two- dimensional state of stresses. General state of stress in 3D in cylindrical coordinate System (6 hrs) **Module-2:** Analysis of Strain: types of strain, strain tensors, strain transformation. Principal strains, strain invariants, octahedral strains, Mohr's Circle, equations of Compatibility for Strain (6 hrs) **Module-3:** Stress-strain relations: Stress-strain relations, Generalized Hooke's law, Relation b/w elastic moduli. Strain energy in an elastic body, Stress-formulation, Displacement-formulation, Principle of Superposition, St. Venant's principle, Uniqueness theorem, reciprocal theorem. (6 hrs) **Module-4:** Two dimensional problems in Cartesian coordinate system: plane stress and plane strain problems. Stress function, stress function for plane stress and plane strain cases. Solution of two- dimensional problems with different loading conditions by the use of polynomials. (6 hrs) **Module-5:** Two dimensional problems in polar coordinate system strain-displacement relations, compatibility equation, stress- strain relations, stress function and Biharmonic equation. Axisymmetric problems, thick-walled cylinders, rotating disks of uniform thickness, stress concentration, effect of circular holes on stress distribution in plates. (4 hrs) **Module-6:** Torsion of prismatic bars: Saint Venant's semi-inverse approach, Prandtl's stress function, torsion of circular,elliptic cross sections, equilateral triangle c/s. Prandtl's membrane analogy, torsion of thin walled and multiple cell closed sections. (6 hrs) **Module-7:** Thermal Stresses: Thermoelastic Stress–Strain Relations, Equations of Equilibrium,Strain– Displacement Relations, Examples: Thin Circular Disk: Temperature Symmetrical about Centre, Long Circular Cylinder. (3 hrs) **Module-8:** 2D Problems in Curvilinear Coordinates: Curvilinear coordinates, Stress components in curvilinear coordinates; Stress functions and displacements in terms of complex functions; Resultant of
4	**Texts/References**	**Texts:** **1.** S.P. Timoshenko, J. N. Goodier, Theory of Elasticity, 3rd Ed, McGraw Hill, 1970, **2.** **3.** L.S. Srinath, Advanced Mechanics of Solids, 2nd Ed, TMH Pub Co., New Delhi, 2003, 3. C.T. Wang, Applied Elasticity, McGraw-Hill, 1953. **Ref:** **1.** MH. Sadd, Elasticity: Theory, Applications, And Numerics, 3rd Ed., Academic Press, 2014. **2.** J.R. Barber, Elasticity, , 3rd edition, Kluwer Academic, 2009, (3) A.P. Boresi, K Chong, J. D. Lee, Elasticity in Engineering Mechanics, 2010, Wiley. **3.** A.F. Bower, Applied Mechanics of Solids, 1st Ed., 2009, CRC Press. **4.** P Chou, N Pagano. Elasticity: Tensor, Dyadic and Engineering Approaches, Dover Pub, 1992.

1	**Title of the course** (L-T-P-C)	**Rocket Propulsion** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Calculus, Linear Algebra, Probability, Random Processes, Ability to code in Python
3	**Course content**	Motion in Space: Introduction, Motion in space. Rotational frame of reference and orbital velocities, Velocity requirements(4hr) Theory of Rockets: Theory of rocket propulsion,Specific impulse,Rocket equation and Staging of rocket,Review of rocket principles, Propulsion efficiency,Examples illustrating theory of rocket propulsion(3hr) Nozzles Introduction to nozzles,Therory of nozzles, Nozzle shape, Area ratio of nozzles: Under expansion and over expansion,characteristics velocity and thrust coefficient,Divergence loss in conical nozzles and Bell nozzles,Unconventional nozzles and problems in nozzles(7hr) Solid Propellant Rockets: Introduction to solid propellant rockets,Burn rate of solid propellants and equilibrium pressure in solid propellant grains, Ignition of solid propellant rockets,Review of solid propellant rockets(6hr) Liquied Propellant Rockets: Feed systems for liquid Propellant rockets, feed system cycles for pump fed liquid propellant rockets,Analysis of gas generator and staged combustion cycles and introduction to injectors,injector configurations, Cooling of chambers and mixture ratio distribution Efficiencies due to mixture ratio distribution and incomplete vaporization, Pumps and Turbines:Propellant feed system at zero'g' conditions, Review of liquid be -propellant rockets and introductions to mono-propellant rockets, instability in liquid propellant rockets,instability in liquid propellant rockets(8hr) Hybrid Rockets: Introduction to hybrid rockets and simple illustration of combustion(3hr) Electrical,Nuclear Rockets: Principles of electrostatic and electromagnetic rockets Electrical thrusters.Electrical and nuclear rockets,Advanced propulsion(4hr)
4	**Texts/References**	**1.** Hill,P.G and Peterson,C.R..,Mechanics and Thermodynamics of Propulsion,2nd ed.,Reading Massachusetts:Addison Wesley Publishing Company,1992. **2.** Sutton,G.P.and Biblarz,O.,Rocket Propulsion Elements, 9th Ed., New York: Wiley Intescience pulications,2001. **3.** Mukunda,H.S..,Understanding Aerospace Propulsion, Bangalore:Interline Publishing,2004. **4.** Turner, M.J.L.., Rocket and Spacecraft propulsion,Springer Praxis Publishing. 2004. **5.** Ramamurthi.K..,Rocket Propulsion, Macmillan 210

1	**Title of the course** (L-T-P-C)	**Systems and Energy Efficiency in Buildings** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Introduction:** Energy efficiency policies for buildings, SAVE directive and energy performance of buildings directive (EPBD), Asian legislation for energy efficiency in buildings, Indian green building council, Green rating integrated habit assessment (GRIHA), ZEB and NZEB. **(6 hrs)** **Energy Audits:** Types of energy audits such as walk-through assessment, energy survey and analysis, Case Study - I: Energy Audit of an Office Building, Case Study - II: Energy Audit of an lecture theatre complex, Verification methods of energy savings, Maximum demand reduction, Energy management. **(7 hrs)** **Building Envelope:** Basic heat transfer concepts: Conduction, covection, and radition, Basic electrical systems: Electrical motors, Lighting systems, Electrical appliances, Electrical distribution systems, Quality of power, Walls and roofs, Windows and air leakage, Overall Thermal Transfer Value (OTTV), Simplified calculation tools for building envelope audit, HVAC, Introduction to EnergyPlus. **(8 hrs)** **Air-Conditioning and central chiller systems:** Refrigeration, Central air-conditioning systems, Chiller efficiency rating, Energy saving measures for chiller systems. **(4 hrs)** **Boilers and heating systems:** Boilers construction and efficiency, Energy saving measures for boiler systems, Pumping systems, Energy saving measures for pumping systems, Cooling towers **(4 hrs)** **Air-Handling and distribution systems:** Air-handling units (AHUs), Control of moisture content and temperature, System curves and fan performance, Types of air distribution, constant air volume and variable air volume. **(4 hrs)** **Lighting systems**: Lumens, Types and efficiencies of lamps, Lighting power density, Energy saving measures, Daylighting. **(3 hrs)** **Solar space heating and cooling:** Thermal load estimation, occupancy load, Passive space-heating design, Solar heating and solar cooling. **(4 hrs)** **Energy-efficient building materials (2 hrs)**
4	**Texts/References**	**<u>Textbooks</u>**: **1.** L. Jayamaha, Energy-Efficient Building Systems, Green Strategies for Operation and Maintenance, McGraw-Hill, 1st Edition, 2006. **<u>References</u>**: **2.** F. Asdrubali, U. Desideri, Handbook of Energy Efficiency in Buildings: A Life Cycle Approach, Elsevier, 1st Ed., 2018. **3.** M. Krarti, Energy Audit of Building Systems: An Engineering Approach, McGraw-Hill, 2st Ed, 2010. **4.** S.A. Kalogirou, Solar Energy Engineering: Processes and Systems, Elsevier; 2nd Ed., 2014.

1	**Title of the course** (L-T-P-C)	**Atmosphere and Ocean Dynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Fluid dynamics
3	**Course content**	Introduction to ocean-atmosphere system, their interdependence, and motivation for their study, Review of fluid dynamics, fluids at rest and in motion Effect of gravity in a non-rotating frame, and in a density-stratified fluid, inviscid shallow water theory, combined rotation and stratification effects, homogeneous models of wind-driven oceanic circulation, baroclinic and barotropic instabilities, quasi-geostrophic theory, atmospherics and ocean general circulation, qquatorial dynamics
4	**Texts/References**	1. A. E. Gill, “Atmosphere-Ocean Dynamics,” Academic Press, 1982. 2. Benoit Cushman-Roisin and Jean-Marie Beckers, “Introduction to Geophysical Fluid Dynamics,” Academic Press 2009. 3. Olbers, Willebrand, and Eden, “Ocean Dynamics,” Springer, 2012.

1	**Title of the course** (L-T-P-C)	**Smart Manufacturing** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Module: 1.** Introduction to Smart manufacturing, various Smart Manufacturing Technologies, Smart foundry, Reverse engineering, Traditional manufacturing, Rapid Tooling, Rapid Manufacturing; Indirect Processes - Indirect Prototyping. Indirect Tooling, Indirect Manufacturing. Introduction to Additive Manufacturing (AM): Overview of Additive Manufacturing (AM) (6) **Module: 2.** Software & Methods, Solid moduling**,** designing for Additive Manufacturing (DfAM), Software Tools vs. Requirements, Pre- & Post-processing 3D Scanning & the Scanning Process, Sculpting & Repairing Data, AM File Formats, STEP File Format, More Detail on NURBS Model Validation, Data formats, conversion, checking, repairing and transmission. Synergic integration technologies Part slicing and Build Orientation, Area-filling strategies, applications and limitations of AM. (6) **Module: 3.** Introduction: NC/CNC, CNC machines, Industrial applications of CNC, economic benefits of CNC. CNC Machine Tools (5): **Module: 4.** CNC tooling: Qualified and pre-set tooling, tooling systems, tool setting, automatic tool changers, work holding and setting. Programming: Part programming language, programming procedures, proving part programmes, computer aided part programming (6) **Module: 5.** AM technologies,classification of AM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion,Binder Jetting, and Direct Energy Deposition, Popular AM processes. Additive manufacturing of different materials (6). **Module: 6.** Smart Materials, discussion on different materials used in AM, use of multiple materials, multifunctional and graded materials in AM, role of solidification rate, Biomaterials, Heirarchical Materials &Biomimetics, Ceramics & Bio-ceramics, Shape-Memory Materials, 4D Printing & Bio-active materials (5). **Module: 7.** Case studies of smart manufacturing, Case studies of information systems for key manufacturing functions: PLM, Life cycle, supply chain, enterprise, quality, maintenance, materials, energy and sustainability information systems. (6)
4	**Texts/References**	**1.** Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing. Evener, 2014 **2.** C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing. World Scientific, 2003.Lu, L., Fuh, J., Wong, YS., 2001, Laser Induced Materials and Processes for Rapid Prototyping, Kluwer. **3.** Pique, A., Chrisey, DB., 2002, Direct Write Technologies for Rapid Prototyping Applications: Sensors, Electronics and Integrated Power Sources, Academic Press. **4.** Venuvinod, PK., Ma, W., 2004, Rapid Prototyping - Laser Based and Other Technologies, Kluwer. **5.** Warren S. Seames, Computer numerical control: concepts and programming, Thomson Learning, 2001 **6.** William W. Luggen, Computer numerical control: a first look primer, Thomson Publishing, 1996 **7.** Learning Barry Leatham - Jones, Introduction to Computer Numerical Control, Pitmans, London, 1988. **8.** T.K. Kundra, P.N. Rao and N.K. Tewari, Numerical control and Computer Aided Manufacturing, Tata McGraw Hill Publishing Company Limited, New Delhi 1985."

1	**Title of the course** (L-T-P-C)	**Aerodynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Introduction**: relevance of aerodynamics and applications. **Review of mathematical background:** vector calculus, tensor notation and algebra; **Kinematics and dynamics of fluid motion; Governing equations of fluid motion; Potential flow:** elementary potential flows, Kutta-Joukowski theorem, conformal transformation, source panel method; **Flow over airfoils**: airfoil nomenclature and characteristics, thin airfoil theory, vortex panel method; **Finite wing aerodynamics:** Prandtl lifting line theory, lifting surface theory and vortex lattice method; execution of relevant numerical technique(s) using scientific computing tools; **Compressible flows:** governing equations of compressible flow, elements of supersonic flows, subsonic compressible flow over airfoils; **Boundary layers:** solutions to the boundary layer equation, boundary layer separation
4	**Texts/References**	**Text books:** **1.** Houghton, E. L., and P. W. Carpenter, "Aerodynamics for engineering students," Elsevier, 2015. **2.** Anderson Jr., John D, "Fundamentals of aerodynamics," McGraw-Hill Education, 2017. **References:** **1.** Abbott, I. H., and A. E. von Doenhoff. "Theory of Wing Sections, Including a Summary of Airfoil Data." Dover Publications Inc., 1959. **2.** Bertin, John H., and Russel M. Cummings, "Aerodynamics for Engineers," Pearson, 2014. **3.** Anderson Jr., John D. "Modern Compressible Flow: with Historical Perspective." McGraw-Hill Education, 2021. **4.** Anderson Jr., John D. "Introduction to Flight (SI Units)." McGraw-Hill Education, 2017. **5.** Van Dyke, Milton. "An Album of Fluid Motion." Parabolic Press, 1982.

1	**Title of the course** (L-T-P-C)	**Introduction to Aerospace Materials** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	▪ Importance of Aerospace Materials Selection, Aerospace Materials: Past Present & Future, Critical requirements of Aerospace Materials: Mechanical, Physical and Chemical Properties, Strengthening Mechanisms of Aerospace Alloys, Mechanical testing and Durability of aerospace materials, Production and casting of aerospace metals, Processing and machining of aerospace metals ▪ Aluminium alloys for aircraft structures, Aluminium-Lithium Alloys, Titanium alloys for aerospace structures and engines, Magnesium alloys for aerospace structures, Steels for aircraft structures, Single crystal Ni-based superalloys for turbine blade, Nickle and Cobalt based Superalloys for gas turbine engines, Refractory Metals for Aerospace Applications, Stealth materials ▪ Polymers for Aerospace Structures, Fiber reinforced Polymeric composites, Metal & Ceramic Matrix Composite, transparent materials, Coating material and technologies ▪ Fracture processes of aerospace materials, Fatigue, Corrosion and Creep in Aerospace Materials, Non-destructive inspection and health monitoring of, aerospace materials, Ashby plots
4	**Texts/References**	**Text books:** 1. Aerospace Materials and Material Technologies, Volume 1: Aerospace Materials, Editor: N. Eswara Prasad, R. J. H. Wanhill, Springer Singapore, doi: https://doi.org/10.1007/978-981-10-2134-3, 2017 2. Introduction to Aerospace Materials, Editor(s): Adrian P. Mouritz, Woodhead Publishing, 2012, Pages 1-14, ISBN 9781855739468, https://doi.org/10.1533/9780857095152.1 3 .Introduction to Aerospace Structures and Materials by René Alderliesten, Publisher: TU Delft Open, 2018, https://open.umn.edu/opentextbooks/textbooks/647 **References:** 1. Material Selection in Mechanical Design by Michael F. Ashby, (2017) 5th Edition, ISBN: 9780081006108, 9780081005996 2. Additive Manufacturing for the Aerospace Industry, Editor(s): Francis Froes, Elsevier, 2019, ISBN 9780128140628, https://doi.org/10.1016/B978-0-12-814062-8.00001-7

1	**Title of the course** (L-T-P-C)	**Fundamentals of Tribology** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Introduction – Materials and surfaces:** Tribology — Historical perspective, Industrial Significance, Economic considerations; Solid structure and properties — Atomic Structure, Bonding and Coordination, Disorders in Solid Structures, Elastic and Plastic Deformation, Fracture and Fatigue, Time Dependent Viscoelastic & Viscoplastic Deformation. Surfaces — Nature of surfaces, Characteristics of Surface Layers, Surface texture, Surface parameters, Measurement of surface parameters, Statistical properties of surfaces, Analysis of Surface Roughness. **Contacts:** Analysis of Contacts — Single Asperity, Multiple Asperity Contacts, Measurement of the Real Area of Contact, Stress distribution, Displacements due to loading, Hertzian and non-Hertzian contacts, Rough surfaces in contact, Deformation mode, Thermal effects; Adhesion — Solid–Solid Contact, Contact with liquid mediation. **Friction:** Friction — Measurement, Causes, Theories, Plastic interaction of surface asperities, Ploughing effect, Elastic hysteresis losses, Solid–Solid Contact, Liquid-Mediated Contact, Friction of Materials; Rolling Motion — Free rolling, Microslip in rolling, Tyre-road contacts. **Wear:** Wear — Definitions, Mechanisms, Wear Debris, Wear of Materials, Indentation cracking, Factors affecting wear, Experimental considerations, Wear control, Application of wear in design, Characteristics of friction induced vibrations. **Lubrication:** Lubricants — Viscosity, Measurement of viscosity, Lubricating oils, Greases; Lubrication — Regimes of Fluid Film Lubrication, Viscous Flow and Reynolds Equation, Hydrostatic Lubrication, Hydrodynamic Lubrication, Elasto-hydrodynamic Lubrication.
4	**Texts/References**	1. Introduction to Tribology, Bharat Bhushan, John Wiley & Sons. 2. Principles of Tribology, Halling, J. (Ed), Macmillan, 1975.

1	**Title of the course** (L-T-P-C)	**Advanced Heat Transfer** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Module-1: Conduction:** Equations and boundary conduction in different coordinate systems; Analytical Solutions: separation of variables, Laplace Transform, Duhamel's theorem: Non-impulse initial conditions; Numerical Methods: Finite difference and flux conservation; Interfacial heat transfer. **Module-2: Convection:** Conservation equations and boundary conditions; Heat transfer in laminar developed and developing boundary layers: duct flows and external flows, analytical and approximate solutions, effects of boundary conditions; Heat transfer in turbulent boundary layers and turbulent duct flows; Laminar and turbulent free convection, jets, plumes and thermal wakes, phase change. **Module-3: Radiation:** Intensity, radiosity, irradiance, view factor geometry and algebra; formulations for black and non–black surfaces, spectrally–selective surfaces (solar collectors); Monte Carlo methods for radiation exchange; The radiative transfer equation, extinction and scattering properties of gases and aerosols, overview of solution methods and applications. **Module-4: Interaction between conduction, convection and radiation:** Coupled problems; Examples in manufacturing and electronic cooling applications; Micro channels and micro fins.
4	**Texts/References**	**1.** M N Ozisik, Heat Conduction, 2nd ed, John Wiley & Sons, 1993. **2.** Kakaç, S., Yener, Y., Heat Conduction, 3rd edition, Taylor & Francis, 1993. **3.** F P Incropera and D P Dewitt, Introduction to Heat Transfer, 3rd ed, John Wiley & Sons, 1996. **4.** W. M. Kays and E. M. Crawford, Convective Heat and Mass Transfer, Mc Graw Hill,1993. **5.** Adrian Bejan, Convective Heat Transfer, John Wiley and Sons, 1995. **6.** M F Modest, Radiative Heat Transfer, McGraw-Hill, 1993. **7.** R Siegel and J R Howell, Thermal Radiation Heat Transfer, 3rd ed, Taylor & Francis, 1992.

1	**Title of the course** (L-T-P-C)	**Introduction to Turbulence and its Modelling** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	ME203 Fluid Mechanics.
3	**Course content**	• **Introduction to Turbulence**: Nature of turbulence, origin of turbulence, laminar and turbulent boundary layers, diffusion of turbulence, concept of eddy viscosity • **Statistics of Turbulence**: Statistical aspects of turbulence, scales in turbulence, spectrum of turbulence, energy cascade in isotropic turbulence, Kolmogorov hypotheses • **Mathematical Theory of Turbulence**: The Reynolds equation, Reynolds decomposition, equations for the mean flow, Reynolds stress, mixing length model, turbulent heat transfer, limitations of mixing length theory • **Dynamics of Turbulence**: Dynamics of turbulence, Taylor microscale, Reynolds stress and vorticity, the vorticity equation • **Boundary-free and Wall-bounded Turbulence**: Turbulent wakes, turbulent jets and mixing layers, turbulent flows in pipes and channels, experimental techniques for turbulence characteristics • **Introduction to Turbulence Modelling**: Turbulence modelling and closure problem, algebraic models, modern variants of the mixing length model, one equation models, k-□ and k-□ models, Spalart–Allmaras turbulence model • **Introduction to Numerical Techniques for Turbulence**: Direct numerical simulations (DNS), large eddy simulations (LES) and Reynolds averaged Navier-Stokes (RANS) modelling techniques, spectral methods and particle based methods for turbulence
4	**Texts/References**	**TEXTBOOKS** **1.** Tennekes H. and Lumley J., A first course in turbulence, M.I.T. Press. **2.** Tritton D.J., Physical Fluid Dynamics, Oxford University Press. **3.** Davidson P.A., Turbulence: An Introduction for Scientists and Engineers, Oxford Uni Press. **4.** Townsend A.A., The structure of turbulent shear flow, Cambridge University Press., 1980. **5.** Wilcox D.C., Turbulence modeling for CFD, DCW Industries, Incorporated, 1994.

1	**Title of the course** (L-T-P-C)	**Advanced Finite Element Methods** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Finite Element Methods
3	**Course content**	**FEM formulation for time dependent problems (16 hours)** - Transient heat transfer problems - Structural dynamics problem - Explicit and Implicit methods of solutions - stability, accuracy and convergence study of solution methods **Introduction to reduced order modelling technique: (6 hours)** - Introduction to reduced order modeling - Methods of reduced order modeling ○ Static condensation, ○ mode superposition, ○ component mode synthesis, ○ Krylov subspace technique. **Nonlinear Finite Element Method (18 hours)** - Introduction to Nonlinear FEM - FEM for geometric nonlinearity and forcing nonlinearity, - FEM for elastic-plastic analysis ○ Strain hardening model ○ Kinematic hardening model - Methods to solve nonlinear problems ○ Newton Raphson method ○ Secant method ○ Continuation method - Convergence of nonlinear solutions ○ Force convergence Displacement convergence
4	**Texts/References**	**1.** J.N. Reddy, Introduction to Finite Element Method, Tata McGraw-Hill, 2006 **2.** J. N. Reddy, An Introduction to Nonlinear Finite Element Analysis, Oxford University Press, 2004. **3.** K. J. Bathe, Finite Element Procedures, PHI Learning Pvt. Ltd., 1996 **4.** T. J. R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Publications, 2000 **5.** Zu-Qing Qu, Model Order Reduction Techniques with Applications in Finite Element Analysis, Springer, 2004

1	**Title of the course** (L-T-P-C)	**Multiphase Flow** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	• **Introduction and overview :** History, Motivation and Application • **Transport phenomena :** Introduction, Reynolds transport theorem, Continuity equation, Momentum equation • **Fluid mechanics with interface :** Interfacial tension and its role in multiphase flow, Surface energy and capillary forces, Measurement of surface tension, Laplace pressure and Young's law, Curvature computation, Capillary rise, Capillary force on floating bodies, Wetting, Wetting of a rough surface, Contact angle hysteresis, Singularities • **Boundary conditions in multiphase flows :** Kinematic and dynamic boundary conditions, Stress conditions at fluid interfaces, Stress on deforming surfaces • **Scaling analysis :** Introduction, Buckingham's theorem and dimensionless numbers for multiphase flow systems, Dimensional analysis and physical similarity, Self-similarity • **Introduction of asymptotic analysis :** Asymptotic expansion, Pulsatile flow : Analytical and asymptotic solution, Domain perturbation method • **Lubrication model/Thin film approximation :** Derivation of basic equation of lubrication theory, Thin film approximation with free surfaces : Derivation of governing equations and boundary conditions, Self-similar solution, Application of lubrication theory • **Flow instabilities:** Fluid jets, Rayleigh-Plateau Instability, Fluid sheets, Rupture of soap film and derivation of Taylor-Culick velocity, Rayleigh-Taylor Instability, Kelvin-Helmholtz instability • **Numerical solution of Navier-Stokes equation:** Time integration, Spatial discretization, Marker and Cell method, Boundary conditions • **Advection of fluid interfaces:** Fundamentals, Numerical definition of interface, Heaviside function, Advection of color function, Volume of fluid method, Level set method, Numerical model of surface tension driven flows • **Applications:** Bubbly flows, drop collision and splashing, Breakup and Atomization
4	**Texts/References**	**<u>TEXTBOOKS</u>** **1.** L. Gary Leal, Advanced Transport Phenomena, First Edition, 2007, CUP. **2.** G. Tryggvason, R. Scardovelli, and S. Zaleski, Direct numerical simulations of gas-liquid multiphase flows, First Edition, 2011, Cambridge University Press **<u>REFERENCE</u>** **1.** P.G. de Gennes, F. Brochard-Wyart and D. Quéré, Capillarity and Wetting Phenomena : Drops, Bubbles, Pearls, Waves, First Edition, 2003, Springer Publication **2.** E. J. Hinch, Purterbation Methods, First Editions, 1991, Cambridge University Press **3.** G. I. Barenblatt, Scaling, First Edition, 2003, Cambridge University Press. **4.** J. Eggers & M.A. Fontelos, Singularities: Formation, structure & propagation, 1st Ed., 2015, CUP

1	**Title of the course** (L-T-P-C)	**Additive and Forming Manufacturing Processes** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Module 1:** Introduction to Smart manufacturing, various Smart Manufacturing Technologies, Smart foundry, Reverse engineering, Traditional manufacturing, Rapid Tooling, Rapid Manufacturing; Indirect Processes - Indirect Prototyping, Indirect Tooling, Indirect Manufacturing. Introduction to Additive Manufacturing (AM): Overview of Additive Manufacturing (AM), Introduction to flexible manufacturing processes **Module 2:** AM technologies, classification of AM processes: Sheet Lamination, Material Extrusion, Photo- polymerization, Powder Bed Fusion, Binder Jetting, and Direct Energy Deposition, Popular AM processes. Additive manufacturing of different materials **Module 3:** Advance in welding techniques, Robotic welding, characterization, Non-traditional Manufacturing processes, **Module 4:** Introduction: CAD/CAM, NC/CNC, CNC machines, Industrial applications of CNC, economic benefits of CNC. CNC Machine Tools, CNC tooling: Qualified and pre-set tooling, tooling systems, tool setting, automatic tool changers, work holding and setting. Programming: Part programming language, programming procedures, proving part programmes, computer aided part programming **Module 5:** Metal forming: Bulk and sheet metal forming processes, Fundamentals of plasticity, yield and flow, anisotropy, instability, yield criterion for isotropic materials, plastic stress strain relations for isotropic materials. Force equilibrium method and its application to metal forming processes. Introduction to incremental sheet and bulkmetal forming **Module 6:** Industry 4.0 cases studies of manufacturing
4	**Texts/References**	**1.** Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototypingto Direct Digital Manufacturing. Springer, 2014. **2.** C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing.WorldScientific, 2003. **3.** Theory of Plasticity by J. Chakrabarty, McGrawHill Book Co., InternationalEdition, 19874. **4.** Messler, R. W. (2008). Principles of Welding: Processes, Physics, Chemistry, and Metallurgy.Germany:Wiley. **5.** Ibrahim Zaid, R. Sivasubramanian, CAD/CAM: Theory and Practice. McGraw Hill Education,2nd edition,2009. **6.** M. P. Groover, E. W. Zimmers, CAD/CAM: Computer-aided design and manufacturing.Pearson, 2013.

1	**Title of the course** (L-T-P-C)	**Nonlinear Solid Mechanics for Finite Element Method (3-0-0-6)**
2	**Pre-requisite courses(s)**	Solid Mechanics and Finite Element is recommended
3	**Course content**	1. **Introduction to Tensors:** Overview of conventions & mathematical identities in vector calculus and tensor algebra 2. **Review of Linear Elasticity:** Linear strain tensor, compatibility conditions, stress tensor, equilibrium equation 3. **Kinematics of Deformation:** Material and spatial derivatives, Deformation gradient, Strain tensor, Velocity gradients, Spin tensor, Lie time derivatives 4. **Concept of Stress:** Cauchy stress theorem, Piola transformation, First Piola-Kirchhof (PK) stress, Principal directions, Alternative stress definitions such as Second PK stress, Biot stress, Corrotated cauchy stress tensors 5. **Balance Principals and Constitutive relation:** Conservation of mass, Reynolds' Transport theorem, Principals of Momentum and Energy balance 6. **Hyperelasticity:** Various strain-energy constitutive formulations - invariant based model, isotropic model, incompressible model, composite material model, examples from the field of soft tissue biomechanics and tyre industry 7. **Viscoelasticity:** Generalized Maxwell Model, Relaxation time 8. **Finite Element for Non-linear material:** Variational Principles, Objective stress rates, Linear Consistent Tangent Modulus, numerical challenge due to incompressibility
4	**Texts/References**	**<u>Text-books:</u>** 1. Gerhard A. Holzapfel, *Non-linear Solid Mechanics- A continuum approach for engineering,* John Wiley and Sons Ltd. 2000. **<u>References:</u>** 2. J. Bonet, RD. Wood, *Non-linear Continuum Mechanics for Finite Element Analysis* (2nd Ed), Cambridge University Press., 2008. 3. LA. Taber, *Non-linear Theory of Elasticity – Applications in Biomechanics*, World Scientific Publishing, 2004. 4. Rene de Borst, Mike A. Crisfield, Joris J.C. Remmers, and Clemens V. Verhoosel, *Non-linear Finite Element Analysis of Solid and Structures,* (2nd Edition), John Wiley and Sons Ltd., 2012.

1	**Title of the course** (L-T-P-C)	**Advanced Solid Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module 1: Analysis of Stress:** Concept of traction, Cauchy Stress formula: Traction on arbitrary planes, Equality of cross-shears, Principal stresses and Principal Planes, Stress invariants, State of Stress Referred to Principal Axes – Octahedral stresses, Mohr's Circles for 3D State of Stress, Equations of equilibrium – Cartesian and Cylindrical coordinate systems. **Module 2: Analysis of Strain:** Displacement field, Deformation gradient, Change in length of a linear element andits linearization and physical interpretation, State of Strain at a point, Change in thedirection of a linear element, cubical dilatation, change in the angle between two linear elements – shear strain, Principal axes of strain and Principal strains, Strains in cylindrical coordinate systems, compatibility of linear strains. **Module 3: Stress-strain Relations – Linear Elastic Solids:** Generalized Hooke's Law, Material Symmetry Planes – Monoclinic, Orthotropic and Isotropic, Lames's constants, Bounds on moduli. **Module 4: Formulations, General theorems and Solution Strategies:** Stress formulation – Beltrami-Michell Compatibility relations, Navier-Lame Equations of equilibrium, Strain Energy Concept, Saint Venants principle, Principle of Superposition, Uniqueness theorem; General Solution strategies. **Module 5: Plane elasticity:** Plane stress, Pane strain, 2D stress formulation in Cartesian and Polar Coordinates: Airy stress function. **Module 6: 2D Problems:** Cartesian coordinate Problems: Using Polynomials and Fourier series , Polar coordinate Problems: Axisymmetric problems - Lame, Rotating Disk, curved beams under pure moments, Infinite/Semi-infinite body subjected to concentrated loads – Kelvin and Flamant problems, Stress concentration in an infinite plate with a small hole – Kirsch problem. **Module 7: Extension, Flexure and Torsion of Prismatic bars:** Extension formulation; Torsion formulation: SaintVenants semi-inverse approach, Prandtl's stress function approach, Membrane analogy, Solution using Fourier series, Torsion of thin-walled tubes – Bredt-Batho formula; Flexure formulation without twist.
4	**Texts/References**	**Text-books:** **1.** M.H.Sadd,"Elasticity: Theory, Applications and Numerics",Academic Press, 2013. **2.** J. R. Barber, Elasticty, Springer, 2010. **3.** L.S.Srinath,"Advanced Mechanics of Solids" Tata McGraw Hill, 2007. **References:** **1.** S.P. Timoshenko and J.N. Goodier, "Theory of Elasticity," McGraw-Hill, Third Ed., New York,1970. **2.** Allan F. Bower, Applied mechanics of Solids.. CRC press, 2009. **3.** Adel S. Saada , Elasticity: Theory andApplications, Second Edition, Revised & Updated.. J. Ross Publishing, ,2009. **4.** Robert William Soutas-Little,Elasticity, Courier Corporation, 2012.

1	**Title of the course** (L-T-P-C)	**Advanced Fluid Mechanics and Heat Transfer (3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Boundary layer theory: fundamentals, derivation of N-S equations, exact solutions of N-S equations,Boundary-layer equations in plane flow, coupling of thermal boundary layers and velocity field of the temperature field, internal flows Potential flow and flow past immersed bodies Turbulence: high Re flows, energy-transfer concepts, turbulent boundary layers, free-shear flows like jets, wakes, andmixing layers, turbulence modelling Compressible flows: energy equation, assumptions, compressible flows, stagnation properties, speed of sound, isentropic and non-isentropic flows, potential and rotational flows, effect of area change, shaft work, heat addition, mass addition and friction on flow states in a compressible (channel) flow. Pool Boiling: Nukiyama curve, boiling regimes, correlations, enhancement of boiling heat transfer Two phase flow and heat transfer: liquid-vapor interface, contact angle hysteresis, bubble formation,flow regimes,flow models, condensation. Radiation: Intensity, radiosity, irradiance, view factor geometry and algebra, radiative heat transfer equation, extinction and scattering properties of gases and aerosols, overview of solution methods and applications. Radiation in Enclosures – Gas Radiation – Diffusion and Convective Mass Transfer – Combined Heat and Mass Transfer
4	**Texts/References**	**Texts:** **1.** Hermann Schlichting, and Klaus Gersten. Boundary layer theory. 9th edition. Springer, 2017. **2.** Tennekes, Hendrik, and John L. Lumley. A first course in turbulence. MIT press, 2018. **3.** Anderson, John D. Modern compressible flow. Tata McGraw-Hill Education, 2003. **4.** Carey, Van P. Liquid-vapor phase-change phenomena: an introduction to the thermophysics ofvaporization and condensation processes in heat transfer equipment. CRC Press, 2018. **5.** Incropera, Frank P., et al. Fundamentals of heat and mass transfer. Wiley, 2007. **6.** Modest, Michael F. Radiative heat transfer. Academic press, 2013. **References:** **7.** Davidson, Peter Alan. Turbulence: an introduction for scientists and engineers. Oxford universitypress, 2015. **8.** Pope, Stephen B. "Turbulent flows." (2001): 2020. **9.** Bejan, Adrian. Convection heat transfer. John wiley & sons, 2013. **10.** Kays, William Morrow. Convective heat and mass transfer. Tata McGraw-Hill Education,2011.

1	**Title of the course** (L-T-P-C)	**Advanced Mechanisms and Dynamics ofMechanical Systems (3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	● Review of Grashof criterion and its derivation ● Synthesis of Mechanisms - Four bar linkage and Slider crank mechanisms ○ Two position Double rocker design ○ Two position motion generation ○ Three position motion generation ○ Function Generation ○ Synthesis of crank-rocker for a specified rocker amplitude ● Path synthesis -- practical Approaches ○ Roberts Cognate Theorem ● Review of Special Mechanisms ○ Straight Line generating mechanisms ○ Ackermann Steering Mechanism ○ Pantograph Mechanism and its derivation ● Brief introduction to spatial linkages ○ Serial Chain ○ Closed loop linkages ● Review of Dynamics of particles ○ Newton's laws, Impulse Momentum ○ Moment of a force and Angular Momentum, Work and Energy ○ System of particles ● Fundamentals of Analytical Mechanics ○ Degrees of freedom and generalized coordinates ○ Systems with constraints ○ The stationary value of a function and a definite integral ○ The principle of virtual work ○ D' Alembert's principle ○ Hamilton's principle ○ Lagrange's equation of motion ○ Lagrange's equations for impulsive forces ○ Conservation laws ○ Routh's method for ignoration of coordinates ○ Rayleigh's dissipation Function ○ Hamilton's equations
4	**Texts/References**	**TEXTBOOKS** **1.** "Kinematics Dynamics and Design of Machinery", Kenneth Waldron and Gary L. KInzel,Second Edition, John Wiley and Sons. **2.** "Analytical Dynamics", Leonard Meirovitch, First Edition, McGraw Hill.

1	**Title of the course** (L-T-P-C)	**Compressible Flow and Gas Dynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	● **Introduction**: Gas dynamics, review of basic mass, momentum and energy conservation lass for compressible flows, speed of sound, wave equation, regimes of Mach number, shocks, wave propagation, sound speed, Mach number, isentropic flow, static and stagnation properties ● **One-dimensional flow**: Governing equations for one dimensional flow, Converging-diverging nozzles, shock waves, moving and reflected waves, blast waves, wind tunnels, supersonic engines, 1D equations for stationary normal shock, Entropy change across a normal shock, Crocco's theorem, Hugoniot equation, moving normal shock and reflected shock waves ● **Two Dimensional Flow**: Oblique shock wave theory, conical oblique shock waves, concepts of attached and detached shock waves, Prandtl-Mayer expansion fans, supersonic inlets and diffusers. ● **Compressible Pipe Flow**: Fanno-Line flow, Rayleigh pipe flow, natural gas flow in pipelines ● **Compressible Potential Flow**: Method of characteristics, supersonic nozzle design ● **Introduction to Hypersonic Flows.** ● **Introduction to Numerical Solutions**: Characteristic relations and Riemann invariants, representative model problems, convection-diffusion equation, Burgers' equation, Riemann problems, Roe's approximate Riemann solver for the Euler equations
4	**Texts/References**	● J.D. Anderson, Modern Compressible Flow, McGraw-Hill, (3rd Edition), 2017 ● S.M. Yahya. Fundamentals Of Compressible Flow With Aircraft And Rocket Propulsion, New Age International Publishers; 6th Edition, 2018. ● Doyle D. Knight, Elements of Numerical Methods for Compressible Flows, Cambridge Aerospace Series, Cambridge University Press, 2012. ● Hodge & Koenig, Compressible Fluid Dynamics, PEI, 1st edition, 2015. ● H.W. Liepmann and A. Roshko, Elements of Gas Dynamics, Dover Pub., 2013. ● Shapiro, Ascher H., Dynamics and thermodynamics of compressible fluid flow, John Wiley 1953.

1	**Title of the course** (L-T-P-C)	**Design of Heat Exchangers** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Fluid Mechanics and Heat Transfer
3	**Course content**	Classification of heat exchangers, Basic design methods of heat exchangers Single phase heat exchangers: Forced Convection Correlations for the Single-Phase Side of Heat Exchangers, Design of double pipe heat exchangers, shell and tube heat exchangers, compact heat exchangers Fundamentals of two phase flow, Essentials for the design of two phase heat exchangers, Design Correlations for Condensers and Evaporators, Design of evaporators and condensers
4	**Texts/References**	**1.** Ramesh K. Shah, Dusan P. Sekulic, Fundamentals of Heat Exchanger Design, John Wiley and Sons, USA, 2003, ISBN:9780471321712, First Edition **2.** Sadik Kakac, Hongtan Liu, Anchasa Pramuanjaroenkij, Heat Exchangers: Selection, Rating, and Thermal Design, CRC Press, 2020, ISBN 9781138601864, Fourth Edition **3.** W.M. Kays and A.L. London, Compact heat exchangers, McGrawhill Book Company, 1984, ISBN: 9780070334182, Third Edition **4.** Arthur P Fraas, Heat Exchanger Design, John Wiley and Sons, 1989, ISBN: 978-0-471-62868-2. Second Edition

1	**Title of the course** (L-T-P-C)	**Tribology** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Introduction – Materials and surfaces:** Tribology — Historical perspective, Industrial Significance, Economic considerations; Solid structure and properties — Atomic Structure, Bonding and Coordination, Disorders in Solid Structures, Elastic and Plastic Deformation, Fracture and Fatigue, Time Dependent Viscoelastic & Viscoplastic Deformation. Surfaces — Nature of surfaces, Characteristics of Surface Layers, Surface texture, Surface parameters, Measurement of surface parameters, Statistical properties of surfaces, Analysis of Surface Roughness. **Contacts:** Analysis of Contacts — Single Asperity, Multiple Asperity Contacts, Measurement of the Real Area of Contact, Stress distribution, Displacements due to loading, Hertzian and non-Hertzian contacts, Rough surfaces in contact, Deformation mode, Thermal effects; Adhesion — Solid–Solid Contact, Contact with liquid mediation. **Friction:** Friction — Measurement, Causes, Theories, Plastic interaction of surface asperities, Ploughing effect, Elastic hysteresis losses, Solid–Solid Contact, Liquid-Mediated Contact, Friction of Materials; Rolling Motion — Free rolling, Microslip in rolling, Tyre-road contacts. **Wear:** Wear — Definitions, Mechanisms, Wear Debris, Wear of Materials, Indentation cracking, Factors affecting wear, Experimental considerations, Wear control, Application of wear in design, Characteristics of friction induced vibrations. **Lubrication:** Lubricants — Viscosity, Measurement of viscosity, Lubricating oils, Greases; Lubrication — Regimes of Fluid Film Lubrication, Viscous Flow and Reynolds Equation, Hydrostatic Lubrication, Hydrodynamic Lubrication, Elasto-hydrodynamic Lubrication.
4	**Texts/References**	**1.** Introduction to Tribology, Bharat Bhushan, John Wiley & Sons. **2.** Principles of Tribology, Halling, J. (Ed), Macmillan, 1975.

1	**Title of the course** (L-T-P-C)	**CNC & Part Programming** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Manufacturing processes
3	**Course content**	**Module: 1** Introduction: NC/CNC, CNC machines, Industrial applications of CNC, economic benefits of CNC. CNC Machine Tools (6 hr) **Module: 2** Classification of machine tools, CNC machines tool design, control systems (8 hr) **Module: 3** Position control, velocity control and machine tool control, Interpolation and electronics. Data Input: Punched tape, manual data input, tape punch, reader error checking (8 hr) **Module: 4.** CNC tooling: Qualified and pre-set tooling, tooling systems, tool setting, automatic tool changers, work holding and setting. Programming: Part programming language, programming procedures, proving part programmes, computer aided part programming (9 hr) **Module: 5.** Advances: Advances in CNC programming, integration with CAD, material handling in CNC machines, manufacturing systems (9 hr)
4	**Texts/References**	**1)** Warren S. Seames, Computer numerical control: concepts and programming, Thomson Learning, 2001 **2)** William W. Luggen, Computer numerical control: a first look primer, Thomson Publishing, 1996 **3)** Learning Barry Leatham - Jones, Introduction to Computer Numerical Control, Pitmans, London, 1988. **4)** T.K. Kundra, P.N. Rao and N.K. Tewari, Numerical control and Computer Aided Manufacturing, Tata McGraw Hill Publishing Company Limited, New Delhi

1	**Title of the course** (L-T-P-C)	**Linear Viscoelasticity** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Concepts of Viscoelasticity** – Force-extension equations of the simple models, Creep and relaxation behaviour, Complex modulus and compliance, Stored and dissipated energies, Creep and relaxation behaviour of some real materials. **Fundamental Aspects of Viscoelastic Response** – Introduction, Nature of Amorphous Polymers, Mechanical Response of Viscoelastic Materials, Energy Storage and Dissipation, Glass Transition and Regions of Viscoelastic Behavior, Aging of Viscoelastic Materials. **Constitutive Equations in Hereditary Integral Form** – Boltzmann's Superposition Principle, Principle of Fading Memory, Closed-Cycle Condition, Relationship Between Modulus and Compliance, Alternate Integral Forms, Work and Energy. **Constitutive Equations in Differential Operator Form** – Fundamental Rheological Models, Rheological Operators, Construction of Rheological Models, Simple Rheological Models, Generalized Models, Composite Models. **Constitutive Equations for Steady-State Oscillations** – Steady-State Constitutive Equations from Integral Constitutive Equations, Steady-State Constitutive Equations from Differential Constitutive Equations, Limiting Behavior of Complex Property Functions, Energy Dissipation. **Structural Mechanics** – Bending, Torsion, Column Buckling, Viscoelastic Evens, Elastic– Viscoelastic Correspondence, Mechanical Vibrations. **Thermoviscoelasticity** – Thermodynamical Derivation of Constitutive Relations, Restrictions and Special Cases, Time Temperature Superposition, Relationship to Nonnegative Work Requirements, Formulation of the Thermoviscoelastic Boundary Value Problem, Temperature Dependence of Mechanical Properties, Thermorheologically Simple Materials, Phenomenology of the Glass Transition, Glass Transition Criterion, Effect of Pressure on the Glass Transition Temperature, Hygrothermal Strains, Heat Conduction.
4	**Texts/References**	**1.** Engineering Viscoelasticity, Gutierrez-Lemini, Danton, Evener, 2014. **2.** Theory of Viscoelasticity, R. M. Christensen, 2nd Edition, Dover Civil and Mechanical Engineering. **3.** The Theory of Linear Viscoelasticity, D. R. Bland, Dover Books on Physics. **4.** Viscoelasticity of Engineering Materials, Haddad, Y.M., Evener, 1995.

1	**Title of the course** (L-T-P-C)	**Experimental Methods in Thermal and Fluid Engineering (3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Planning experiments: preliminary intermediate and final stages in experimental investigations. Steady state and transient techniques, selection measuring devices based on static dynamic characteristic and allowable uncertainties .Analysis of experimental data and determantion of overall uncertainties in experimental investigation curve filting and report writing calibration of condition optical and radiation Method of measuring heat fluxes Measurement of thermal radiation and associated parameters calibration of pressure vacuum measuring devices Estimation of uncertainness in measurements of pressure vacuum calibration of flow and velocity measuring devices uncertainties in measurement under various condition. Measurement of turbulence, Hot wire film anemometers measurement of thermophysical properties
4	**Texts/References**	**1.** Mesurement system: Application Design, E, O Docbelin Fourth ed.1990 McGraw Hill **2.** theory and Deign for mechanical measurement, R S Fagiola and D E Beasley, fourth edition,2008,john wily and sons **3.** Mechanical Measurement, T J Beck with ,Marangoni, J H Line hard,2007 Prentice Hall **4.** Measurement and instrumentation principles, Alan moirés Third Edition 2001, Butterworth Heinemann **5.** Op – amps and linear integrated Circuits, R A Gayakwad. 2000 prentice Hall

1	**Title of the course** (L-T-P-C)	**Mechanics of Composite Materials** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	**Module 1: Basic Concepts, Materials, Processes and Characteristics**: Conventional materials and composite materials; Terminologies definition; composite materials Classification; Scales of analysis and basic lamina properties; Constituent Materials Manufacturing methods **Module 2: Lamina's elastic and strength behaviour - Micromechanics**: Micromechanics model; Longitudinal and transverse elastic properties of continuous fibers; In-plane shear modulus; Longitudinal properties of discontinuous fibers or short fibers – Shear lag analysis; Strength – longitudinal tensile and compressive behaviour, transverse tensile and compressive behaviour, in- plane shear, pout-of-plane behaviour **Module 3: Lamina's elastic and strength behaviour - Macromechanics**: Stress-strain relation – Anisotropic; orthotropic, transversely isotropic and isotropic; Stress-strain relations for a lamina; Transformations- stress, strain elastic moduli in 2D and 3D; Failure theories – Maximum stress, maximum strain, Tsai-Hill; Failure-mode-based theories. **Module 4: Multi-directional Laminate's elastic and strength behaviour**: Strain-displacement relations; Stress-strain relation; Laminate's stiffness/compliance; Types of laminates – symmetric, balanced, orthotropic and quasi-isotropic laminates; Determination of elastic parameters for uni- directional and angle-ply laminates; Modified lamination theory for transverse shear; Strength – types of failure, stress analysis and strength component for first-ply failure of symmetric laminates; Extension to multidirectional laminates; Carpet plots **Module 6: Bending, Buckling, And Vibration Of Laminated Plates**: governing equations for bucklion, vending and vibrations; flexural deflection of simply supported laminated plates; buckling of simply supported laminated plates; vibration of simply supported laminated plates **Module 7: Hygrothermal effects**: Introduction, CoTE (thermal expansion) and CoME (Moisture- expansion) for a lamina; Load-deformation relations in hygrothermalelasticity; COTE and COME for multi-directional laminates; Warpage and residual stresses; Effect on strength of mechanical and hygrothermal loading on multi-directional laminates. **Module 8: Experimental characterisation and testing of Composite materials:** Characterisation of constituent materials; Determination of tensile/compressive and shear properties of uni-directional laminae; Through thickness properties; Biaxial testing; Stress concentration characterization and structural testing
4	**Texts/References**	**Text-books:** • M. Daniel and O. Shai, Engineering Mechanics of Composite Materials, 2nd ed., Oxford University Press. • R. M. Jones, Mechanics of Composite Materials, 2nd Ed., CRC Press. **References:** • Kaw, Mechanics of Composite Materials, 2nd Ed., CRC Press. • V.V. Vasiliev and E.V. Morozov, Mechanics And Analysis Of Composite Materials, , Elsevier, 2001. • R.M. Christensem, Mechanics of Composite Materials, Dover**,** • H. Altenbach, J. Altenbach, W. Kissing, Mechanics of Composite Structural Elements, Springer-Verlag Berlin Heidelberg, 2004 • Parameterized Complexity, R. G. Downey, and M. R. Fellows. Springer Science and Business Media. 2012

1	**Title of the course** (L-T-P-C)	**Mechanical Vibrations** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Module 1:** Concepts of Vibrations: Harmonic motion and definitions and terminology, Harmonic analysis, Fourier series expansion, Importance of vibration, Basic concepts of vibration, Classification of Vibration, Vibration analysis procedure; Discrete System Components – Springs, Dampers and Masses. **Module 2:** One DOF systems: Free Vibrations, Harmonic Oscillator, Types of damping, Viscously Damped Single DOF Systems, Measurement of Damping, Coulomb Damping – Dry Friction. Forced Vibrations – Response of Single DOF System to Harmonic Excitations, Response to Periodic Excitations, Response of Single DOF systems to Nonperiodic Excitations. **Module 3:** Two DOF Systems: System Configuration, Equations of Motion of 2 DOF Systems, Free Vibration of Undamped Systems Natural Modes, Response to Initial Excitations, Coordinate Transformations – Coupling, Orthogonality of Modes - Natural Coordinates, Beat Phenomenon, Response of Two-Degree-of-Freedom Systems to Harmonic Excitations, Undamped Vibration Absorbers. **Module 4:** Vibrations of Continuous Systems: Vibrating String, Longitudinal vibrations of Bar, Torsional vibrations of Rod. Lateral vibrations of Beam. Analytical Dynamics: Degrees of Freedom and Generalized Coordinates, Principle of Virtual Work, Principle of D'Alembert, Hamilton's Principle, Lagrange's Equations. **Module 5:** Multi-Degree-of-Freedom Systems: Equations of Motion for Linear Systems; Flexibility, Stiffness Influence Coefficients and Mass Coefficients; Lagrange's Equations; Linear Transformations; The Eigenvalue Problem; Orthogonality of Modal Vectors; Systems Admitting Rigid-Body Motions; Decomposition of the Response in Terms of Modal Vectors; Response to Initial Excitations by Modal Analysis;Eigenvalue Problem in Terms of a Single Symmetric Matrix; Geometric Interpretation of the Eigenvalue Problem; Rayleigh's Quotient and Its Properties; Response to Harmonic External Excitations; Response to External Excitations by Modal Analysis – Undamped systems, Systems with proportional damping; Systems with Arbitrary Viscous Damping; Discrete-Time Systems. .
4	**Texts/References**	**<u>Text-books:</u>** **1.** S S Rao, Mechanical Vibrations, Pearson Education, 5 th Edition, 2004. **<u>References:</u>** **2.** W T Thomson, M D Dahleh and C Padmanabha, Theory of Vibration with applications, Pearson Education, 2008. **3.** Leonard Meirovitch, Fundamentals of Vibrations, McGraw-Hill, 2000. **4.** Den Hartog, Mechanical Vibrations, Dover Publications, 4 th Edition.

1	**Title of the course** (L-T-P-C)	**Fundamentals of Acoustics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Fluid Mechanics
3	**Course content**	**Review of classical acoustics**: review of classical acoustics, linearized equations of motion, classical wave equation. Speed of sound, harmonic waves, acoustic energy/intensity, decibel scale. Acoustic impedance and admittance, reflection and transmission at the interface of two media, Impedance tube technique. **Sound propagation:** plane and spherical waves, Travelling and standing waves, boundary conditions, Eigen frequency and Eigen modes. Effects of area variation, reflection and transmission of waves in pipes. Acoustic wave propagation in homogeneous and inhomogeneous media; **Models for acoustic sound sources:** point sources, monopoles, dipoles and quadrupoles, Aero-acoustic sources: Lighthill's acoustic analogy, integral solutions and far-field approximations; effect of solid surface; **Losses:** Viscous and thermal conduction losses, absorption coefficient, sound absorption in pipes **Measurement** of sound signals, microphones, time series analysis using Fast Fourier Transform, Discrete Fourier Transform, Transfer function, and Bode plots. Solving numerical problems. **Applications to engineering problems**: Aero-acoustic jet noise, Thermoacoustic instability, fan/rotor noise and numerical evaluation.
4	**Texts/References**	**1.** Lawrence E. Kinsler, Austin R. Frey, and Alan B. Coppens, 2000. Fundamentals of acoustics. 4th edn. John-Wiley & Sons, Inc. **2.** Pierce, Allan D. Acoustics: an introduction to its physical principles and applications. Springer, 2019. **3.** Munjal, M. L. (1987). Acoustics of ducts and mufflers with application to exhaust and ventilation system design. John Wiley & Sons. **4.** Tim C. Lieuwen, 2012. Unsteady combustor physics. 1st edn. Cambridge University Press.

1	**Title of the course** (L-T-P-C)	**Turbomachinery Aerodynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Thermodynamics, Fluid Mechanics during UG
3	**Course content**	**Introduction to Turbomachineries** **Axial flow compressors and Fans:** Introduction; Aero-Thermodynamics of flow through an Axial flow Compressor stage; Losses in axial flow compressor stage; Losses and Blade performance estimation; Secondary flows (3-D); Tip leakage flow and scrubbing; Simple three dimensional flow analysis; Radial Equilibrium Equation; Design of compressor blades; 2-D blade section design: Airfoil Data; Axial Flow Track Design; Axial compressor characteristics; Multi-staging of compressor characteristics; Transonic Compressors; Shock Structure Models in Transonic Blades; Transonic Compressor Characteristics; 3-D Blade shapes of Rotors and Stators; Instability in Axial Compressors; Loss of Pressure Rise; Loss of Stability Margin; Noise problem in Axial Compressors and Fans **Axial flow turbines:** Introduction; Turbine stage; Turbine Blade 2-D(cascade) analysis Work Done; Degree of Reaction; Losses and Efficiency; Flow Passage; Subsonic, transonic and supersonic turbines, Multi-staging of Turbine; Exit flow conditions; Turbine Cooling; Turbine Blade design – Turbine Profiles: Airfoil Data and Profile construction. **Centrifugal Compressors:** Introduction; Elements of centrifugal compressor/ fan; Inlet Duct Impeller; Slip factor; Concept of Rothalpy; Modified work done; Incidence and lag angles; Diffuser; Centrifugal Compressor Characteristics; Surging; Choking; Rotating stall; Design **Radial Turbine:** Introduction; Thermodynamics and Aerodynamics of radial turbines; Radial Turbine Characteristics; Losses and efficiency; Design of radial turbine. Use of CFD for Turbomachinery analysis and design.
4	**Texts/References**	**1.** Dixon, S. Larry, and Cesare Hall, "Fluid mechanics and thermodynamics of turbomachinery," Butterworth-Heinemann, 2013. **2.** Lakshminarayana, Budugur, "Fluid dynamics and heat transfer of turbomachinery," John Wiley & Sons, 1995. **3.** Cumpsty, Nicholas A., "Compressor aerodynamics," Longman Scientific & Technical, 1989. **4.** Hill, Philip G., and Carl R. Peterson, "Mechanics and thermodynamics of propulsion," AW (1992). **5.** Johnsen, Irving A., and Robert O. Bullock, eds., "Aerodynamic Design of Axial-Flow Compressors," NASA SP-36, 1965. **6.** Glassman, Arthur J., ed., "Turbine design and application," NASA-SP-290, 1975.

1	**Title of the course** (L-T-P-C)	**Metal Forming and Plasticity** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Manufacturing Science
3	**Course content**	**Introduction:** Different metal forming processes, importance of plasticity in the course. **Module 1:** Analysis of stress: transformation relations, principal stresses and directions, maximum normal and shear stresses, invariants, hydrostatic and deviatoric parts; Analysis of (infinitesimal) strain: transformation relations, principal strains, invariants, hydrostatic and deviatoric parts; (Infinitesimal) rotation, Stress strain relations for isotropic, linearly elastic material. **Module 2:** Experimental observations on plasticity: yielding, strain hardening, visco plasticity, temperature softening, Baushinger effect, hysteresis, incompressibility of plastic deformation, anisotropy, plastic instability. **Module 3:** Yield criterion for isotropic materials: von Mises and Tresca yield criterion, their geometric interpretation, convexity of the yield surfaces, experimental validation. **Module 4:** Incremental and rate forms of the measures of plastic deformation: linear incremental strain tensor, strain rate (i.e. the rate of deformation) tensor and their relation, incremental rotation tensor and spin tensor. **Module 5:** Change in yield criteria due to isotropic hardening: strain hardening and work hardening hypotheses, experimental validation of the hypotheses. **Module 6:** Plastic stress strain relations for isotropic materials: plastic potential and associated flow rule, incremental and rate forms of elastoplastic stress strain relations, simplifications for non- hardening and rigid plastic materials (Prandtl Reuss and Levy-Mises relations), Objective measures of stress rate and incremental stress.
4	**Texts/References**	**1.** The Mathematical Theory of Plasticity by R. Hill, Oxford University Press **2.** Theory of Plasticity by J. Chakrabarty, Butterworth-Heinemann, 3rd edition **3.** Metal Forming Mechanics and Metallurgy, William F. Hosford, Robert M. Caddell Cambridge University Press; 4th edition

1	**Title of the course** (L-T-P-C)	**Mechanical Engineering Experimental Laboratory** **(1-0-3-5)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Theory**: Design of Experiments: Types of Experiments, Experiment Design Factors, Experiment Planning, Static and Dynamic Calibration. General Data Acquisition System, Signal Conditioning, Data Transmission, Analog-to-Digital and Digital-to-Analog Conversion, Data Storage and Display, Causes and Types of Experimental Errors, Evaluation of Uncertainties. Error Propagation, Central limit theorem, 95% confidence interval, Pressure Measurement, Measurement of Temperature, Thermal and Transport-Property Measurements. Pitot and static tubes, Intrusive and non-intrusive flow measurements. Probability Density Function, Auto- and Cross-correlations, Correlation functions and their use in experiments, Inverse techniques, Digital image analysis. • **Exp. 1.** CNC part programming, Job preparations, tool setting, job setting, fundamentals of part programming, path generation. • **Exp. 2**. Effect of process parameters on weld bead geometry, Characterization • **Exp. 3.** 3D printing of simple to composite material, path planning, STL processing, post planning composite and tensile testing • **Exp. 4**. Sheet metal formability test; Erichsen cupping test • **Exp. 5**.Tensile (MS and Al), Compression and 3-point bend test on 100 kN machine • **Exp. 6.** Determination of ductile to brittle transition temperature of Mild Steel and Aluminum using Impact Testing Machine. • **Exp. 7.** Fatigue Tests and Endurance limit • **Exp. 8.** Hertzian apparatus, stress and strains in membrane and Measurement of stress concentration factor in a specimen with holes using photo-elasticity method. • **Exp. 9.** Observation of mode shapes and measurement of natural frequencies of cantilever (damped and undamped) • **Exp. 10.** Measurement of Mode I fracture toughness using a compact tension (CT) specimen • **Exp. 11:** Wind tunnel experiments: measurement of static, dynamic pressure and forces acting on cylinder, symmetric and asymmetric airfoils at different Reynolds numbers • **Exp. 12:** Measurement of flow through anemometer, DAQ and its components, low-pass, high-pass filters and spectrum analysis • **Exp. 13:** Turbulent jets and plumes, flow visualization and analysis • **Exp. 14:** Experiments on Boiling and Condensation
4	**Texts/References**	1. Springer Handbook of Experimental Solid Mechanics, Sharpe, 2008. 2. Flow Visualization, Wolgang Merzkirch, Academic Press, 3 3. Mechanical Measurements, Beckwith and Buck, Addison-Wesley, 1982., 4. Measurement Science for Engineers, Regtein, 2004., 5. Experimental Methods for Engineers, J P Holman, McGraw-Hill, 2011., 6. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, J R Taylor, University Science Books, 1997.

1	**Title of the course** (L-T-P-C)	**Sustainable Energy for Transportation** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None for M. Tech SSM. For others, instructor consent is required
3	**Course content**	**Introduction**: Introduction to conventional energy for transportation, Internal combustion (IC) engines and Gas Turbine Engines, Emission formation and Environmental issues; Hydrocarbon fuels and Sustainability. **Battery operated vehicles**: Introduction, Types, Batteries, Accessories; Hybrid vehicles: Introduction, Classification, Advantages and disadvantages; Different types of sustainable electricity production: Solar, Wind, Hydro renewable energy, Direct Energy Conversion: thermionic and thermoelectric converters, photovoltaic generators, MHD generators, Integrated Gasification Combined Cycle (IGCC), Clean Coal Technologies, Geological CO_2 sequestering. **Fuel cells**: Introduction, Fuel cell system, Classification, Thermo dynamics and performance of fuel cells and their applications. Operational issues; **Hydrogen Energy**: General introduction to hydrogen production, storage, dispensing and utilization. Hydrogen Utilization in I.C. Engines, gas turbines, and marine applications. Hydrogen fuel quality, performance, COV, emission and combustion characteristics of Spark Ignition engines for hydrogen, back firing, knocking, volumetric efficiency, hydrogen manifold and direct injection, fumigation, NOx controlling techniques, dual fuel engine, durability studies. Hydrogen Safety. **Bioenergy**: Introduction to bioenergy; characterization of biomass feedstock (physico-chemical properties, ultimate, proximate, compositional, calorific value, thermogravimetric, differential thermal and ash fusion temperature analyses); classification of biomass feedstock: first, second and third generation biofuels; hybrid biofuels, basic principles of chemical thermodynamics; carbon neutral fuels. utilization of biofuels in gas turbine, internal combustion engines and fuel cells; **Alternative fuels for ground transportation**: Alternative fuels -liquid and gaseous fuels, Physico- chemical characteristics, Alcohol fuels: ethanol & methanol, fuel composition, Fuel induction techniques, Applications to engines and automotive conversions, Biodiesel formulation techniques, Transesterification, Application in diesel engines, Dimethyl ether (DME), properties fuel injection consideration general introduction to Liquefied Petroleum Gas (LPG) and Liquefied Natural Gas (LNG), Compressed natural gas (CNG), Biogas, Producer gas and their characteristics, System development for engine application. **Plasma trusters**: Thermal, non-thermal plasmas; Aerospace, Plasma thrusters, Micro-satellite application, Collection and removal of fine particles in plasma chambers; Hazardous waste problem.
4	**Texts/References**	**1.** Moran M.J., H.N. Shapiro., Fundamentals of Engineering Thermodynamics, 3rd Ed., Wiley, 1995. **2.** Rand D.A. J., Woods R. & Dell R.M., Batteries for Electric Vehicles, Research Studies Press (1998). **3.** Linden D. & Reddy T.S., Handbook of Batteries, 3rd Edition, McGraw-Hill, (2002). **4.** Nikolai Khartekenko, Advanced Energy Systems, Taylor & Francis (1988). **5.** Angrist S. W., Direct Energy Conversion, Pearson, 1982. **6.** Bagotsky V.S., Fuel Cell Problems and Solutions, John Wiley & Sons, 2009. **7.** Ball M. and Wietschel M., The Hydrogen Economy Opportunities and Challenges, CPU (2009). **8.** Mukunda, H. S., Understanding Clean Energy and Fuels from Biomass, Wiley, 2011. **9.** Babu M.K.G., Subramanian K.A. Alternative Transportation Fuels: Utilization in Combustion Engines, CRC Press (2013). **10.** Bechtold R.L., Alternate Fuels-Transportation Fuels for Today and Tomorrow, Society of Automotive Engineers (SAE), 2002.

1	**Title of the course** (L-T-P-C)	**Practicum** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	None for M. Tech SSM. For others, instructor consent is required
3	**Course content**	**Pre-mid semester:** **1.** Overview on components, subsystems in EV **2.** Reverse Engineering: **a.** Two/Three/Four Wheel EV, **b.** Conventional IC Vehicle **3.** Site visits to testing and manufacturing centers or colloquium with **Industry experts** **Post-mid semester:** **1.** Hands-on on fabrication, manufacturing, machining and metrology **a.** Sheet metal **b.** Welding processes **c.** Machining processes **d.** 3D Printing **e.** Material characterization; static and dynamic loading **f.** Impact tests
4	**Texts/References**	TEXTBOOKS **a.** Elements of Workshop Technology Vol. 1 (2015), S. K. Hajra Choudhary, A. K. Hajra Choudhary and Nirjhar Roy, Media Promoters and Publishers Pvt. Ltd. **b.** W. A. J. Chapman, Workshop Technology, Vol. 1 (2006), Vol 2 (2007), and (1995), CBS Publishers. **c.** Handbooks of Convenctional IC Engine Vehicle and EV vehicles

1	**Title of the course** (L-T-P-C)	**Introduction to Statics and Dynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None for M. Tech SSM. For others, instructor consent is required
3	**Course content**	• Recapitulation of concepts of Units system, Vectors, Force, Moments, Couples, the concept of free body diagram; Equivalent systems for a system of forces - reducing a system of forces to a single force and couple, wrench; First moment of area, second moment of area, mass moment of inertia; • **Equilibrium conditions** for a particle, a rigid body, system of rigid bodies (structures - truss, frames), Friction - Columb laws, Applications of friction: Journal bearing, belt drives • **Energy and stability**: Principle of virtual work for a particle, rigid body and system of rigid bodies,; Potential Energy - linear springs and gravitational potential energy; Stability - stable, unstable and neutral equilibrium, conditions for the stability. • **Kinetics & Kinematics** of particles - Motion in 3D - Recap of vector calculus, Path coordinates system - tangential and normal coordinate system, Radial coordinate system, Relative motion - translating and rotating frame of references. • Introduction to the **deformable bodies**, **concepts of stress** - normal and tangential, concept of strain - normal and shear, material characterization and stress-strain relations, Structural member - bars, beams and shafts, deflection, twist; • **Introduction to mechanisms** - 2D, Relation for the degree of freedom and the links, Types of joints and mechanisms, machine elements - gears, shafts, clutches • **Introduction to vibration**: Single degree systems - damped and undamped - free and forced vibrations;
4	**Texts/References**	**TEXTBOOKS** **1.** Beer, Johnston, Cornwell, Sanghi - Vector Mechanics for Engineers: Statics and Dynamics, 10th Edition, McGraw-Hill, 2017 **2.** Crandall, Dahl, Lardner, Shivkumar - An Introduction to Mechanics of Solids, 3rd Edition, McGrraw-Hill, 2017 **3.** Norton RL, Machine Design – An Integrated Approach, 4th Edition, Pearson Education, 2010 **4.** Norton RL, Kinematics & Dynamics of Machinery, 1st Edition, McGraw-Hill, 2010 **REFERENCE** 1. Richard Budynas, Keith Nisbett , Shigley's Mechanical Engineering Design, 10th Edition, McGraw-Hill, 2014

1	**Title of the course** (L-T-P-C)	**Smart manufacturing and material selection (3-0-0-6)**
2	**Pre-requisite courses(s)**	None for M. Tech SSM. For others, instructor consent is required
3	**Course content**	• Introduction to Smart manufacturing, various Smart Manufacturing Technologies, Smart foundry, Reverse engineering, Traditional manufacturing, Rapid Tooling, Rapid Manufacturing; Indirect Processes - Indirect Prototyping • Materials and design, Evolution of Engineering Materials and their Properties, Materials selection charts, Selection of Engineering materials and shape, Selection of Manufacturing Processes, Examples and Case studies. • Introduction to Additive Manufacturing, classification of AM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion, Binder Jetting, and Direct Energy Deposition, Popular AM processes functional material. • Introduction: NC/CNC, CNC machines, Industrial applications of CNC, economic benefits of CNC. CNC Machine Tools • Surface coating, painting, Industry 4.0, Robotics and automation in manufacturing.
4	**Texts/References**	**1.** Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing. Evener, 2014 **2.** C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing. World Scientific, 2003. **3.** Lu, L., Fuh, J., Wong, YS., 2001, Laser Induced Materials and Processes for Rapid Prototyping, Kluwer. **4.** Michael F. Ashby, Materials selection in mechanical design, Elsevier **5.** G Boothroyd, P Dewhurts W A Knight, Product Design for Manufacture and Assembly, CRC press, Taylor and Francis

1	**Title of the course (L-T-P-C)**	**Modeling of Metal Plasticity: Discrete and Continuum approaches (3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction: Importance of Metal Plasticity, Plasticity as multiscale phenomenon, Different approaches to model plasticity Plasticity at discrete dislocation level **Module 1** Fundamentals of dislocation mechanics: Classification of defects, line defects, Dislocation and its Characteristics, classification of dislocations, Dislocation as source of plasticity **Module 2** Discrete Dislocation Dynamics method: Stress field of a dislocation, Volterra construction, Dislocation motion, Driving force on a dislocation, Evaluation of dislocation velocity, Discretization and adaptive remeshing of dislocation lines, Time integration of equations of motion, Dislocation reactions **Module 3** Dislocation dynamics code and examples: Introduction to ParaDis, Simulation procedure, Basic simulation examples (Frank-Read source, Strain Hardening simulation, dislocation relaxation) Plasticity at Continuum scale **Module 4** Structure and Properties of Metals and Introductory Mechanics: Crystal structure, slip systems, elastic and plastic deformation, anisotropy Stress and strain tensors, principle stresses, Yield criteria **Module 5** Small and Large deformation theory: Infinitesimal strain theory, Kinematics, Deformation gradient, Different stress and strain measures, Velocity gradient, Elastoplastic decomposition, Mechanical Equilibrium, Finite element method as a solver **Module 6** Different continuum plasticity models: Constitutive modeling (Yield condition, flow rule, hardening law), Phenomenological crystal plasticity model, Dislocation density based models, Microstructure based modeling, Dislocation based constitutive laws, Integration of other deformation mechanisms (Mechanical Twinning, Phase transformation) **Module 7** Crystal plasticity modeling procedure and examples: Abaqus UMAT, DAMASK, FreeFem++, Time integration, Pre-processing, Running Crystal plasticity simulation, Post-processing of simulation results, Virtual Tension tests, Indentation and Micro-bending Simulations
4	**Texts/References**	▪ Ryan B. Sills, William P. Kuykendall, Amin Aghaei, Wei Cai, Fundamentals of Dislocation Dynamics Simulations, Multiscale Materials Modeling for Nanomechanics. Vol. 245. Springer ▪ Franz Roters, Philip Eisenlohr, Thomas R. Bieler, Dierk Raabe Crystal Plasticity Finite Element Methods: In Materials Science and Engineering, John Wiley & Sons, 2011 ▪ Ellad B. Tadmor, Ronald E. Miller, Modeling Materials - Continuum, Atomistic and Multiscale Techniques, Cambridge University Press, 2011

1	**Title of the course** (L-T-P-C)	**Design of Mechatronic Systems** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Introduction: Elements of mechatronics system: Sensor, actuator, plant, and controller. Applications of mechatronics system. Systems like CDROM, scanner opened to see whats there inside and why?. Integrated mechanical-electronics design philosophy. Examples of real life systems. Smart sensor concept and utility of compliant mechanisms in mechatronics. Microprocessor building blocks, combinational and sequential logic elements, memory, timing and instruction execution fundamentals with example of primitive microprocessor. Microcontrollers for mechatronics: Philosophy of programming interfaces, setting sampling time, and Getting started with TIVA programming Microcontroller programming philosophy emphasis on TIVA, programming different interfaces PWM, QEI etc. Mathematical modeling of mechatronic systems, Modeling friction, DC motor, Lagrange formulation for system dynamics. Dynamics of 2R manipulator, Simulation using Matlab, Selection of sensors and actuators. Concept of feedback and closed loop control, mathematical representations of systems and control design in linear domain, Basics of Lyapunov theory for nonlinear control, notions of stability, Lyapunov theorems and their application Trajectory tracking control development based on Lyapunov theory, Basics of sampling of a signal, and signal processing Digital systems and filters for practical mechatronic system implementation. Research example/ case studies of development of novel mechatronics system: 3D
4	**Texts/References**	• Devdas Shetty, Richard A. Kolk, “Mechatronics System Design,” PWS Publishing company • Boukas K, Al-Sunni, Fouad M “Mechatronic,Systems Analysis, Design and Implementation,” Springer, • Sabri Cetinkunt, “Mechatronics with Experiments,” 2nd Edition, Wiley • Janschek, Klaus, “Mechatronic Systems Design,” Springer

1	**Title of the course** (L-T-P-C)	**Advanced CAM** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	**Geometric modeling:** **Representation of curves:** wireframe models, wireframe entities, analytic curves, synthetic curves - cubic splines, Bezier curves, B-Spline curves. **Representation of surfaces:** surface models, surface entities, analytic surfaces, synthetic surfaces **Representation of solids:** solid models, solid entities, fundamentals of solid modeling, boundary representation (B-rep), constructive solid geometry (CSG) . CAD/CAM data exchange: evolution of data exchange formats, STL, IGES, STEP formats Numerical control: principles of numerical control, numerical control systems, NC controllers. NC part programming: manual part programming, computer assisted part programming, sculptured surface machining/forming/deposition, path verification. **Digital manufacturing science**: system of digital manufacturing science, manufacturing informatics, intelligent manufacturing, key technology in digital manufacturing, impact of digital manufacturing in industrial transformation. **Digital twins:** concept of digital twin, digital twin modeling, digital twin driven smart manufacturing, cyber physical fusion in digital twin, digital twin and big data. **Industry 4.0 cases studies of manufacturing.**
4	**Texts/References**	**Textbook:** **1**. Ibrahim Zeid, R. sivasubramanian. CAD/CAM theory and practice, 2nd edition, McGrawHill , 2019 **2**. TS chang. Computer aided manufacturing, 3rd edition, Pearson Prentice Hall 2005 **3**. Zude Zhou, Shane Xie, Deju Chen. Fundamentals of digital manufacturing science, Springer series in advanced manufacturing, SpringerLink, 2013 **4**. A.Y.C. Nee, Fei Tao, Meng Zhang. Digital twin driven digital manufacturing, 1st edition, Academic press, 2019

1	**Title of the course** (L-T-P-C)	**Design and Manufacturing of Composites** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Design:** Micromechanics of Composites: Density; Mechanical properties – Prediction of elastic constants, Micromechanical approach, Halpin-Tsai equations, Transverse stresses; Thermal properties – COTE for composites, Thermal conductivities, Hygral and thermal stresses; Mechanics of load transfer from matrix to fibre. Macromechanics of composites -Elastic constants of an isotropic material and lamina, Variation of lamina properties with orientation; Laminated composites; Stresses and strains in laminated composites, Interlaminar stresses and edge stresses; Monotonic strength and Fracture: Tensile strength of uni-direction FRC; Max strain theory, Tsai-Hill criterion, Quadratic interaction. Fatigue and Creep: S-N curves-FCP tests, Fatigue of composites. Creep **Traditional and Additive Manufacturing**: Thermosets and Thermoplastic; Fiber Reinforcement, Lay-up processes, Spray up process; Fiber placement process and Traditional Manufacturing of composites. Various Additive Manufacturing technologies for composites and comparison, Thermoforming Metal and ceramic matrix composites: **Composites for Industrial Applications:** Material requirements for applications, Aerospace applications, Automotive and Road transportation applications, Architectural / building applications, Wind energy applications, Marine transportation and ship building applications, Defence applications, Advancements in composites, New Technologies.
4	**Texts/References**	**Textbook:** **1.** Krishan K. Chawla, Composite Materials Science and Engineering· Springer International Publishing, 2016 **2.** M. Balasubramanian, Composite Materials and Processing, 1st edition CRC Press **3.** T. W. Clyne, D. Hull, An Introduction to Composite Materials,3rd edition Cambridge University Press. **References:** **1.** Krishan Chawla, Fibrous materials, Cambridge university press, 2016. **2.** Krishan Chawla, Ceramic matrix composites, Springer Science & Business Media, 2013

1	**Title of the course** (L-T-P-C)	**Energy for Transportation** **(3-0-0-3)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction: Introduction to conventional energy for transportation, Internal combustion (IC) engines and Gas Turbine Engines, Emission formation and Environmental issues; Hydrocarbon fuels and Sustainability. Battery operated vehicles: Introduction, Types, Batteries, Accessories; Hybrid vehicles: Introduction, Classification, Advantages and disadvantages; Different types of sustainable electricity production: Solar, Wind, Hydro renewable energy, Direct Energy Conversion: thermionic and thermoelectric converters, photovoltaic generators, MHD generators, Integrated Gasification Combined Cycle (IGCC), Clean Coal Technologies, Geological CO2 sequestering. Fuel cells: Introduction, Fuel cell system, Classification, Thermodynamics and performance of fuel cells and their applications. Operational issues; Hydrogen Energy: General introduction to hydrogen production, storage, dispensing and utilization. Hydrogen Utilization in I.C. Engines, gas turbines, and marine applications. Hydrogen fuel quality, performance, COV, emission and combustion characteristics of Spark Ignition engines for hydrogen, back firing, knocking, volumetric efficiency, hydrogen manifold and direct injection, fumigation, NOx controlling techniques, dual fuel engine, durability studies. Hydrogen Safety.
4	**Texts/References**	**1**. Moran M.J., H.N. Shapiro., Fundamentals of Engineering Thermodynamics, 3rd Ed., Wiley, 1995. **2.** Rand D.A. J., Woods R. & Dell R.M., Batteries for Electric Vehicles, Research Studies Press (1998). **3**. Linden D. & Reddy T.S., Handbook of Batteries, 3rd Edition, McGraw-Hill, (2002). **4**. Nikolai Khartekenko, Advanced Energy Systems, Taylor & Francis (1988). **5**. Angrist S. W., Direct Energy Conversion, Pearson, 1982. **6**. Bagotsky V.S., Fuel Cell Problems and Solutions, John Wiley & Sons, 2009. **7**. Ball M. and Wietschel M., The Hydrogen Economy Opportunities and Challenges, CPU (2009).

1	**Title of the course** (L-T-P-C)	**Fracture Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Theory of Elasticity or equivalent
3	**Course content**	**Module 1: Background** Kinds of Failure; Historical Aspects; Brittle and Ductile Fracture; Modes of Fracture Failure **Module 2: LEFM** Griffith's Theory of Brittle Fracture; Irwin-Orowan Modification; Stress Intensity Factor (SIF) Approach; Concepts of Strain Energy and Potential Energy Release Rates; Determination of Crack-Tip Stress and Displacement Field - Airy Stress Function Approach, Westergaard Stress Function Approach, Williams' Eigenfunction Expansion. Determination of Stress Intensity Factors: Analytical Methods, Numerical and Experimental Methods. Mixed Mode Brittle Fracture: Theory based on Potential Energy Release Rates, Maximum Tangential Stress Criterion, Maximum Tangential Principal Stress Criterion, Strain Energy Density Criterion **Module 3: Anelastic Deformation at Crack Tip** Irwin Plastic Zone Size Correction; Dugdale-Barenblatt Model for Plastic Zone Size; Crack-Tip Mode I, II and III Plastic Zone Shape; Thickness Dependence of Fracture Toughness KC; Crack Opening Displacement; Rice's Path-Independent Integral J; Resistance Curve; Stability of Crack Growth **Module 4: Elastic Plastic Fracture Mechanics** Crack Opening Displacement Criterion; Mode I Crack-Tip Field - Rice-Rosengren Analysis, Hutchinson’s Analysis; Crack-Tip Constraints: T Stress and Q Factor; Crack Propagation and Crack Growth Stability **Module 5: Fatigue Crack Growth** Fatigue Crack Growth Rate under Constant Amplitude Loading; Factors Affecting Fatigue Crack Propagation; Crack Closure; Life Estimation Using Paris Law; Variable Amplitude Cyclic Loading **Module 6: Experimental Measurement of Fracture Tougness Data** Measurement of Plane Strain Fracture Toughness KIC, Critical COD δC, K-Resistance Curve - Linear Elastic Material and Elastic Plastic Material
4	**Texts/References**	<u>**Text-books:**</u> **1.** T. L. Anderson, Fracture Mechanics: Fundamentals and Applications, 4th ed. – Boca Raton 2017. **2.** D. Broek, Elementary Engineering Fracture Mechanics, 3rd Revised Edition, Springer Netherlands, 1982, **3.** Maiti S.K, Fracture Mechanics: Fundamentals and Applications. – 1st Edition, Delhi: Cambridge University Press, 2015. <u>**References:**</u> **1**. Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw-Hill. Education, 2009, **2**. CT Sun, Fracture Mechanics, Academic press, 2012, **3.** T. Kundu, Fundamentals of Fracture Mechanics, CRC Press, 2008.

1	**Title of the course** (L-T-P-C)	**Functional Materials Manufacturing for Energy and Biomedical Applications (1-0-0-2)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**1. Introduction to Functional Materials** **a.** Crystal structures **b.** Morphology and Microstructure **c.** Defects, dislocation and microcracks **d.** Thermal Treatment and Recovery Mechanisms **2. Magnetic Materials** **a.** Types of Magnetic Materials **b.** Permanent Magnets as Magnetic Field Source **c.** Magnetoelastic Materials **d.** Magnetocaloric Materials **3. Ferroelectric Materials** **a.** Types of Ferroelectric Materials **b.** Piezoelectric Materials for Energy Harvesting **c.** Piezoelectric Polymers **4. Fabrication of Nanostructured Functional Materials** **a.** Thin Films: Pulsed Laser Deposition and Atomic Layer Deposition **b.** Nanoparticles: High Energy Ball Milling, Hydrothermal Reactions **5. Additive Manufacturing of Functional Materials** **a.** Review of AM Technologies Suitable for Functional Materials **b.** Anisotropy Consideration Towards Tuning Functional Properties **c.** Compositional Grading **6. Functional Additive Manufacturing Case Studies and applications** **a.** Magnetocaloric Regenerators **b.** Brain Phantoms **c.** Transcranial Magnetic Stimulation Coils
4	**Texts/References**	**Text Books**: None **Reference Books:** **1.** D. C. Jiles, Introduction to Magnetism and Magnetic Materials, CRC Press, Tylor & Francis Group, 2015, **2.** A. Kitanovski, J. Tušek, U. Tomc, U. Plaznik, M. Ozbolt, and A. Poredoš, Magnetocaloric Energy Conversion: From Theory to Applications. Springer International Publishing, 2015. **3.** H. Huang and J. F. Scott, *Ferroelectric Materials for Energy Applications.* John Wiley & Sons, 2019. **4.** Ian Gibson, David Rosen, Brent Stucker, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. **Resources from Peer-Reviewed Research Journals:** **1.** H. Magsood and R. L. Hadimani, "Development of anatomically accurate brain phantom for experimental validation of stimulation strengths during TMS," *Materials Science and Engineering: C*, p. 111705, 2020, doi: 10.1016/j.msec.2020.111705. **2.** 2. H. Hou *et al.*, "Fatigue-resistant high-performance elastocaloric materials made by additive manufacturing," *Science*, vol. 366, no. 6469, pp. 1116–1121, Nov. 2019, doi: 10.1126/science.aax7616. **3.** 3. C. V. Mikler *et al.*, "Laser Additive Manufacturing of Magnetic Materials," *JOM*, vol. 69, no. 3, pp. 532–543, Mar. 2017, doi: **4.** 10.1007/s11837-017-2257-2.

1	**Title of the course** (L-T-P-C)	**Engineering Mathematics for Advanced Studies (3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module-1:** Linear Algebra: Vector Spaces, Matrices, Linear algebraic equations, Eigen-values and Eigen- vectors of matrices, Singular-value decomposition **Module-2:** Tensor Algebra: Index Notation and Summation Convection, Tensor Algebra **Module-3:** Vector Calculus: Dot and Cross Product, Curves. Arc Length. Curvature. Torsion, Divergence and Curl of a Vector Field, Line Integrals, Green's Theorem, Stokes's Theorem, use of Vector Calculus in various engineering streams **Module-4:** Ordinary Differential Equations: Initial Value Problem, Method to solve first order ODE, Homogeneous, linear, 2nd order ODE, Non-homogeneous, linear, 2nd order ODE, System of 1st order ODE **Module-5:** Laplace and Fourier transformation: First and Second Shifting Theorems, Transforms of Derivatives and Integrals, Fourier Cosine and Sine Transforms, Discrete and Fast Fourier Transforms **Module-6:** Partial Differential Equations: Basic Concepts of PDEs, Modeling: Wave Equation, Heat Equation, Solution by Separating Variables, Solution by Fourier Series, Solution by Fourier Integrals and Transforms **Module-7:** Numerical Methods: Methods for Linear Systems, Least Squares, Householder's Tridiagonalization and QR-Factorization, Methods for Elliptic, Parabolic, Hyperbolic PDEs **Module-8:** Complex Analysis and Potential Theory: The Cauchy-Riemann Equations, Use of Conformal Mapping, Electrostatic Fields, Heat and Fluid Flow Problems, Poisson's Integral Formula for Potentials **Module-9:** Optimization and Linear Programming: Method of Steepest Descent, Linear Programming Fundamental theorem of linear inequalities, Cones, polyhedra. and polytopes, Farkas' lemma, LP- duality, max-flow min-cut, Simplex Method, primal- dual, Fourier-Motzkin elimination, relaxation methods **Module-10:** Probability Theory and Statistics: Experiments, Outcomes, Events, Permutations and Combinations, Probability Distributions, Binomial, Poisson, and Normal Distributions, Distributions of Several Random Variables, Testing Hypotheses, Goodness of Fit, $\chi 2$-Test **Module-11:** Abstract Algebra: Groups, Sub-groups, Cosets and Lagrange's theorem, Group actions, direct and semi-direct products.
4	**Texts/References**	**1.** E. Kreyszig. Advanced Engineering Mathematics, John Wiley & Sons, 2011. **2.** P.V. O'Neil. Advanced Engineering Mathematics, CENGAGE Learning, 2011. **3.** D.G. Zill. Advanced Engineering Mathematics, Jones & Bartlett Learning 2016. **4.** B. Dasgupta. Applied Mathematical Methods, Pearson Education, 2006. **5.** A. Schrijver, Theory of Linear and Integer Programming, 1998. **6.** D.S. Dummit, R.M. Foote, Abstract Algebra, 2004.

1	**Title of the course** (L-T-P-C)	**Fatigue and Fracture Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Strength of Materials/Mechanics of Materials (& Theory of Elasticity)
3	**Course content**	**<u>Module 1</u>**(10 hours): Introduction and historical overview, Types of fatigue – low cycle fatigue, highcycle fatigue, very high cycle (giga cycle) fatigue, Fatigue test methods and equipment, Totallife approaches based on cyclic stress and cyclic strain, Cyclic hardening and softening in single crystals and polycrystals. **<u>Module 2</u>**(10 hours): Crack initiation and propagation, Mechanisms, Macro-structural and microstructural aspects, Use of fracture mechanics in fatigue **<u>Module 3</u>**(10 hours): Local strain approach, effect of different factors on fatigue – Stress concentration, Size, Surface, Temperature, Frequency, Environment, Microstructure, Residual stresses, Fretting, Creep-fatigue interaction, Multiaxialstresses, Thermomechanical loading, Variable amplitude loading, Load sequence, Crack closure **<u>Module 4</u>**(10 hours): Fatigue behaviour of different materials – Metallic materials and weldments, Ceramics, Polymers, Composites, Metallic glasses, Shape memory alloys, Ultrafine grained materials, Nanocrystalline materials, Biomaterials, Metallic foams, Case studies on fatigue failures, Design considerations, Methods for fatigue life improvement
4	**Texts/References**	1. Fatigue of Materials, Suresh, Cambridge India, 2015 2. Fracture Mechanics, Fundamentals and Applications, T.L. Anderson, CRC Press 2017

1	**Title of the course** (L-T-P-C)	**Combustion and Fire Dynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Fundamentals**: Motivation for studying combustion, Fuels and their combustion properties: diesel, gasoline, aviation fuels, natural gas, coal, Thermochemistry: the composition of a gas mixture: mass and mole fraction, Chemical reactions – theoretical and actual combustion processes, Enthalpy of formation and enthalpy of combustion, Adiabatic flame temperature, Introduction to mass transfer, Chemical equilibrium. Chemical kinetics – reaction rates, chemical time scales. **Flames**: Conservation equations with chemical reaction, Laminar premixed flames – flame speed, governing equations, flammability limits, flame stability, Laminar diffusion flames – diffusive burning of liquids, stagnation layer model – pure convective burning, radiative convective burning, Droplet evaporation and burning – Spalding number. **Measurement in Fire** Measurement of temperature – thermocouples, plate thermometer for the measurement of temperature and heat flux, heat flux sensors, cone calorimetry, measurement of soot volume fraction, soot yield and spectral measurements. **Introduction to Numerical Fire Simulations** Governing equations – hydrodynamics model, combustion model, radiation model, solution algorithm, simulation of typical fires.
4	**Texts/References**	**1.** Stephen R. Turns, An Introduction to Combustion: Concepts and Applications, Third edition, McGraw Hill Education (India) Private Limited, New Delhi, 2012. **2.** James G. Quintiere, Fundamentals of Fire Phenomena, John Wiley and Sons, Wet Sussex, 2006. **3.** The SFPE Handbook of Fire Protection Engineering, fourth edition, National Fire Protection Association (NFPA), Massachusetts, 2008.

1	**Title of the course** (L-T-P-C)	**Convective Heat Transfer** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Flow classifications, mass momentum and energy relation in differential form Exact and approximate solution to convection in laminar and turbulent, internal and external flow. solution to natural convection problems.
4	**Texts/References**	**1** kays w,, Crawford M, Wigand B., connective Heat and mass Transfer Fourth Edition McGraw Hill Education, 2017 **2** sodic kakac and Yamane yenar, connective Heat Transfer, Second Edition, CRC Press 1994 **3** Louis C Burmiester, connective Heat Trasfer Second Edition, john wily and sons 1993 **4** Bejan A, connective Heat Transfer Third Edition, wily,2006 **5** Kavinay M, Principles of connective heat transfer, second Edition springer,2001.

1	Title of the course (L-T-P-C)	**Satellite Attitude Dynamics and Control** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	**Review of Newtonian particle mechanics**. **Rigid-body Kinematics**: Direction cosines, Euler angles, Principal rotation vector, Euler parameters, Rodrigues parameters, Homogeneous transformations. **Rigid-body Dynamics**: Newton-Euler equation of motion, Torque-free rigid-body rotation. **Generalized methods of analytical dynamics**: Generalized coordinates, D'Alembert's principle, Lagrangian dynamics. **Stability and control**: Stability of torque free rotation, Gravity gradient modeling and stabilization, Spin stabilized satellite, Satellite attitude control using reaction wheels and control moment gyros, Attitude stabilization using magnetic torquers and Lorentz force, Attitude Control using thrusters
4	**Texts/References**	References: **1.** Analytical Mechanics of Space Systems, Hanspeter Schaub and John Junkins, American Institute of Aeronautics and Astronautics, 2003 **2.** Spacecraft Attitude Dynamics, Peter Hughes, Dover Publication, 2004 **3.** Spacecraft Dynamics and Control - A practical engineering approach, Marcel Sidi, Cambridge University Press, 2002

1	**Title of the course** (L-T-P-C)	**Automobile Engineering Fundamentals** 3-0-0-6
2	**Pre-requisite courses(s)**	ATD, ToM
3	**Course content**	Introduction - Overview of automobile components, Classification of IC Engines, Engine components, Engine cycles, Engine performance, Turbocharging and Supercharging, Combustion in ICE, Fuel delivery systems – Carburetion and Fuel Injection systems, Engine emissions, Emission control systems, Automotive powertrain - Automotive clutch, Transmission, Manual transmission, Automatic transmissions, Powertrain analysis, Transmission matching, Brake system – Components of brake system, Drum brake, Disc brakes, Hydraulic brakes, Air brakes, Anti-lock-braking (ABS) systems, Braking analysis, Steering system, Manual steering systems, Power steering systems, Steering analysis, Wheel alignment, Suspension systems, Shock absorbers, Independent and dependent suspensions, Suspension analysis, Safety systems – Airbags, ABS, Electronic Brake Distribution (EBD), Electronic Stability Control (ESC) systems, Advanced Driver Assistance System (ADAS) Introduction to Electric and Hybrid Powertrains
4	**Texts/References**	**References:** **1.** R. Stone and J. K. Ball, Automotive Engineering Fundamentals, SAE International, **2.** D. B Astow, G. Howard and J. P. Whitehead, Car Suspension and Handling, SAE International, **3.** K. Newton, W. Steeds and K. Garrett, The Motor Vehicle, Butterworths, **4.** R. Limpert, Brake Design and Safety, SAE International, **5.** V. Ganesan, Internal Combustion Engines, Tata McGraw Hill, **6.** H. Heisler, Vehicle and Engine Technology, SAE International,

<table>
<tr><td>1</td><td>Title of the course
(L-T-P-C)</td><td>Nonlinear Oscillation
(3-0-0-6)</td></tr>
<tr><td>2</td><td>Pre-requisite courses(s)</td><td>None</td></tr>
<tr><td>3</td><td>Course content</td><td>Phase plane analysis: Classification of linear systems, Lyapunov stability, Structural stability
Duffing Oscillator: Lindstedt’s method
van der Pol Oscillator: Method of averaging, Hopf Bifurcation, Homoclinic Bifurcations, Relaxation Oscillations
Forced Duffing Oscillator: Two variable expansion method, Cusp Catastrophe
Forced van der Pol Oscillator: Entrainment
Mathieu’s equation: Floquet Theory, Hill’s equation, Harmonic Balance
Coupled conservative oscillators: Nonlinear normal modes, Modal equation
Center Manifolds</td></tr>
<tr><td>4</td><td>Texts/References</td><td>Text books:

1. Richard Rand. “Lecture Notes on Nonlinear Vibration” URL [https://ecommons.cornell.edu/handle/1813/28989].

References:

2. Ali H. Nayfey, Dean T. Mook, “Nonlinear Oscillation”, Wiley, 2008.
3. Chihiro Hayashi. “Nonlinear Oscillations in Physical Systems”, Princeton University Press, 2014.
4. Vladimir I. Nekorkin , “Introduction to Nonlinear Oscillations”, 2016.</td></tr>
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1	**Title of the course** (L-T-P-C)	**Applied Elasticity** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	Equilibrium Equations, Relations in Curvilinear Cylindrical and Spherical Coordinates Deformation: Displacements and Strains (6 hrs) Small Deformation Theory, Strain Transformation, Principal Strains, Spherical and Deviatoric Strains, Strain Compatibility, Curvilinear coordinate system: Cylindrical, Spherical system relations Material Behavior: (3 hrs) Linear Elastic Materials—Hooke's Law Physical Meaning of Elastic Moduli, Thermoelastic Constitutive Relations, Anisotropy - Basic Concepts, Material Symmetry, Restrictions on Elastic Moduli, Strain Energy Formulation and Solution Strategies:(2 hrs) Stress Formulation, Displacement Formulation, Principle of Superposition, Saint-Venant's Principle, Uniqueness theorem, Reciprocal theorem Two-Dimensional Formulation: (9 hrs) Plane Strain, Plane Stress, Generalized Plane Stress, Airy Stress Function, Polar Coordinate Formulation, Cartesian Coordinate Solutions; Curvilinear coordinates; Complex Variable Methods: Complex Formulation of the Plane Elasticity Problem, Resultant Boundary Conditions, General Structure of the Complex Potentials: Extension, Torsion, and Flexure of Elastic Cylinders (6 hrs) Extension Formulation; Torsion, Flexure Formulations, Flexure Problems without Twist Thermoelasticity (2 hrs) General Uncoupled Formulation, Two-Dimensional Formulation, Displacement Potential Solution, Stress Function Formulation 3D Elasticity: Displacement Potentials and Stress Functions (4 hrs) Helmholtz Displacement Vector Representation, Lame´'s Strain Potential, Galerkin Vector Representation, Papkovich-Neuber Representation; Spherical Coordinate Formulations, Stress Functions.
4	**Texts/References**	**Texts:** **1.** MH. Sadd, Elasticity: Theory, Applications, and Numerics, 3rd Edition, Academic Press, 2014. **2.** J. R. Barber ,Elasticity, 3rd edition, Kluwer Academic, 2009. References: **3.** S. P. Timoshenko, J. N. Goodier, Theory of Elasticity, 3rd Edition, McGraw Hill Pub. 1970. **4.** ArthurP. Boresi, Ken Chong, James D. Lee, Elasticity in Engineering Mechanics, 2010, Wiley. **5.** Allan F. Bower, Applied Mechanics ofSolids, 1st Edition, 2009, CRC Press. **6.** R. W. Soutas-Little, Elasticity, DoverPublications, 1999 **7.** P Chou, N Pagano. Elasticity: Tensor, Dyadic and Engineering Approaches, DoverPub., 1992. **8.** A. S. Saada, "Elasticity Theory and Applications", Cengage Learning, New Delhi, 2014. **9.** Mark Kachanov,Igor Tsurkov, Handbook of Elasticity Solutions, Evener, 2003 **10.** W.S. Slaughter, The Linearized Theory of Elasticity, Birkhäuser, 2002 **11.** V. V. Novozhilov, Theory of Elasticity, Pergamon Press, 1961.

1	**Title of the course** (L-T-P-C)	**BIO ENERGY CONVERSION** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	**Introduction**: Global and Indian energy scenario, Issues with conventional energy sources, climate change, alternative energy sources **Bio Energy sources:** Photosynthesis, Biomass characteristics, Energy content of various bio energy sources, Biomass conversion methodologies **Physical conversion:** Briquetting, Pelletization **Thermo chemical conversion**: Direct combustion, Working principal of high efficiency stoves **Gasification:** Chemical reaction in gasification, Producer gas, Types of gasifiers, Working principal of fixed bed and fluidized bed gasifiers, Application of producer gas in engines **Pyrolysis:** Liquefaction of biomass through pyrolysis, Methanol production **Bio chemical conversion:** Anaerobic digestion, Bio gas production, Factors affecting bio gas yield, Types of bio digestors, Bio fermentation for ethanol production, Application of ethanol in engines **Chemical conversion:** Bio diesel, Sources of bio diesel, methods of bio diesel production, Transesterification of bio oil, Application of bio diesel in engines **Introduction to Algal Biofuel:** Sources and methodologies of utilization
4	**Texts/References**	**Textbooks:** • Understanding Clean Energy and Fuels from Biomass, H. S. Mukunda, Wiley-India, 2011 • Introduction to Biomass Energy Conversions, Sergio Capareda, CRC Press Inc, 2013 • Bio Gas Technology, B. T. Nijaguna, New Age International, 2006 • Renewable Energy Engineering and Technology, A Knowledge Compendium, Edited by VVN Kishore, TERI Press, 2009 • Algal Biofuel: Sustainable Solution, Editors, Richa Kothari, Vinayak V Pathak and and V V Tyagi, TERI Press, 2023 **References:** • Renewable Energy Resources, Joh, W. Twidell, Anthony, D. Weir, EC BG-2001 • Sustainable Energy, Choosing Among Options, Jefferson W. Tester et.al., PHI Publications, Second Edition, 2012 • Gasification, Christopher Higman, Maarten van der Burgt, 2nd Edition, Elsevier Publications, 2008

1	**Title of the course** (L-T-P-C)	**Fluid Dynamics** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	● Continuum concept, control volume equations, Ideal fluid flow, derivation of N-S equations, exact solutions of N-S equations, boundary-layer equations, internal flows, Falkner-Skan similarity solutions of the laminar boundary-layer equations, von Kármán- Pohlhausen approximate method, coupling of thermal boundary layers and velocity field of the temperature field, ● Potential flow, flow over a nose of a cliff, doublets, cylinder in a stream, and flow past other immersed bodies ● High Re flows, energy-transfer concepts, turbulent boundary layers, free-shear flows, turbulence modeling (RANS and LES) ● Concept of compressible flow, one dimensional isentropic flows, normal shock, flow with friction, heat transfer, quasi 1D flow and oblique shocks, expansion waves. ● Surface tension and surface tension driven flows
4	**Texts/References**	**1.** Y Çengal, MA Boles, Fluid Mechanics: Fundamentals and Applications, Tata McGraw Hill, 2006. **2.** Y Frank M. White, Fluid Mechanics, 4th Tata McGraw Hill, 1999. **3.** Pope, Stephen B. Turbulent flows, (2001): 2020. **4.** Tennekes, Hendrik, and John L. Lumley. A first course in turbulence, MIT press, 2018. **5.** Hermann Schlichting, and Klaus Gersten, Boundary layer theory, 9^{th} edition, Springer, 2017.

1	**Title of the course** (L-T-P-C)	**Advanced Thermodynamics** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Concepts of classical thermodynamics. Application of I and II laws to closed and open systems. Availability analysis of thermal systems and the concept of energy conservation. Phase and reaction equilibria. Equilibrium constants. calculation of equilibrium composition of multi component gasesous mixtures. Equations of state and calculation of thermodynamics and transport properties of substances. Reaction rates and first, second and higher order reactions. Reactions in gaseous, liquid and solid phases. Combustion and flame velocities, Laminar and turbulent flames. Premixed and diffusion flames their properties and structures. Theories of flame propagation, thermal, diffusion and comprehensive theories, Problems of flame stability, flashback and blow off. Combustion of solid, liquid and gaseous fuels. Combustion of fuel droplets and sprays. Measurements in combustion systems. Combustion systems. Combustion in closed and open systems. Applications to IC Engines. Boilers, gas turbine combustors and rocket motors.
4	**Texts/References**	**1.** K.G. Denbigh, Principles of Chemical Equilibrium, Cambridge, 1971. **2.** A.G. Gaydon and H.G. Wolfhard, "Flames" Chapman Hall, 1979. **3.** B. Lewis and G. Von Elbe, Combustion, Flames and Explosions of Gases, Academic Press, 1961. **4.** M.W. Zemansky, Heat and Thermodynamics 4Ed. McGraw Hill, 1968.

1	**Title of the course** (L-T-P-C)	**Research Methodology** **1-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Scientific Literature:** Research articles, resources, types of publications, identifying authentic sources **Reading:** Reading research articles; experimental, numerical, analytical, and review publications. **Writing:** Communicating formally (letters, emails) Styling; Units; Writing research articles; Automations using LaTeX, MS Word, Mendeley, BibTex; Research ethics **Presentations:** Presenting research work, Content and time management. Presentation tools: MS PowerPoint, Beamer, Excel; Plotting tools: Grapher, Origin, Tecplot, Matlab; *Figures:* quality, scaling, vector vs raster formats; **Oral Communication:** Stage manners, voice modulation **Hybrid Mode Presentations:** Initial setup and the tools required
4	**Texts/References**	**1.** A Manual for Writers of Research Papers, Theses, and Dissertations, Kate L Turabian, Ninth Edition, The University of Chicago Press, 2018. **2.** Communication Skills for Engineers and Scientists, Sangeeta Sharma and Binod Mishra, Second Edition, PHI Learning, 2009. **3.** The elements of style, William Strunk Jr and E White, Fourth Edition, Pearson Education, 1999. **4.** A New Approach to Research Ethics Using Guided Dialogue to Strengthen Research Communities, Henriika Mustajoki and Arto Mustajoki, First Edition, Routledge Publications, 2017. **References:** 1. Wren and Martin “High School English Grammar and Composition”, Regular edition, January 2017

1	**Title of the course** (L-T-P-C)	**Mechatronics and Robotics** 2-0-2-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	• Mechatronics vs robotics • Modeling friction, DC motor, Lagrange formulation for system dynamics. • Dynamics of 2R manipulator, Simulation using Matlab, Selection of sensors and actuators. • Concept of feedback and closed loop control, mathematical representations of systems, linearization of the system, stability analysis and control design for regulation and tracking • Basics of sampling of a signal, and signal processing • Navigation: environment description, map building, path planning and collision avoidance • Vision systems: 2-D Projective Geometry, camera geometry, point clouds, range image processing, clustering and classification, examples • Dimensionality reduction and sparse representation Hands on project
4	**Texts/References**	• Indri and Oboe, “Mechatronics and Robotics: New Trends and Challenges:, CRC Press, 1st edition, 2020 (ISBN 9780367562045) • Boukas K, Al-Sunni, Fouad M “Mechatronic,Systems Analysis, Design and Implementation,” Springer, 2012 • Katsuhiko Ogata, Modern Control Theory, Prentice Hall Ogatta, 1990

1	**Title of the course** (L-T-P-C)	Design of Mechanical Transmission Systems 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Basics: Review of Mechanical Engineering Design, Materials, Load and Stress Analysis, Deflection, and Stiffness. Failure Prevention: Review of Failures Resulting from Static Loading, Review of Fatigue Failure Resulting from Variable Loading. Design of Mechanical transmission systems: Shafts: Design for Stress, Deflection Considerations, Critical Speeds for Shafts, Miscellaneous Shaft Components, Limits and Fits. Lubrication and Journal Bearings: Types of Lubrication, Petroff's Equation, Thick-Film Lubrication, Hydrodynamic Theory, Thrust Bearings Design Considerations Rolling-Contact Bearings: Types, Bearing Load Life at Rated Reliability, Reliability versus Life—The Weibull Distribution, Relating Load, Life, and Reliability, Combined Radial and Thrust Loading Gears: Gears—General, Spur, Helical, Bevel, and Worm gears: The Lewis Bending Equation, Surface Durability, AGMA Stress Equations, AGMA Strength Equations-Geometry Factors, Dynamic Factor, Overload Factor, Surface Condition Factor, Size Factor, Load-Distribution Factor, Hardness-Ratio Factor, Stress-Cycle Factors, Reliability Factor, Temperature Factor, Rim-Thickness Factor, Safety Factors. Gearbox: Introduction, Evaluation, and application of Gearbox, Step Ratio, Preferred Numbers, Structural Formula & Rules of optimum Gearbox, Ray diagram construction, Machine Tool Gearbox - Kinematic diagram construction, Centre distance, and teeth calculation Brake -Torque requirement for drum brake systems, Torque requirement for disc brake systems, static and dynamic analysis, brake force distribution. Braking efficiency & distance and brake factor. Thermal analysis and braking conditions, braking power absorbed by lining and drum/disc Clutch: Types and working method, Torque transmitting capacity – uniform pressure & wear theories. Multiple discs and cone clutches, Centrifugal clutch, Dynamic analysis. Belt Drives - Introduction and types, Geometrical relationship for open and crossed belt drives - V and micro-v belts, Selection of V and micro-v belts, V and micro-v pulley design.
4	**Texts/References**	**1.** Richard G. Budynas, J. Keith Nisbett, Shigley's Mechanical Engineering Design, McGraw-Hill Higher Education, 2017 **2.** Stephen P Radzevich , Dudley's Handbook of Practical Gear Design and Manufacture, CRC Press, 2012. **3.** Peter Lynwander, Gear Drive Systems Design and Application, CRC Press, 2019. **4.** Hani M. Tawancy, Anwar Ul-Hamid, Nureddin M. Abbas, Practical Engineering Failure Analysis, CRC Press, 2004.

1	**Title of the course** (L-T-P-C)	**Dynamics and Control** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Kinematics:** ● Mathematical representation of position and orientation of a rigid body in 3D space, Euler angles, quaternions, transformation matrix ● Linear velocity, angular velocity from rotation matrix, acceleration of a rigid body in 3D space ● System of rigid bodies, degrees of freedom, holonomic and non- holonomic constraints, generalized coordinates ● Position, velocity and acceleration of multi body systems. **Dynamics:** ● Mass, inertia of a rigid body, linear and angular momentum, external forces and moments. ● Free body diagram, Newton-Euler formulation, equations of motion, examples ● Lagrangian formulation for equations of motion, comparison with Newton-Euler formulation, example solution of equations of motion using computer ● Modeling and simulation of multi-body systems using computer tools ● Vibration: 1 DOF oscillations, free/forced/damped responses, MDOF oscillations, natural frequencies, normal modes, time response, frequency response, bode plots **Controls:** ● Linearizing equations of motion, state space formulation, solution of state space equations ● Stability, controllability and observability in SISO systems, examples ● Root locus, bode plots, the relationship of classical and state space methods ● Design of controllers using state space and root locus Case studies of control of mechanical systems
4	**Texts/References**	**1.** A. Ghosal, Robotics: Fundamental Concepts and Analysis, Oxford University Press, 2006 **2.** “Analytical Dynamics”, Leonard Meirovitch, First Edition, McGraw Hill. 1970 **3.** Advanced Dynamics, Donald T Greenwood, Cambridge University Press; Reissue edition (2 November 2006) **4.** G. F. Franklin, J. D. Powell, and A. Emami-Naeini, Feedback Control of Dynamic Systems, Pearson, 2006/5th edition

1	**Title of the course** (L-T-P-C)	**Fundamentals of Casting and Welding** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Casting:** Introduction; Classification of casting processes; Advantages and drawbacks; Historical background; Foundry practice on video; Casting of BMW car wheels on video; Patterns; Shrinkage and Mechanical allowances; Moulds; Gating system; Properties of moulding sand; Gating design; Vertical gating: aspiration effect; Optimum riser design. Solidification of pure metal and alloy; Solidification time: Chvorinov's rule; Categories of metal casting processes; Steps in sand casting; Mould properties and characteristics; Shell moulding; Investment casting: Process characteristics, Process to show through video, Advantages and disadvantages; Multiple mould casting, Steps in permanent mould casting; Die casting: Hot and Cold Chamber die casting; Centrifugal casting; Continuous casting; Cost analysis of casting; Casting defects; Product design considerations in casting; **Welding Processes:** Preamble, classification of joining processes; Welding: advantages and limitations; Joints in welding; Fusion welding processes; Heat density; Comparison among welding processes; Features of a Fusion Welded Joint; Typical Fusion Welded Joints; Heat Affected Zone; Solidification of Weld; Solid-State (Phase) Welding: Forge welding, butt welding, friction welding, explosion welding, resistance welding. Ultrasonic welding process characteristics and applications; Electron beam welding; Laser beam welding; Plasma arc welding; Arc welding: characteristics; Consumable and non-consumable electrodes; Power source; Shielded metal arc welding: Principles and applications; Gas metal arc welding; Gas Tungsten Arc Welding; Tungsten-Inert Gas Welding (TIG); Submerged Arc Welding; Gas Welding: Principles, types of flames; Brazing and Soldering: Process capabilities; Welding defects
4	**Texts/References**	**1.** A.Ghosh and Asok Mallik - Manufacturing Science, 2nd Edition, East-West Press Pvt Ltd, Year 2010. **2.** G.K.Lal and S.K.Choudhury - Fundamental of Manufacturing Processes Alpha Science International, 2005 **3.** Richard Flinn - Fundamentals of Metal Casting, Addison-Wesley Publishing Co., Inc., 1963. **4.**Kalpakjian and Schmid - Manufacturing Processes for Engineering Materials, 2nd Edition Pearson Education 2010

1	**Title of the course** (L-T-P-C)	**Physical and Mechanical Metallurgy** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Module 1:** Structure of Metals, Unit Cells, Crystal structure of metals, Coordination Number 7 1.9 Anisotropy, Textures or Preferred Orientations, Miller Indices, The Stereographic Projection, Structure of Alloys, Imperfections in Crystals, Different Characterization Techniques: XRay Diffraction, Electron Microscopy **Module 2:** Phase Diagrams, Phase Rule, Binary Phase Diagram, Microstructural Changes during cooling, Fe-C Equilibrium diagram, Effect of alloying element on Fe-C diagram, Ternary and Quaternary Phase diagram, Phase transformations, diffusion in solids, Nucleation and growth Kinetics, Solidification, Examples of phase transformation, Precipitation and Age hardening, Recovery, Recrystallization and grain growth, Heat Treatment of Steels, T-T-T, C-C-T diagram **Module 3:** Stress and Strain Relationships for Elastic Behavior: Stress state, Mohr's Circle, stress tensor, strain at a point, Hydrostatic and Deviatoric stress, Hooke's law, Strain Energy, Anisotropy, True stress and True Strain, Yield Criteria and Locus, Yield Anisotropy, Plastic Stress-Strain relations **Module 4:** Dislocation Mediated Plasticity, Critical Resolved Shear Stress, Deformation of Cubic Crystals, Deformation Twinning, Strain Hardening of Single Crystals, Observation of Dislocations, Dislocation Characteristics, Stress Fields and Energies of Dislocations, Forces on Dislocations, Cross-slip and climb, Frank-Read source, Dislocation Interactions, Slip Systems, Dislocation density and Stress, grain boundary **Module 5:** Strengthening Mechanisms: Grain Boundaries Strengthening, Strain Hardening, Solid-Solution Strengthening, Precipitation Strengthening, Dispersion Hardening, Introduction to Fracture in Metals, Theoretical Cohesive Strength of Metals, Griffith Theory of Brittle Fracture, Fractography, Dislocation Theories of Brittle Fracture, Ductile Fracture **Module 6:** Materials Testing and Mechanical Properties: Tension Test, Hardness Test, Torsion Test, Fracture Mechanics, Fatigue of Metals, Creep and Stress Rupture, Brittle Fracture and Impact Testing, Fundamentals of Metalworking: forgoing, rolling, extrusion, sheet-metals, Machining, Ferrous and Nonferrous Engineering alloys
4	**Texts/References**	**1.** Materials Science and Engineering: A First Course by V. Raghavan **2.** Physical Metallurgy Principles by Robert E. Reed-Hill **3.** Mechanical Metallurgy by George E. Dieter **4.** Materials Science and Engineering: An Introduction by William D. Callister **5.** Physical Metallurgy Principles and Practice by V. Raghavan

1	**Title of the course** (L-T-P-C)	**CNC and Additive Manufacturing** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	• Introduction to Computer Numerical Control (NC/CNC), CNC machines, Industrial applications of CNC, and economic benefits of CNC. CNC Machine Tools, CNC tooling: Qualified and pre-set tooling, tooling systems, tool sets, automatic tool changers, work holding, and setting. Programming: Part programming language, programming procedures, proving part programs, computer-aided part programming. Geometry code (G-Code). • Introduction to Additive Manufacturing (AM): Overview of Additive Manufacturing (AM), AM technologies, classification of AM processes: Sheet Lamination, Material Extrusion, Photo- polymerization, Powder Bed Fusion, Binder Jetting, and Direct Energy Deposition, Popular AM processes. Additive manufacturing of different materials. Metal Additive Manufacturing, Reverse Engineering. • Design for additive manufacturing, Path planning, STL file processing, • Materials for Additive Manufacturing, • Characterization of Additive Manufacturing • Large scale Additive manufacturing, • Case studies of Additive Manufacturing and Integration of hybrid manufacturing technologies.
4	**Texts/References**	**1.** Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing. Springer, 2014. **2.** C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing. World Scientific, 2003. **3.** Ibrahim Zaid, R. Sivasubramanian, CAD/CAM: Theory and Practice. McGraw Hill Education,2nd edition, 2009. **4.** M. P. Groover, E. W. Zimmers, CAD/CAM: Computer-aided design and manufacturing. Pearson, 2013.

1	**Title of the course** (L-T-P-C)	**Mechanics of Machining and Forming** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Principles of metal cutting; Mechanics of chip formation; Geometry of cutting tools and tool signatures; Orthogonal and oblique cutting; Metal cutting models: Merchant model, Lee- Shaffer model; Forces in metal cutting; Thermal aspects of machining; Tool wear, tool life, tool materials, Overview of tool coatings and coating techniques; Economics of machining; Machinability; Cutting fluids: properties, types, application techniques, emissions and its adverse effects; Recent advances in machining: hard turning, high speed machining, diamond turning, machining of difficult to cut materials, machining with minimum quantity cutting fluids and cryogenic fluids; Metal forming: Bulk and sheet metal forming processes, Fundamentals of plasticity, yield, and flow, anisotropy, instability, yield criterion for isotropic materials, plastic stress-strain relations for isotropic materials. Force equilibrium method and its application to metal forming processes. Introduction to incremental sheet and bulk metal forming.
4	**Texts/References**	**1.** M. C. Shaw, Metal Cutting, Tata McGraw Hill, New Delhi, 2004. **2.** M. C. Shaw, Principles of Abrasive Processing, Oxford University Press, 1996. **3.** G. K. Lal, Introduction to Machining Science, New Age International Publishers, 2007. **4.** G. Boothroyd and W. A. Knight, Fundamentals of Machining and Machine Tools, CRC-Taylor and Francis, 2006. **5.** A. Ghosh and A. K. Malik, Manufacturing Science, East West Press, 2010. **6.** Theory of Plasticity by J. Chakrabarty, McGraw-Hill Book Co., International Edition, 19874.

1	**Title of the course** (L-T-P-C)	**Modeling and Simulation in Materials and Manufacturing** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Density Functional Theory (DFT):** Introduction to DFT: Principles and theoretical foundations, Electron density, exchange-correlation functionals, Predicting and analyzing material properties (e.g., electronic, optical, and magnetic). **Molecular Dynamics (MD) Simulations:** Basics of MD Simulation: Principles and algorithms, force fields, Energy minimization, Ensembles, Applications in studying dynamic material behavior: Estimation of glass transition temperature, polymer-metal/polymer-polymer/metal- filler/polymer-filler interaction energy. Estimation of bond and non-bond interactions. **Coarse-Grained (CG) simulations:** Coarse-Grained Modeling: Principles and techniques, force field: MARTINI, Applications in polymers and complex systems, Hands-on with CG models (MARTINI model). **Discrete Dislocation Dynamics:** Classification of defects, Dislocation Characteristics and classification, Dislocation plasticity, Stress field of a dislocation, Volterra construction, Dislocation motion, Driving force on a dislocation, Evaluation of dislocation velocity, Discretization and adaptive remeshing of dislocation lines, Time integration of equations of motion, Dislocation reactions Introduction to ParaDis: A discrete dislocation dynamics code **Continuum Modeling of Metals:** Crystal structure, slip systems, elastic and plastic deformation, anisotropy, Stress and strain tensors, principle stresses, Yield criteria, Hardening laws, Small and Large deformation theory, Constitutive modeling, Crystal Plasticity Finite Element Modeling, Software tools for continuum mechanics (ABAQUS, DAMASK, COMSOL), Deep drawing simulation, Extrusion simulation.
4	**Texts/References**	**1.** Understanding Molecular Simulation, From Algorithms to Applications, by Daan Frenkel and Berend Smit **2.** Molecular Dynamics Simulation, Fundamentals and Applications, by Kun Zhou and Bo Liu **3.** Ryan B. Sills, William P. Kuykendall, Amin Aghaei, Wei Cai, Fundamentals of Dislocation Dynamics Simulations, Multiscale Materials Modeling for Nanomechanics. Vol. 245. Springer **4.** Franz Roters, Philip Eisenlohr, Thomas R. Bieler, Dierk Raabe Crystal Plasticity Finite Element Methods: In Materials Science and Engineering, John Wiley & Sons, 2011 **5.** Ellad B. Tadmor, Ronald E. Miller, Modeling Materials - Continuum, Atomistic and Multiscale Techniques, Cambridge University Press, 2011

1	**Title of the course** (L-T-P-C)	**Production Planning and Control** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction: Functions of PPC, types of production, production- consumption cycle, coordination of production decisions. Product Characteristics, Economic Analysis, production Aspect. Forecasting: Introduction, Time Series Methods, Casual Methods, Forecast Errors. Facility Layout: Introduction, Flow Systems, Types of Layouts: Product, Process, Group Layout, Computerized Layout. Production Order: Purpose of production order, procedure for formulating production order, process outlines, process and activity charts, operation, and route sheet. Machine Output: Machine output, multi-machine supervision by one operator, machine interference, balancing of machine lines. Production and Operations Planning: Aggregate Planning, Strategies, and techniques for Aggregate Planning, Production Planning in Mass Production Systems and Assembly Line Balancing, Sequencing problems such as one machine n jobs, two machines n jobs & and its extension, m machines two jobs. Inventory Control: Inventory and its purpose, the relevant costs, selective inventory analysis (ABC analysis), Classical Inventory Model, EOQ with quantity discounts
4	**Texts/References**	**1.** Buffa, E.S., Sarin, R.K., "Modern Production / Operations Management," Eighteenth Edition, John Willey and Sons, 2007. **2.** Adam, Jr., E.E., Ebert, R.J., "Production and Operations Management Concept, Models and Behavior", Fifth Edition, Prentice Hall of India, 2001. **3.** Mukhopadhyaya, S.K., "Production Planning and Control – Text and Cases", Second Edition, Prentice Hall of India Learning Private Limited, 2007. Seetharama L. Narasimhan, Dennis W. Mcleavy, Peter J. Billington, "Production Planning and Inventory Control (Quantitative Methods and Applied Statistics Series)," Second Edition, Pearson Publisher, 1994.

1	**Title of the course** (L-T-P-C)	**Advanced Materials and Processing** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Atoms, molecules, bonds in solids crystallinity, defects in metallic structure,dislocations and plastic deformations fracture, iron carbon equilibrium diagrams, steels and cast irons, transformation hardening in steels, TTT diagrams, other heat treatment processes, formation of alloys in steel and cast irons, non ferrous alloys and their applications, special alloys. Polymers and polymerization, structure and properties of thermoplastics and thermosets: engineering applications, property modifications, mechanical and thermal behavior, composites with polymer matrix, metal matrix and ceramic matrix: fabrication methods, applications, properties and mechanics. Processing of polymers and ceramics, thermal spraying, ion beam machining, laser and electron beam processing, superplastic forming, thin films and their deposition, diamond coating techniques, tribological applications.
4	**Texts/References**	1. J.T. Black, R.A. Kohser, Degarmo's, Materials and Processes in Manufacturing, John Wiley & Sons, 2011. 2. G.E. Dieter, Mechanical Metallurgy, McGraw-Hill Book Company, Third Edition, 2013. 3. Properties and Selection: Iron, Steel and High- Performance alloys, ASM Handbook, Volume-1. 4. I.J. Polmear, Light Alloys- From Traditional alloys to Nanocrystals, 4th Edition, Elsevier Publication, 2006. 5. T.W. Clyne and P.J. Withers, An Introduction to Metal Matrix Composites, Cambridge University Press, 2003. R. M. Jones, Mechanics of Composite Materials, 2nd Edition, CRC Press, 2015.

1	**Title of the course** (L-T-P-C)	**Operations Research** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction: Linear programming methods: Simplex method, Big M method, Two phase method, Special cases - Goal programming. Duality analysis, sensitivity analysis, changes in right hand side constraints, changes in objective function coefficient, adding new constraints, adding new variables. Dual simplex method, Cutting plane algorithm, Branch and Bound technique, Zero-one implicit enumeration algorithm, applications of dynamic programming, Cargo loading model, Workforce size model, Equipment replacement model, Inventory model. Shortest path model, Maximal flow problem, Crashing of project network, Resource leveling & Resource allocation technique. Unconstrained nonlinear algorithms, Constrained algorithms, Separable programming, Quadratic programming, Geometric programming, Stochastic programming.
4	**Texts/References**	**1.** Handy M. Taha, Operations Research, An introduction, 10th edition, Prentice Hall of India, New Delhi,2018 **2.** Don. T. Philips, A.Ravindram and J. Soleberg, Operations Research, Principles & Practice, John Wiley & sons, 1992. **3.** Panneerselvam ,R, "Operations Research", 3rd edition, Prentice – Hall of India, New Delhi,2023

	Title of the course (L-T-P-C)	**Industrial Engineering and Technology Management** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Productivity, Factors Affecting the Productivity, Improving the Productivity: Introduction to Work Study, Work Study Human Component and Method Study, Recording Techniques for Method Study, Recording Techniques Critical Examination, Principles of Motion Economy, Work Measurement, Performance Rating Allowance, Work Measurement: Work Sampling, PMT System Standard Data Method, Organization at Work, Working Conditions Lights Vibrations. Materials Management, Materials Requirement Planning, Sales Forecasting, Capacity Planning, Network Analysis, Facility Design Part, Materials Handling, Quality Concepts, Value Engineering, Reliability, Industrial Safety
4	**Texts/References**	**1.** Introduction to Work Study – ILO, 4th edition 1992. **2.** Mark. S. Sanders and Ernest. J McCornick. "Human Factor in Engineering and Design", McGraw-Hill Book Co., Inc., New York, 4th edition, 2013. **3.** S. Dalela and Sourabh, "Work Study and Ergonomics". Standard publishers 2013. **4.** Wesley Woodson, Peggy Tillman and Barry Tillman, "Human Factors Design Handbook", McGraw-Hill; 2nd edition, 1992. **5.** Ralph M. Barnes, "Motion and Time Study", Wiley International, 7th Edition. **6.** B. Niebel and Freivalds, Niebel's Methods Standards and Work Design, McGraw-Hill, 12th Edition, 2009.

1	**Title of the course** (L-T-P-C)	Hybrid Manufacturing Processes 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	1. Introduction to Hybrid Manufacturing Processes 1.1. Need and basis of classification of hybrid manufacturing processes 1.2. Classification of hybrid manufacturing processes 1.3. Selection of hybrid manufacturing processes 1.4. Advantages and limitations of hybrid manufacturing processes 2. Process planning of Hybrid Manufacturing Processes 2.1. Casting - subtractive process 2.2. Injection molding – subtractive process 2.3. Additive – subtractive process 2.4. Process planning for hybrid manufacturing processes 2.5. Challenges in hybrid manufacturing processes 3. Electrochemical dissolution-based hybrid machining techniques 3.1. Electrochemical grinding 3.2. Electrochemical arc machining 3.3. Electrochemical discharge machining 4. Hybrid machining techniques assisted with abrasives 4.1. Abrasive assisted water jet cutting 4.2. Abrasive assisted electric discharge machining 4.3. Abrasive assisted electrochemical machining 5. Laser assisted hybrid machining techniques 5.1. Laser assisted mechanical machining 5.2. Laser assisted advanced machining 6. Advanced machining techniques assisted with vibrations 6.1. Vibration assisted mechanical machining 6.2. Vibration assisted electric discharge machining 6.3. Vibration assisted electrochemical machining Vibration assisted laser beam machining
4	**Texts/References**	**1.** Jain, V.K., 2009. Advanced machining processes. Allied publishers.1st Ed. **2.** Bhattacharyya, B. and Doloi, B., 2019. Modern machining technology: Advanced, hybrid, micro machining and super finishing technology. Academic Press. 1st Ed. **3.** Luo, X. and Qin, Y., 2018. Hybrid machining: theory, methods, and case studies. Academic Press. 1st Ed. **4.** Bhattacharyya, B., 2015. Electrochemical micromachining for nanofabrication. MEMS and Nanotechnology, William Andrew Applied Science Publishers, Imprint of Elsevier Inc., Massachusetts, 270. 1st Ed.

1	**Title of the course** (L-T-P-C)	**Product Design and Manufacturing** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Customer Needs And Product Specifications, Product Development process, Product development organizations. Gather raw data, Interpret raw data, organize the needs into a hierarchy, Relative importance of the needs. Specifications – Refining specifications. Concept Generation, Selection And Product Architecture Clarify the problem. Search internally – Search externally – Explore systematically. Concept Screening, Concept scoring. Product architecture, Implication of architecture, Establishing the architecture, Related system level design issues. Industrial Design, Prototyping And Economics Of Product Development Need for industrial design, Impact of industrial design, Industrial design process, Management of industrial design process, Assessing the quality of industrial design. Estimate the manufacturing cost, Reduce the component cost, Reduce the assembly cost, Reduce the support cost, Impact of DFM decisions on other factors. Principles of prototyping, Planning for prototypes. Elements of economic analysis, Case financial model, Sensitivity analysis, Influence of the quantitative factors.
4	**Texts/References**	**1.** Karal, T.Ulrich Steven D.Eppinger, “Product Design and Development”, McGraw Hill, International Editions, 2003. **2.** Mudge, Arthur E. “Value Engineering”- A systematic approach, McGraw Hill, New York, 2000. **3.** S.Rosenthal, “Effective Product Design and Development”, Irwin, 1992. **4.** Charles Gevirtz, “Developing New products with TQM”, McGraw Hill, International Editions, 1994.

1	**Title of the course** (L-T-P-C)	**Advanced Material Characterization Techniques** 3-0-0-6
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Spectroscopic characterization: Vibrational spectroscopy (FTIR and Raman spectroscopy), UV-visible and photoluminescence, XPS, NMR, mass spectroscopy. Thermal analysis: Principles and applications of differential scanning calorimetry (DSC), differential thermal analysis (DTA), thermogravimetric analysis (TGA). Structure Analysis Tools: Introduction to X-rays, Brief description of crystal lattices or crystal structures, structural factor, principle of X-ray diffractions (XRD), Calculation of average crystallite size, Peak-Broadening, wide-angle X-ray diffraction, small angle X-ray scattering of polymer samples. Microscopy Techniques: Optical, fluorescence, confocal microscopy, Digital Image Correlation (DIC), Electron microscopy, Construction details of electron microscopes e.g. SEM, TEM and STM and their detailed working principle to study different nano/micro/meso structures; Principle and usage of Atomic Force Microscopy (AFM). Chemical Analysis: Brief description to X-ray fluorescence, atomic absorption and electronic spin resonance spectroscopy.
4	**Texts/References**	**1.** Goodhew P.J., Humphreys J. and Beanland, R., “Electron Microscopy and Analysis”, 3rd Ed., Taylor and Francis. **2.** Cullity B.D. and Stock S.R., “Elements of X-Ray Diffraction”, 3rd Ed., Prentice Hall. **3.** Williams D. B. and Carter, C. B., “Transmission Electron Microscopy: A Textbook for Materials Science”, 2nd Ed., Springer. **4.** Goldstein J., Newbury D.E., Joy, D.C., Lyman C.E., Echlin P., Lifshin E., Sawyer L. and Michael J.R., “Scanning Electron Microscopy and X-ray Microanalysis”, 3rd Ed., Springer. **5.** Speyer R., “Thermal Analysis of Materials”, CRC Press.

1	**Title of the course** (L-T-P-C)	**Polymer Science and Engineering** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**1.** Introduction: Basics of polymers, Types of polymers, Polymer Composites, particulate, short fiber and continuous fiber reinforced polymer composites, polymer nanocomposites. **2.** States of Aggregation in Polymers and Structure: Amorphous polymers, Crystalline polymers, Orientation and crystallization, Orientation in linear amorphous polymers, Cross-linked structures. Glassy and amorphous structure, Theories of glass transition, Physical ageing, Viscoelastic behavior, Factors affecting the glass transition temperature, Crystallization, Factors affecting crystallization and melting point, Thermal characterization of polymers. **3.** Polymer blend miscibility: Introduction to polymer blends, criterion and thermodynamics of miscibility, composition and temperature dependence of miscibility, miscibility by solubility parameters and polymer-polymer interactions. **4.** Polymeric Nanocomposites: Fundamentals, processing, structure, properties and applications of polymeric nanoparticle and nanofiber composites. **5.** Introduction to Polymer Processing: Quantitative aspects of polymer product processing additives and compounding – fillers, plasticizers, antioxidants, colorants, flame retardants, stabilizers compounding, mixing and compounding equipment. **6.** Property Prediction using Traditional Group contribution method: Understanding traditional group contribution methods, prediction of polymer physical properties e.g. density, viscosity, melting point, specific heat, Glass transition temperature, bulk modulus, thermal conductivity, water and CO_2 diffusivities, electrical resistance, refractive index using group contribution method (GCM).
4	**Texts/References**	**1.** Ghosh P., “Polymer Science and Technology”, 3rd Edition, McGraw Hill Education (India) Private Limited. **2.** Korschwitz J., “Polymer Characterization and Analysis”, John Wiley and Sons.

1	**Title of the course** (L-T-P-C)	**Computational Gas dynamics|** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Governing Equations of Gasdynamics**: Integral form of Euler equations, Rankine-Hugoniot relations, characteristic form of Euler equations and physical interpretation **Basic Concepts** of expansion waves, compression and shock waves, contact discontinuities, linear advection equation, Burger's equation, entropy condition **Riemann Problem** for Euler equation, Roe's approximate Riemann solver for Euler equations, other approximate Riemann solvers **Principles of Computational Gasdynamics**: Conservative Finite-Volume and Finite-Difference methods, von-Neumann stability, upwinding, introduction to flux averaging and flux splitting, Total Variation Diminishing (TVD), Essentially Non-Oscillatory (ENO) and montone methods Methods of **Computational Gasdynamics** for scalar conservation laws, Lax-Friedrichs and Lax-Wendroff, Godunov's, Roe's and Harten's first-order upwind method, Beam-Warming second-order upwind, Fromm's method Methods for the Euler Equations: Flux approach, flux-limited methods (Sweby, Chakravarthy-Osher, Davis-Roe, Yee-Roe), flux-corrected methods, flux vector splitting (Steger-Warming, Van Leer, Liou-Steffen), reconstruction and evolution methods, boundary treatments
4	**Texts/References**	**Textbooks:** **1.** Computational Gasdynamics, Culbert B. Laney, 1st Edition, 2020, ISBN 978-1-108-79907-2, Cambridge University Press. **References:** **2.** Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics, Charles Hirsch, ISBN: 978-0-7506-6594-0, 2nd Edition, 2007, Elsevier. **3.** Elements of Numerical Methods for Compressible Flows, Doyle D. Knight, ISBN: 978-0-5116-1744-7, 2006, Cambridge University Press. **4.** Finite volume methods for hyperbolic problems, R.J. LeVeque, ISBN: 978- 0-5117-9125-3, 2002, Cambridge University Press.